# A Research on Critical Thinking Skill, Attitudes, and Career Interests through Project Based Learning in STEM Education among Japan and Indonesia Middle School Students


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# A RESEARCH ON CRITICAL THINKING SKILL, ATTITUDES, AND CAREER INTERESTS THROUGH PROJECT BASED LEARNING IN STEM EDUCATION AMONG JAPAN AND INDONESIA MIDDLE SCHOOL STUDENTS

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## ABSTRACT

This research analyzed students` critical thinking skill, attitudes, and career interests by using STEM education perspective through Project Based Learning approach. This study applied mixed methods convergent parallel research design. Mixed methods research design is a procedure for collecting, analyzing, and "mixing" both quantitative and qualitative methods to understand research problems. In these lessons, the participants were 160 first grade Japanese middle school students from four classes and 111 first grade Indonesian middle school students from three classes. They were divided into nine groups each class. The instruments consist of worksheets to explore students' initial knowledge about how to clean up a wastewater and critical thinking processes, and the questionnaire to explore students` attitudes toward STEM and career interests. Worksheet for a wastewater treatment activities consist of designing solution and understanding of concepts. Students were asked to design tools to clean up the wastewater. Students were given more than one attempt to design the best product for the wastewater treatment. The unit consist of six lessons. First lesson was introduction of colloid, solution, and suspension, and discussion about a wastewater. From second lesson to fourth lesson were finding solutions and designing products. Fifth lesson was to watch video of a wastewater treatments in Japan and to optimize the solutions or products. Last lesson was to make conclusion, presentations, and to develop discussions.

The result showed that mean score of Japanese students` critical thinking skill was 2.82. Criteria of Japanese students` critical thinking skills were advanced thinker: 41.6%, practicing thinker: 30.6%, beginning thinker: 25%, and challenged thinker: 2.8%. And the average criteria of Japanese students` critical thinking are *practicing thinker.* The result of Japanese students` showed that the attitudes toward STEM fields of Japanese male students and female students not different significantly. Students` career interest showed that both male and female students had generally moderate interests in STEM careers. Female students were more

interested in careers in medicine, but male students were more interested in careers in computer science and engineering.

The result showed that mean score of Indonesian students` critical thinking skill was 2.10. Criteria of Indonesian students` critical thinking skill were practicing thinker: 29.63%; beginning thinker 51.85%; and challenged thinker 18.52%. Also the average criteria of Indonesian students` critical thinking is *beginning thinker*. The result of Indonesian students` showed that male students had more positive attitudes toward STEM than female students. Findings indicated that the attitudes toward STEM fields of Indonesian male students and female students not different significantly. Students` career interest showed that both male and female students had generally moderate interests in STEM careers. Female students were more interested in careers in medicine, but male students were more interested in careers in engineering.

There are differences between Japanese and Indonesian students in critical thinking skills (p-value > $\alpha/2$). Japanese students master than Indonesian students in critical thinking skills, because the problem in this lesson related to daily life. The range of mean score in critical thinking skill between Japanese students and Indonesian students are 0.717, this gap point is big enough. Based on the solutions that designed by students, Japanese students have more variety of solutions and they could evaluate their solutions.

There are not differences between Japanese and Indonesian students` attitudes toward STEM in all aspect; Mathematics, Science and Technology and Engineering (p-value < $\alpha/2$). It is mean that both Japan and Indonesia have same attitudes toward STEM. Both Japanese female students` and Indonesian female students` were more interested in career in medicine. Japanese male students` career interest were more interested in careers in computer science and engineering, but Indonesian male students` career interested in career in energy and engineering.

There is correlation between Japanese and Indonesian students` critical thinking skills and attitudes toward STEM. Japanese students have high correlation between critical thinking skills and attitudes toward STEM. And Indonesian students have moderate correlation between critical thinking skills and attitudes toward STEM.

These results of research cannot become a judgment of education level in Indonesia and Japan, because these researches collected data from only one school from each country purposely. The results of research can describe the condition in education of each nation if the data are collected from many schools with random sampling.

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# CHAPTER I
# INTRODUCTION

In economic theory, improvement of national economic should be considering the policy complementarities in a large dynamic system perspective. One of this system perspective is education (Aghion, et. al, 2008). Innovation of education is required to Science, engineering, technology, and mathematics education is one of ways to develop national economic (NRC, 2011).

According to Courses of Study of Japan, the Japanese education has general aims of education namely student should have fundamental knowledge and skills, abilities to think, decision-making skills, and expressing themselves (communication skills). Furthermore, Japanese Ministry of Education has goals through science education involving developing problem-solving skills, understanding of natural phenomena, and to foster scientific perspectives and ideas (MEXT, 2008).

In NGSS, Japanese Course of Study, and Indonesian Curriculum mention that the goal of science education is performance expectations. Students not only master in content of knowledge, but also master in context knowledge. In other word, students must possess skills in implementing of contents knowledge into contextual or daily life problems and communication skills (Japanese Course of Study, 2008; NGSS, 2013; Indonesian Curriculum, 2013). In future, students able to adapt in their workplace and contribute in their society after they finish all grade levels (K-12). Especially in NGSS, performance expectations should be taught and be able to be conducted at each grade level (NRC, 2015).

There are some pedagogies of educational such as behaviorism, constructivism, social constructivism, and social cultural. In behaviorism, there are two components namely effect (reward or punishment) and exercise (particular responses of teaches in certain condition that influence to students thinking).

### A. Roles of STEM Education

The decreasing Japanese population might be a problem to become a world leader in science and technology, it is very important task for Japan to encourage and secure human resources in science and technology. The Japanese government is focused on comprehensive human resource development steps that cover everyone from children to leading researchers and engineers to leading science and technology in the world. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) make efforts through developing young people's talents, increasing knowledge of children who are interested in science, and awareness an environment where various people including young, female, and foreign researchers can practice their skills, and promote professional engineer systems (MEXT, 2008). Japanese government have been spending the budget for these projects (MEXT,2008). Perhaps, STEM (Science, Technology, Engineering, and Mathematics) education would be one of solution to foster and secure human resource in science and technology.

Moreover, Indonesian Ministry of Education emphasizes that students must be able to apply their knowledge in workplace and society. Therefore, the education system that integrated all of science subjects are required for students' future (Indonesian Ministry of Education and Culture, 2013).

The job in STEM sectors will increase in the next decade than jobs in other sectors (Committee on STEM Education National Science and Technology Council 2013; Klobuchar, 2014). Therefore, the importance of STEM education has been realized by government, academia, industry, and society. In the future, the students possibly do not work based on their educational background. The role of education as basic to career advancement has been aimed in international setting (OECD 2013). Furthermore, STEM education could be a way to bridge the gap between education and required workplace skills (Bybee, 2013).

The United State Department of Labor suggests that the importance of STEM education competencies involve *problem solving skills (ill-defined problem), system skills, technology and engineering skills, and time, resource, and knowledge management skills* (Jang, 2015). The learning in this new era, scientific experiments are not sufficient to improve students' 21$^{st}$ century skills, but how to apply scientific concepts to design the technologies or products and solve problems are required.

The change of human life will be accompanied by the evolution of technology. Therefore, students have to be prepared for the future challenges. Scientific inquiry, scientific practices, and engineering practices are required to encourage students to be a citizen who can adapt to face new conditions and problems (Bybee, 2013; NRC, 2012). Scientific practices involve the habits and skills that used by scientist and engineer to solve problems and strive the human being needs.

Kumano (2016) mentions that contexts of science education in Japan involve basic characteristics of present course of study; challenging to highly knowledge intensive society; knowledge creation system in science and technology; education for the sustainable society; formative and authentic assessment; focusing on more inquiry base learning. The definition of STEM education remains vague and most of what is called STEM education frequently lacks the concepts that form the core scientific ideas (Kumano, 2014).

Make students become expert thinkers is one of expectation of an educator, because the students have to possess skill to identify and solve the problems or issues in the future. In order to solve problems or issues, there are no similar solution for each problems or issues. In the $21^{st}$ century, the development of a country's economic conditions affects international competition and globalization challenges. The development of discovering and innovation in advancing technologies (STEM fields) is one of the solutions toward these issues. How to develop the advanced technologies? Ultimately, Science, Technology, Engineering, and Mathematics education will be the solution to answer these issues, because education system influence development of a country (U.S Government, 2013; Queensland Government Department of Education, Training, and the Art, 2007). STEM education can be one of the ways to improve students' skills and understanding in conceptual and scientific contexts (Bybee, 2013). STEM emerged in the 1990s at the National Science Foundation (NSF) as an Science, technology, engineering, and mathematics. STEM education exclusively includes educational activities across all grade levels from pre-school to post-doctorate in both formal and informal settings (Bybee, 2013; Gonzales & Kuenzi, 2012; Kearney, 2011).

STEM education is so important for the future, one of the reasons is to increase enrollment of students in STEM fields, it will have effects in increasing of career in STEM field by considering the development of economic condition through technological invention and innovation. (Anlezark, Lim, Semo, & Nguyen, 2008; Kearney, 2011; Gonzales & Kuenzi, 2012). Another reason of the importance of STEM education is to develop 21st century skills such as critical and creative thinking, research, complex communication and social skills, self-management and self-development, adaptability, non-routine problem, and system thinking (NRC, 2010; Kyllonen, 2012; Saavedra & Opfer, 2012).

**B. Project Based Learning**

STEM education and 21st century teaching and learning will succeed through "Project Based Learning" model (Capraro, et. al, 2013; Vasquez, 2014; Kertil and Gurel, 2016). Integrated STEM education through "Project Based Learning" can increase student interest in STEM learning because "Project Based Learning" involve students in solving real world problems using hands on, collaborative with others, and creating real solutions (Rush, 2010). Promote an interdisciplinary approach by giving students "Project Based Learning" on a regular and consistent basis where students have an opportunity to identify problems, develop solutions, follow processes, and then design and market products. STEM Project Based Learning (PBL) in school motivated low performing students to more interest study hard in STEM fields and decrease the achievement gap (Capraro, 2014).

Project Based Learning (PBL) is a learning approach that encourage students to learn in real-world situations or challenges through an extended inquiry processes. PBL learning environment have influence toward students' engagement and students' motivation in learning. PBL gives opportunities to students on communication or interaction with their teachers and their peers in meaningful learning in order to construct their thinking skills (Lund, 2016).

**C. Purpose of Study**

According to result of Program for International Student Assessment (PISA) 2015, Japan has score 538 points for science category, while Indonesia has score 403 points for science category. This data shows that Japanese students and Indonesian students have big gap in thinking skills (OECD, 2016). Through PISA, students' skills or competencies are evaluated with collaborative problem solving (integrated science).

This research is disposed for analyzing Indonesian and Japanese students' critical thinking skills through STEM education perspective. The goals of this research are to analyze middle school science textbooks of both countries for determining the problem solved by students. Furthermore, the second goal is to analyze Indonesian and Japanese students' critical thinking skills through problem in STEM education perspective. By the comparisons between Indonesian and Japanese critical thinking skills. Besides, students' attitudes toward STEM fields and career interests in STEM fields were identified. The correlation between students' attitudes, career interests in STEM fields, and critical thinking skills were investigated, because attitudes and interests had certain influence on motivation in learning. In numerous studies, motivation plays an important role in learning and improving of content knowledge and thinking skills (Deci, et al., 1999; Roberts & Dyer, 2005; Bhushan, 2014; Hu, et al., 2015).

## D. Research Questions of The Study

The research questions of this study focus on analysis critical thinking skills, students` attitudes toward STEM, and students` career interest in STEM education. Also, by conducting of implementation of STEM education through project-based learning, Research questions as follows:

1. How profile Japanese students` critical thinking skills, attitudes toward STEM and career interest in STEM field?
2. How profile Indonesian students` critical thinking skills, attitudes toward STEM and career interest in STEM field?
3. Are there some differences of Japanese and Indonesian students in critical thinking?
4. Are there some differences of Japanese and Indonesian students in attitudes toward STEM and career interests?
5. Is there correlation between critical thinking skill and students' attitudes toward STEM and career interests using STEM education through Project Based Learning?

These studies focused on the analysis students` critical thinking, attitudes, and career interest. The advantages of these studies to find the correlation between critical thinking skill and students` attitudes toward STEM and career interests using STEM education through Project Based Learning. Besides, it gives information about stage of students' critical thinking skills both Indonesian and Japanese students, and then processes of teaching and learning which is connection with STEM education Project Based learning whether provide the needed skills for students. Furthermore, these studies provide suggestions to students, parents, educators, stakeholders, to consider all of aspects in education to increase quality teaching and learning in formal or informal education.

**E. Terminology**

*STEM education* – is a model teaching and learning that integrated the contents and skills of science, technology, engineering, and mathematics. STEM education is one of way to gain the goals of NGSS. NGSS has three big components namely practices, crosscutting concepts, and core ideas. In order to facilitate the student practices component, some educators, researchers, and stakeholders propose STEM education model.

*Project Based Learning* – is a learning approach that encourage students to learn in real-world situations or challenges through an extended inquiry processes. PBL learning environment have influence toward students' engagement and students' motivation in learning. PBL gives opportunities to students on communication or interaction with their teachers and their peers in meaningful learning in order to construct their thinking skills (Lund, 2016).

*Attitude* – is defined as "feelings, beliefs, and values held about an object that maybe the enterprise of science, school science, the impact of science on society or scientists themselves" (Osborne, 2003, p. 1053).

*Critical Thinking Skills* –There are several definitions of the term critical thinking; the most commonly used definition is "purposeful, self-regulatory judgment that results in interpretation, analysis, evaluation, and inference as well as explanation of the evidential, conceptual, methodological, or contextual considerations upon which that judgment is based" (Facione,1990, p. 2).

*Career Interest* – Career Interest represents individual's psychological constructs of personal preference for choosing career behavior that influence to personality performances and activities (Holland, 1997; Hansen & Dik, 2005). Career interest has correlation with young adults' identity status and it related to career decision self-efficacy and differentiation of interest (Khan, 2007).

# CHAPTER II

# LITERATURE REVIEW

Every country has curriculum that explain vision and mission of national education system. Japan has goals to educate the young generation through natural science. Japanese education system is to improve content knowledge and skills, thinking ability, decision-making ability, expressive ability, self-learning ability, and awareness of human nature (MEXT, 2008).

Performance expectations could be trained by tasks that have characteristics namely tasks should be consisted of components that apply the scientific contents knowledge in context problems (practices) which related to disciplinary ideas and cross-cutting concepts; focused on the improvement of learning skills through assessments; and an interpretive evaluating system that used for identifying differences of students' achievements (content knowledge and skills).

The assessment systems of science education suggested must be have strategies or methods in order to generate important information that needed by stakeholder. The assessment systems should have three views as follows: assessments should support learning processes in classroom; observe science learning processes on wider area of education; and a sequence of index to examine whether students are facilitated with adequate chances to conduct authentic learning in science. Therefore, assessment systems can support the progression of students' higher order thinking skills (NAS – National Achievement Survey, 2014).

Systems approach in assessment could be important points in processes of gradation to assessment systems that required to reach the vision of framework.

Systems approach have role in selection of priorities and highlight of some assessment systems. The systems approach to science assessment must be reached by higher order thinking skills. The assessments would support students to improve their higher order thinking skills (NAS, 2014). McGregor (2006) suggestions that there are four kind of higher order thinking skills namely creative thinking, critical thinking, problem solving, and metacognitive skills. However, some references mention that critical thinking is one of thinking skill that has role to achieve effective and efficient solutions or answers (McGregor, 2006; Paul and Elder, 2008). Critical thinking is the thinking skill of analyzing and evaluating thinking with a view to improve value of solutions or answers (Paul and Elder, 2008). The students who have creative thinking only, they cannot generate good solutions and answers, because creative thinking has role to generate new ideas without evaluate and analyze that ideas (McGregor, 2006).

**A. STEM Education**

Next Generation Science Standard has three dimensions namely science and engineering practices, crosscutting concept, and core idea to train and prepare students to be expert in 21$^{st}$ century. The crosscutting concepts in NGSS are adopted from Science for All Americans (AAA 1989) namely scale, proportion, and quantity; structure and function; patterns; cause and effect; system and system model; energy and matter; and stability and change. Crosscutting concept has roles to support other dimensions in NGSS as follows: science and engineering practices, understanding in core idea, understanding correlation of the different areas of disciplinary concepts, incorporation of nature of science and engineering concepts (NGSS, 2013). Therefore, students will comprehend the systems of concepts in science, engineering, and mathematic to create a technology.

In Next Generation Science Standard, there are three components consisted of practices, cross-cutting concepts, and disciplinary core ideas. Practices word in NGSS similar to skills, while practices involve scientific and engineering practices. Therefore, students expected have skills like scientist and engineer. In order to improve students' skills through STEM education, it is needed to know what kind of activities that done by scientist and engineer. Scientist and engineer work in three main activity namely investigation and empirical inquiry, developing explanation and solutions, and evaluating. Investigation activities involve collection data and test solution of real world problems and issues through asking questions, observing, experiment, and measuring. Evaluating activities involve arguing, critique, and analyzing of solutions need critical thinking skills. Developing explanation and solutions involve formulate hypothesis and propose solutions through imaging, reasoning, calculating, and predicting based on theories and models. Therefore, in STEM education learning, students should conduct some activities that done by scientist and engineering (scientific and engineering practices).

STEM learning not only involve scientific and engineering practices, but also it should be considering cross-cutting scientific and engineering concepts. Cross-cutting concepts consisted of seven aspects as follows:

*Patterns.* Observed patterns of forms and situations support organization and classification, and they prompt questions about relationship and the factors that affect them.

*Cause and effect*. Mechanism and explanation. Event have causes, sometimes simple, sometimes complicated. A major activity of science in investigating and explaining causal relationships and the mechanisms by which they are medicated. Such mechanism can then be tested across given contexts and used to predict and explain situations in new contexts.

*Scale, proportion, and quantity*. In considering phenomena, it is critical to recognize what is relevant at different measure of size, time, and energy and to recognize how change in scale, proportion, or quantity affect a system's structure or performance.

*System and system models*. Defining the system under study specifying its boundaries and making explicit a model of that system provides tools for understanding and testing ideas that are applicable throughout science and engineering.

*Energy and matter: Flows, cycles, and conservation*. Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

*Structure and function*. The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

*Stability and change*. For natural and built system alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

The definitions of STEM education are variety based on others' educational programs are aiming for global competitions that stakeholders have to know in detail, adjust dynamically the perspective of environmental and correlated problems or issues, realizing 21st-century workforce skills, and proceed with issues of national safety (Bybee, 2013).

Effective and efficient STEM instructions encourage students' attitudes and experiences toward STEM fields, evaluate and design on their comprehensions and perceptions, the utilize of science and engineering practices, give experience learning that correlated their attraction of STEM fields, and increase higher order thinking skills (NRC 2011; BOSE 2013; Bamberger & Cahill, 2013).

According to Bybee (2013), meaning of STEM literacy is knowledge, beliefs, attitudes, and skills to analyze questions, problems, and issues in contextual daily life situations, to describe the natural and creation of the world, and to design evidence-based interpretations about STEM related-issues; comprehension of the characteristic of STEM fields as forms of citizens knowledge, inquiry, and design; realize about how STEM fields have roles to our knowledge, thinking skills, and cultural environments; and readiness to conduct STEM-related problem or issues and correlated to the ideas of science, technology, engineering, and mathematics (Bybee, 2013). To educate students as 21st century citizen and to improve life skills, knowledge and attitude in their community are the goals of education (Brunello, 2011).

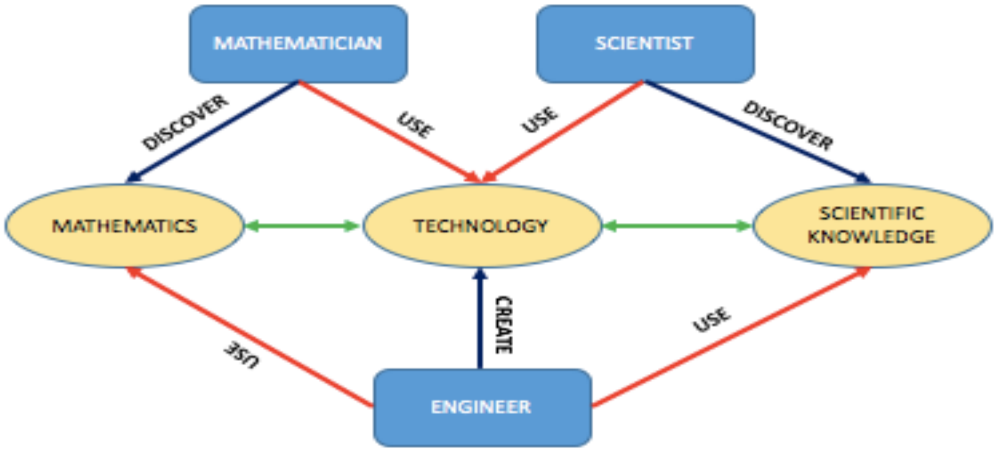



Figure 1. Correlation among Science, Technology, Engineering, and Mathematics

STEM education programs are required some skills and abilities to improve deep technical workforce. They refer to 21st century skills as following:

a. Adaptability (skill or ability and readiness to address indecisive, recent condition, and convert condition on the occupation or learning, including responding effectively to urgent situation or crisis condition and learning new job, procedures and technologies).

b. Social skills and complex communication (ability to manage both verbal and nonverbal information from others to make a respond a logically and understand the perspective from the others).

c. Unfamiliar problem-solving involves skills (involves: acknowledge patterns, talented thinking to investigate a broad reach of information, and limited the information to achieve diagnosis of issues or problems).

d. Self-development skill and self-management (these skills included: the skill to react remotely, independent, and to be self-monitoring and self-motivating).

System of thinking is the process of understanding and conceiving how an entire system work in environment and how things influence to others and how a measure, change, or malfunction in one part of the system influence the rest of the system. STEM education has many perspectives such as the following (Bybee, 2013):

a. STEM education equal to Science or Mathematics. This perspective make STEM education becomes simple system.

b. STEM education equal to Science and Mathematics. This perspective merely combines science and mathematics aspect and take into consideration the decidedly main subject but know presence the imperceptible subjects (process and effect).

c. STEM education includes Science, Technology, Engineering, and Mathematics. This STEM perspective combine component of technology and engineering in lesson with presiding component is science or mathematics.

d. STEM education is Science, Mathematics, Engineering, and Technology separately in lesson. In these STEM lessons, all of the subjects (science, mathematics, engineering, and technology) distinctly seen and differences of each subject.

e. STEM education means science and mathematics that connected by technology and engineering program. In these STEM lessons, technology and engineering as tools or media in studying science and mathematics.

f. STEM education is coordination across disciplines. This perspective integrates science, mathematics, engineering and technology in STEM lesson. Science needs clarification of mathematics concept and engineering concept, and sometime state of mathematics concepts in science or technology.

g. STEM education refers to combination of two or three subjects in one lesson. This perspective does not combine all subject, only two or three subjects (science-mathematics-engineering, or mathematics-engineering-technology).

h. STEM education is complementary overlapping disciplines. This STEM perspective can be merged by sequencing disciplines in lesson.

i. STEM education is trans-disciplinary course as one program. Example of STEM lesson trans-disciplinary: health problems, global climate change, or use of resource energy.

According to Bybee (2013, p 84), the differences of point of view toward STEM education impact on strategies and method that implemented in STEM learning processes. Therefore, several perceptions of integration ways of STEM education as follows:

- Coordinate. Two subjects taught in different classes are coordinated, so contents in one subject correlated with what is needed in another subject. For example, students in mathematics learn integral functions that can be implemented in a chemistry or physic class.
- Complement. While learning the core concept of primary subject, the concept of another subject is taught to complement the primary subject. For example, students design a bike in engineering class, science concepts of aero dynamic, mechanic energy, and friction force are taught to support the designing bike and its efficiency.

- Correlate. Two subjects with similar themes, concepts, or processes are taught in different classes, therefore students can think, analyze, and understand their similarities and differences. For example, you might teach Kerbs Cycle concepts separately in chemistry and biology courses.
- Connections. Use one subject to correlate other subjects. For example, in order to teach students correlation of chemistry, biology, physic, and mathematics, teacher use a technology in daily life as learning material.
- Combine. This approach merges two or more STEM fields through projects, themes, procedures, or another organizing core. For example, one could establish a new course on science, mathematics, and technology that uses student projects to show the relationship between science concepts and mathematic concepts to design technology through engineering processes.

**STEM Integration in Science Education**

Science helps human being to explain and understand phenomena in the world around us. Science is knowledge to explain the facts and to understand processes that correlate to clarification of what, why, and how the nature work. A meaningful understanding of science gives an awareness that science does not manifest anything true; all ideas of science can be revisited and amended in detail of new facts (Chalmers, 1999). However, science cannot prove and explain all ideas and phenomena in the universe. Science needs contribution of technology, engineering, and mathematics that play an important role of working together to ensure our knowledge of phenomena in the world and humans employ to progress society.

Since 2006, educational researchers in America were discussed the need a trans-disciplinary model for teaching science, technology, engineering, and mathematics (STEM) in K-12 education. They were realized that Science, Technology, Engineering, and Mathematics (STEM) education model in science education is important steps to prepare the youth generation to face future challenges. The researchers have opinion that students will realize the correlation among STEM fields. It will give meaningful experiences in learning processes to students, furthermore, it can stimulate the students to conduct actively challenges in real-world experiences (Furner & Kumar, 2007; Smith & Karr-Kidwell, 2000). Hopefully, STEM education model will support students to success academic challenges, increase students' interest in STEM fields, and improve students' motivation to learn the world (Stinson, Harkness, Meyer, & Stallworth, 2009).

Frykholm and Glasson (2005) emphasized that students' experience learning improved through trans-disciplinary model learning in which understanding of concepts in science and math can be mastered. To facing the future, important skills and knowledge required by students. Through trans-disciplinary model learning, skills and knowledge will improve gradually based on the difficulty of authentic tasks or problems (Becker & Park, 2011). Furthermore, integration of contents and contexts in one learning can help students to understand correlation of STEM fields each other and understand the meaning of each concept (Moore & Smith, 2014). These correlation of STEM fields give a new idea to teach and improve students' understanding in science (Roberts, 2013).

New York College of Technology (CITY Tech) emphasized that a trans-disciplinary model can afford explain the strong correlation of STEM knowledge itself and social contexts. The philosophy adopted by this institution is based on the statement that, trans disciplinary studies improve the skills to collect (discover, organize and evaluate) ideas and information from various sources; skills to adapt in groups; skills to apply knowledge in real life problems; and the skills to communicate and solve problems both orally and in writing (Lansiquot, Blake, Liou-Mark & Dreyfuss, 2011, p. 20).

Moreover, STEM integration in science education make a relationship across disciplines, it can inspire association among STEM fields, promote society embarrassment, management in teaching and learning processes address to a society who understand STEM knowledge. As Trevey (2008) suggested that technology improve rapidly and the needs of technology increase, so STEM education is important integrated into science education. Therefore, in some countries government have perspective the important of STEM literacy can support the future economy development. Some educational researchers and economist agree that development of technology in America cannot increase without preparation of youth generation in STEM education (Trevey, 2008). NRC (2012) suggested that aspect engineering in science education has affect to increasing of students' interest to STEM careers and improve the innovation of technology that support to economy conditions of a nation (Moore & Smith, 2014). This perspective emphasized that integration of engineering and science practices are needed in science education. Integration of engineering practices in science and mathematics curriculum can promote students` interest in STEM (Rockland, Bloom, Carpinelli, Burr-Alexander, Hirsch, and Kimmel, 2010). Through integration of engineering and science practices can promote students in making connections between classroom activities and real-world concepts. Other researchers (English, et al., 2013) claimed that integration of engineering into science practices could foster students` respect for engineers and giving students with the awareness of how they have improved society.

**Science and engineering**

The NRC spotlight (2012) that some science educators find it difficult to understand the integration of engineering practices and science education, as some facts in the field showed that the engineering aspect is more obtrusive than the science aspect in science learning activities, due to the fact that technical practices takes more time rather than practices science in transferring the concept of science. In addition, the science educators may face difficulties when faced with too complicated engineering practices in the integration of the STEM field concept. But researchers and educators believe that science practices can be integrated into science education and will develop students' understanding of the concept of science (NRC, 2012). Ringwood, Moaghna & Malcon (2005) said that engineering design and science practices integration in K-12 science education can encourage creativity, improve hands-on activities, and introduce real-world contexts for students. Engineering design in science activities can also develop confidence and self-efficacy of students to be successful in mastered mathematics and science lessons in their next years (DeJarnette, 2012).

A study report presented by the NRC (Katehi, Pearson, & Feder, 2009) reviewed 34 engineering programs that embedded engineering interwoven in science, tech, and math. The result of this study showed three main points of K-12 engineering education. Three main points of K-12 engineering education are: K-12 engineering tend to emphasize engineering design; and finally, K–12 engineering should arrange in line with systems thinking, creativity, critique, optimism, communication, and attention to more considerations to trigger engineering practices. "*These practices in K-12 education can support the development of a diverse student body, enhance teacher knowledge, yield interest in STEM among students, while strengthen our nation's contribution to the global engineering workforce"* (American Society for Engineering Education, 2006; Englishet al., 2013).

According to English et al., (2013), students had an improved understanding of the integrated disciplines using simple technology, students could afford to analyze and understand more simple technology. This skill qualified students to create connection between materials and abstract concepts, and then yield advanced a knowledge of identify constraints in a real problem. The researchers identified students' explanations of the simple technologies used in their engineering design with an assessment of their engineering design. Through engineering problem solving, students were encouraged to design, build, and evaluate their prototype or solution. This research has used a qualitative research method with collected data of audio and video recordings, students' worksheet, designs of students' products, and interview the teachers. A Study showed that students assess in detail their design with considering to the engineering design processes encouraged them to master the science concepts more advance as well by their designs (Lottero-Perdue, Lovelidge and Bowling, 2010). The students worked in engineering design processes to learn science concepts such as changing of energy form, reactions, motion, force, and position through creating and designing windmill plan. Throughout this experience learning, students participated actively with notice the engineering design processes in their worksheet to assess students' understanding in science and engineering.

The integration of engineering design and science practices in both lessons supported students in understanding of existence of science concepts in contexts. Another STEM education research found that student' self-esteem and their interest toward STEM fields increased after conducting in an STEM Learning. In this STEM learning, students were given a task to design electrical circuits in which the electrical knowledge were taught before this STEM learning, therefore students were encouraged to understand the correlation between engineering and science to innovate the technology. Finally, students' interest not only in science but also in engineering field (Inceoglu, 2010; Gero, Yamin, & Stav, 2016). Students' perceptions toward the nature of science, engineering, scientist, and engineer possibility to change that influenced the duration of the learning processes, interviews, and tests (Karatas, Micklos, and Bodner, 2011; Madara & Namango, 2016).

A quantitative research design used to evaluate high school students` perception of engineering concepts through a pre and posttest. The result showed that there was little correlation between the amount of science, mathematics, and technology education courses taken and change in perceptions of engineering (Sullivan, 2007).

Another study (Knight &Cunningham, 2004) about students preconceived idea to engineering and engineers, the result showed that many younger students think that engineers use tools to build construction and can repair car engines. Older students are think that engineer is a person who involved in designing things such as tools, machines, bridge, or buildings. The way of students perceives and imagine engineers and engineering are important, this will be a perception of their careers related to whether students feel they can enter into the career. Capobianco (2013) state that students perception of engineer as a technician, laborer or mechanic and their conceptions require the engineer building, fixing, using tools, engines, or vehicles. And more than half of students drew engineers as a male person.

A phenomenographic research design was used investigate students` conception of engineers and engineering. The result suggested that the students' concepts of engineers and engineering were labile, and easy to change within a certain period of time (Karatas, 2011).

**Science, technology, and engineering**

STEM education integrates engineering with science and increase students to understand about technology. These integrates very important, for example to conduct the research, scientists use technologies that engineers create (computers, analytical instrument, microscopes, and so on). Technology and engineering with their application in society is one of the core disciplinary ideas presented in the new conceptual framework (NRC, 2012). society has an important role in the remarkable progress of scientific discovery through the development of new products and processes.

Technology and engineering are two factors that contribute to the development of this knowledge. When technology and engineering are integrated in science can make effective learning and make students more aware of the development of science. As Lipton's (2005) said: *"the American public would unanimously agree that school should include a technology curriculum and proposed a four-letter acronym, TIDE, for Technology, Innovation, Design, and Engineering."* Meanwhile, based on Sanders' (2009) statement that although there are some people who disagree with integration of technology and engineering in science, todays the engineering program has become an important thing in technology education. Besides that, Litowitz (2008) stated that engineering should be the key point of technology field, because the word engineering is relatable. In addition, by integration technology in science field, made students to become self-motivated learners and researchers (Chacko, 2015). Based on research by Dearing & Daugherty (2004) and Roger (2005) that many programs are evident that engineering is the key point of technology education, these program such as Engineering by Design, Project ProBase, and project Lead the Way. These programs centralized on provide pre-engineering high school level curriculum and also have positive impact in a K-12 environment. Although some technology educators claim that engineering should not be a part of technology education. As Spencer and Roger (2006) said "*the insertion of engineering would add more confusion to the technology discipline*"

Corresponding to them, integration of engineering would put off technology education from being accepted as a program and extend the chase to establish itself. Accordingly, Spencer & Roger (2006) claimed that technology field should not involve of engineering. However, several states in America have involved engineering to technology education. In Indiana, their changed technology education to 'Engineering and Technology Education'. Moreover, some organization changed the name with involve engineering such as International Technology Education Association (ITEA) also changed its name to the International Technology and Engineering Educators Association (ITEEA).

Technology and engineering also can be useful for education especially in teaching and learning. It is made increase students` content understanding, skills and achievement. A quantitative research with participant the students ranged from 9-11 years old determined that pre and post test score indicated that the students in the robotics group did significantly better in posttest that the group control, and inspected students` content knowledge in science, technology and engineering through engagement in informal afterschool engineering robotics program (Barker & Ansorge, 2007). In addition, other studies have reported results that students' conceptual understandings, student engagement and core concept retention increased after class in model-based engineering (Leema K. Berland, 2013).

The studies investigate about middle school students` understanding of science concepts, retention score, and students` engagement. The result showed students from many schools were engaged in a scripted inquiry compared an engineering design-based inquiry, the students develop electrical alarms to learn electricity concepts (Mehalik et al.,2008). Moreover, a quantitative research about robotic challenge with analyze pre and post data during the lessons (Sullivan, 2008). The students studied robotic lessons during a summer camp. The result showed that students` knowledge and understanding increased through robotics challenge. Not only students` knowledge and understanding, but also made students` thinking and process skill increase.

Although, some researcher and educator of technology education disagree about engineering should be a part of technology education (Spencer and Roger, 2006), some research declare that integration of technology and engineering in science can be advantageous. The integration of technology and engineering in science increase students` science concepts and students` achievement. The Next Generation Science Standards [NGSS] (Achieve, Inc., 2013) involve engineering and technology, it would be greatest way to integrate both technology and engineering in science curriculum.

**Science, mathematics, and engineering.**

The integration mathematics and science have been done for many years, almost all the concepts in science need mathematics aspect, primarily the concepts of measurements and motion (Berlin and White, 2012). Furmer and Kumar (2007) investigate about higher-level mathematics used to derive engineering concepts, and the result students` learning and attitudes has increased. Integration mathematics and science teaching learning facilitates students learning, engagement, motivation, problem solving, criticality, and real-life application (Johnston and Walshe, 2015). The implementation of integrated STEM education lift many challenged for teaching and learning mathematics through problem-based learning, project-based learning, scientific inquiry, or engineering design (Renie, Venville, et al, 2012).

The decrease of students overtake engineering degrees in the United States has given rise to great attention for higher education authorities, stake holder, officials, and government organizations. Based on history incident in Sputnik (1959) that led to reforms in science and technology (Bergel, 2014). This difficult situation leads to many developments in the field of mathematics and science, this is similar for improvements in that field because the TIMSS scores in science and mathematics are lower than other countries. Furthermore, the motivation to develop students` achievement in science and mathematics field. On the other hand, with crosscutting between areas and their alignment with engineering, this is an opportunity to integration engineering in science and mathematics (Roberts, 2013). Since the early 20th century, students` achievement in mathematics has been decrease.

### B. Project Based Learning

Project based learning (PBL) is the student-centered pedagogy that involves an instructional method that focuses on 21$^{st}$ century student learning methodology. Froyd and Simpson describe Project Based Learning thus: "*PBL includes challenging questions, or problems involving the students' problem-solving decision-making, and investigative skills. In addition, there is a critical reflection component that involves the teacher as a facilitator, and not as a lecturer*" (Froyd & Simpson, 2008). Another determination of PBL by Thomas Markham is "*PBL integrates knowing and doing. Students learn knowledge and elements of the core* *curriculum, but also apply what they know to solve authentic problems and produce results that matter"* (Markham, 2011). Project Based Learning is a systematic learning that focuses education on the students, not the curriculum, and encourage students in learning authentic essential knowledge and skills.

The objective of PBL is to recognize students to develop their own thought and understanding. In addition, PBL is fundamental in students connecting their classroom experiences to the real world. If successfully implemented, the use of PBL can help students develop new learning habits and critical-thinking skills that can lead students to others. Project-based learning also allows students to connect their classroom experiences with the world outside the classroom. Projects are also based on challenging questions or problems that involves students in designing, problem solving, decision making and investigative activities that ends with a presentation or a realistic product (Thomas, Mergendoller, & Michaelson, 1999).

According to board of regents of the University of Wisconsin (2013) there are characteristic of project-based learning as follows:

- Students making decisions within a framework.
- A problem or issue or challenge to be solved.
- Designing processes of making solution.
- Gathering, managing, and analysis the needed information.
- Continuous evaluating.
- Regularly reflecting on the processes designing solution.
- Evaluate the quality of final solution or product.
- Atmosphere that tolerates error and change.

Different from a conventional way of learning, such as teacher centered learning, listening to a lecture only, and following the directions of a teacher in a classroom setting, PBL allows students to control and arrange their project, and make the resolution to finish as much time on a certain area of learning as needed.

Collaboration and individual work is stressed in a PBL classroom, where discussions among the group to produce new knowledge. In PBL classroom, students working independently in a group, train to take authority to make selection, which help to increase students' involvement in their group. And then, collaboration between groups, build cooperation with the chance to listen to other members' ideas and suggestions are commonly practiced in PBL. The principal focus of PBL is the connection of real world problems to classroom content and to make students more interest in learning processes that encourages them to apply new knowledge in a problem-solving context. The teacher's role is that of a facilitator, who advance significant tasks, provides counsel and support to develop social skills, and evaluate knowledge that is gained from experiences. PBL is a method of learning where students explore the learning process, discover new ideas through a creative process, and develop higher level thinking through self-discovery (Markham, 2011).

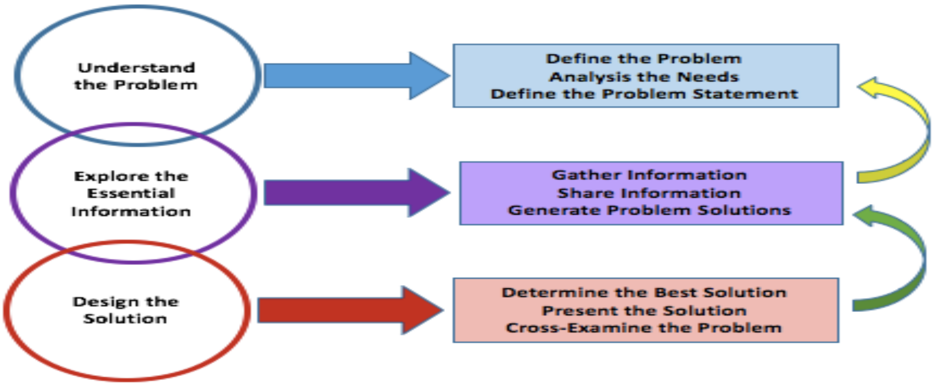



Figure 2. Processes designing solution in project-based learning

1. **Learning and Motivation**

Some researchers suggest that motivation has an important role in students' learning processes and achievement of understanding (Larson & Rusk, 2011; Tai, et al., 2006; Renninger, 2003; Ryan & Deci, 2000; Ames, 1990; Ormerod & Duckworth, 1975). When students are challenged and motivated in learning processes, they will more confident toward their knowledge, skills, and obstinacy in their school. If learning materials or projects are challenged to students, then students will have more opportunities for self-regulated thinking, positive interests, and understanding in the learning processes (Hidi & Harachiewicz, 2000).

Program of schools and teachers can support accelerated developing of educational goals, attitudes, and beliefs in students that influence to quality of education and learning (Ames, 1990). When teachers have efficient method to reach their goals in learning processes, they will design a learning environment that encourage students' self-motivation, then struggling to gain knowledge, and achieve educational goals that designed by teachers. Perhaps, when a technology in the 21st century is used as learning material in STEM field learning, it could motivate students in the learning processes actively. It impacts to improving of students' skills, self-confidence, and self-regulated thinking in solving problems (Heafner, 2004).

Research about correlation between learning and motivation indicated that self-regulation is key to conscious why design learning required in learning processes (Deci & Ryan, 2004). The main point of this statement is why students learn through a specific design to understand a concept and why students attract to designed learning. Students' interest and personal satisfaction are internal aspects that motivate students to learn something. Moreover, reward and punishment could be external aspect that motivate students. Essentially, interest, needs, and satisfaction are keys to motivate students in learning. When students are motivated by themselves, they have an interest and satisfaction towards a subject and are indicated more advance in the classroom (Kyndt el al, 2011). Students who are motivated have a deep interest in a subject, usually they do not think the positive rewards. Intrinsic motivation is play important role in learning because it is affected by one's own challenge, inquiry, regulation, imagination, and correlated to daily life. Students who are motivated to learning, also developing in the educational design, and gain a better quality of learning.

Cooperative learning is referring to small organized group of students who support each other to understand concepts and contexts and its correlation (Mayer & Alexander, 2011). Cooperative learning is effective and efficient approach of learning processes in the classroom because it supports teamwork and communication among the students, encourages other students to be success as learner, and open the minds of students in considering an integrated connection in the learning processes. Cooperative learning and project-based learning support students active in the learning processes, increase interest and satisfaction in learning, and become a motivated learner. When students practice cooperatively in the learning process, this condition could be created a productive learning environment, motivated students who achieved understanding through the learning processes (Roger & Johnson, 2009).

**2. Motivation and Project-Based Learning**

According to some researches that involve teachers, students were learned a content effectively, when they are interested and motivated to the content and enjoy with learning environment would guide students into meaningful understanding. Sustaining students encouraged and motivated in the learning is difficult duty for beginner teacher and experienced teachers (Yates, 2012). Iadiapolo (2011) suggested that students improve higher-order level thinking skills when they were involved actively in solving contextual or authentic problems for implementing knowledge and skills that they were learned. In authentic learning, teachers ask students questions about the connection of what they are learned and daily life problems or technology, in contrast, they will be unmotivated because they think no connection to what is being learned in classroom.

In some schools, students must have memorized facts or formulas, so students’ motivation would decrease (Railsback, 2002). Through PBL connected between students` own experiences, students skills to what was presented in classroom, and students` learning styles. This method helps to remain students interested in what they are learning and further connect their learning experiences to real life problems. “Projects served to build bridges between the phenomenon in the classroom and real-life experiences; the questions and answers that arise in their daily lives are given value and are shown to be open to systematic inquiry” (Blumenfield, 1991). PBL include content standards and arranged throughout questions. the students` assignment is to work towards this goal of answering the questions with a final product or solution the problems.

PBL attach technology which most students are interested to use to keep the students interest in learning process (Boss & Krauss, 2008). The use of technology to surf the internet for web-based information for projects is a factor in bringing change in the learning processes in schools (ChanLin, 2008). Through PBL, students occupied in cooperative learning and discussion effectively among groups to make product or to get conclusions and solutions. intercommunicating actively with group members, teacher, sharing of resources, help and assistance, and motivation for each member in the group could be improved. Collaborative learning also helped to increase inherent motivation because of its high level of independence in determining how a project should look like and the opportunity to work closely with their classmates (Liu et al.,2004). Students also stimulated to work toward set goals that lead significant to them.

The final projects such as a pedagogical instrument rises students` motivation and interest (Wright, 2012). According to Wright (2012), a culminating project or a presentation produced a goal and blended passion for students. Besides, the students who frequently struggle in most academic settings find meaning and confirmation for learning by working on projects (Nadelson, 2000).

**Project-Based Learning and Technology**

PBL is an instructional approach that focuses on produce meaning to students' understanding of concepts in a discipline. When engage PBL in classroom, the process to build this meaning to the student includes problem solving, investigating, and develop personal knowledge skills.

Students can search information easily using a computer connected to internet, this technology helps students to achieve deeper understanding of a concept and context which may not be transferred in classroom. A meaning understanding can be gained if students are actively involved in learning processes. Students can improve skills thinking through the practicing of authentic problem solving (authentic assessment) and utilizing of technology as tools to increase knowledge (Land & Greene, 2000).

Using technology as product of PBL approach help teachers to guide students engage actively in learning processes (students center) to make good learning environment has deeper meaning for them. Students will feel their learning has meaning for their life when they understand the correlation among new information, experiences, contexts, and initial knowledge. Students understand a technology to acquire knowledge and analyze these ideas which may be implemented to different contextual situations.

An important goal of PBL is to develop students' critical thinking skills. As recommended by Roschelle (2000), the use of computer not only supports learning processes, but is useful in the mastering of higher-order thinking skills and scientific inquiry. Besides, internet system is very useful to increase students' management knowledge or information and support students to solve problem easily and quickly (Dogruer, Menevis, & Eyyam, 2011; Geladze, 2015).

In trans-disciplinary problems and issues, students need to regulate information and knowledge to design plan, research, generate solutions, and evaluate effectively and efficiently. In order to solve trans-disciplinary problems and issues are required technological tools, software, and internet connection. Therefore, students easy to manage and gather information, planning, and solutions. Furthermore, students necessary to possess communication skills to explain their ideas, knowledge, planning, and solutions. The important is the ability to processes peers' ideas and themselves ideas to generate the best solution. In discussion processes of communication, sometimes the technological tools, software, and internet connection are required to make effective communication. According to Moursund (1999), Students could be supported by technological information to finish project in a PBL class. Its help students to design solution, gather information, regulated-learning, evaluate solutions, and optimize solutions. In order to finish or solve the projects in classroom scale and the real-world projects are required the skills that explain in above. Therefore, project based-learning in classroom could support the students more communicative, creative, think critically, and evaluate all aspects in finishing the tasks. Project based-learning would be an approach in learning processes to encourage students advance in higher-order thinking skills.

### 3. Implementing and Assessing of Project-Based Learning

Based on research on PBL that this method of learning has motivated students develop the knowledge and skills to be successful in next future. The teacher will implement an assessment plant to evaluate the learning process of the students` project in the end of completed project through PBL. To determine how much the students have learned and how to help the students reach their goals, teachers used assessment plant and implementing of PBL serves as an important tool. The three components of instruction which are classroom activities, assessment, and curriculum are correlation through collaboration and inquiry method to students learning (Barron & Hammond, 2008). in 21st century, teachers have to incorporating new approaches to making learning evaluation more significant. The implementation assessment allowed the students to study and apply the required learning concepts, knowledge and skills in a disciplined way. Furthermore, assessment tools, like assignment guidelines and worksheet define what forms good work and successful collaboration skills for students. As Barron & Hammond (2008) said: *"Formative assessments serve as a guide to give feedback to students and to shape their instructional program throughout a project"*.

The category of assessments teachers uses for PBL appear an important part in make the students' project they are undertaking. Some researchers suggest that PBL request structured performance assessments, to establish the learning tasks of the students and assess what the students have learned. Good implementation assessments extend students' thinking, skills and planning abilities. There are many ways in which evaluation provided to a student learning, for example presentations, projects in multimedia presentations, and power point presentations. PBL assessments combine 21st century skills of collaboration, presentation skills, critical thinking skills, and covers mathematic standards with an in-depth focus (Edutopia, 2011). In addition, PBL also provided the assessment method of formative assessment, apply of student's mind, survey, and interviews used to provide direction for students and teachers based on their project performance and work successes. The successful implementation of PBL is based on the successful of learning plan and implementation of the project, developed by the teacher. PBL change learning process into an active student learning-driven experience, apply technology tools for inquiry, collaboration, and interconnection to the real world beyond the classroom.

## C. Critical Thinking

The concept of critical thinking was explained by Socrates. Definitions of critical thinking vary greatly. Critical thinking has some different definitions according to some researchers, but it is often referred to as discipline and self-directed thinking (Halpern, 1998; Paul & Elder, 2006). Ennis (1985) defined critical thinking as comprising three essential parts. There are three parts of critical thinking as follows: first part is problem solving processes in a real-life context that communicate with the world and other objects. The second part is a reasoning processes, initiated by background knowledge, and previously reasonable conclusions that generated in designing a number of thesis through induction, deduction, and value judgment. The last part was a decision about what to do or what to believe. It can be concluded from Ennis` approach that critical thinking involves not general critical thinking skills but also dispositions towards critical thinking and an eventual decision on how to act.

Bayer (1990), who strongly argued that critical thinking was defined as ability and readiness of individuals to reflect on their own and others` thinking in relation to its truth, value and validity in a logical argument. Beyer has perception that critical thinking and other types of higher thinking skills such as metacognition, problem solving, creative thinking, and decision making are different in some points.

Critical thinking includes purpose, self-regulatory judgment that result in explanation, analysis, evaluation, and conclusion as well as explanation of the matter of fact, conceptual, method, or contextual considerations where that the main point is judgment (Facione, 1990). Willingham (2008) has argumentation that critical thinking is nearly connected with reasoning, problem solving, and decision-making (Willingham, 2008). Another researchers Kek and Huijer, (2011) said that a critical thinker is someone that has the ability to analyze information from related sources, ability to solve problems, and possesses higher-order thinking skills. Biggs (1999) state that students can be trained to think critically, but this requires deeply situation and environment in developing critical thinking skills as an outcome of learning. Additionally, one of the helpful tool for development of critical thinking skills proposed is problems-based learning environments in classroom (Birgili, 2015). Moreover, the increase critical thinking skills in the treatment group's through PBL were also impacted by the STEM integrated PBL problem (Rehmat, 2015).

The classroom activities need to be convert from a teacher centered to a student centered and critical thinking centered environment to develop students` critical thinking skills (Jones, 2012). The classroom atmosphere can make students can learn independently, work together in research, can solve problems, and can apply in the real-world context. Critical thinking skills can contribute to the success of careers in the 21st century. For students who have studied STEM to participate in the workplace, they will engage in scientific practice, collaborative skills, communication skills, the ability to think critically, and become more innovative (Mulnix & Vandergrift, 2014).

Critical thinking is one of important skills for a career in STEM (Baethe, 2013; Rehmat, 2015). Therefore, students must be prepared to advance in critical thinking skill during school time (from elementary school until senior high school). One of the ways to improve students' critical thinking skill through integrated STEM learning in classroom that encourage students in interaction with environment, solving authentic problems, and communication. Through these activities, students improve their thinking skills (DeJarnette, 2012; Hashim, Ali, Shamsudin, 2017). In 2009, President Obama wants innovation in science and technology more advance he stated: *Our nation's governors and state education chiefs to develop standards and assessments that don't simply measure whether students can fill in a bubble on a test, but whether they possess 21st century skills like problem solving and critical thinking, and entrepreneurship and creativity. (as cited in Barell, 2009, p. 197)*

The new science conceptual and contextual framework encourage students to master in 21st century skills through incorporating of scientific inquiry and science and engineering practices that stimulate students to improve and use critical thinking skills when conducting Project Based Learning processes such as investigation, generating ideas, and designing solutions (NRC, 2012; Wekesa & Ongunya, 2016). In STEM learning, students are directed like scientist, they should define problem, gather information, conduct experiment, collect data, analysis data, and discover new knowledge (Tang, Coffey, Elbi, Levin, 2009; Bybee, 2013). Students' critical thinking skills are improved through analysis data, validate solution, and justify conclusion (Pallant, Pryputniewicz, and Lee, 2012; Sudibyo, Jatmiko, Widodo, 2016). The Context Based Learning (CBL) and Project Based Learning (PBL) were conducted in middle and high schools to analysis students' critical thinking skills through, selection of information, designing of solution, and evaluation of solutions (Kek & Huijser, 2011; Sudibyo, Jatmiko, Widodo, 2016). A significant difference on students' pre-post critical thinking scores were found through computer-based learning. An IT/STEM project has been conducted to high school to investigate an IT/STEM project impact to students' critical thinking skills. Where each group focused on three different content specific concepts that were complemented with IT applications. Through this project, students significantly increase their critical thinking skills particularly in the areas of prediction and deductive reasoning, which simulated their interest in STEM filed (Duran & Sendag, 2012).

Styron (2014) state that exchanging ideas within small groups is one of the main behaviors to help promote critical thinking skills as small group conversation among students encourage thought while also promoting collaboration. Besides, this research showed that taking responsibility for learning makes students become critical thinkers. Another researcher (Wheland, Donovan, Dukes, Qammar, Smith, & Williams, 2013) states that reduce anxiety and improve students' attitude and content knowledge can develop critical thinking skills. Many researcher studies about critical thinking skills and they have found positive result. (Hasim and Shamsudin, 2017; Pallant, Pryputniewicz, &Lee, 2012; Rehmat, 2015; VanTassel-Baska et al., 2006).

A recent study by Dole, Bloom and Doss (2017) examined the impact of inquiry-based teaching to critical thinking skills in elementary and middle school. Participants had taken a hybrid course consisting of four weeks online followed by a one-week intensive field experience facilitating problem-based and project-based learning with children in grades 1–9. The result showed that student preference for both the autonomy and collaboration inherent in Problem Based Learning (PBL) and Project Based Learning (PjBL). With regard to practices that support autonomy, PBL and PjBL provide opportunities for student choice, self-regulated learning, critical thinking skills and independent learning in every stage of the learning process.

According to Paul and Willsen (1995), critical thinking was a purposeful and systematic method of thought. They explained that critical thinking skills involved a highly systematic process where there was clear support for solid reasoning, precision, and awareness of thought. Paul emphasized that mastering to disciplines and self-regulated thinking could be trained through unfamiliar problem solving. Paul suggested that critical thinking was developed from other skills, such as generating of conclusions, examining of beliefs and information, analysis of mistakes, and evaluating of results.

Critical thinking is one of high order thinking which most important real-life skills is. Where in Next Generation Science Standard (NGSS) mention that critical thinking and communication skills must be possessed by students for their future (NGSS, 2013). Critical thinking is the intellectual disciplinary process of analyzing and evaluating thinking with a point of view to improving it, self-directed, self-disciplined, self-monitored, and self-corrective thinking. In critical thinking, there are six stages consist of unreflective thinker, challenged thinker, beginning thinker, practicing thinker, advanced thinking, and master thinker (Paul and Elder, 2008).

In addition, critical thinking leads to the ability to analyze information, to determine information and then interpret it in solving problems through design solution (Gagné, 1988). "*It requires high-level thinking; involves the process of analysis, evaluation, reasonableness and reflection"* (Jeevanantham, 2005). According to Paul and Elder (2008), there are 8 elements of thought namely: *purpose, questions at issue, information, interpretations and interferences, concepts, assumptions, implications and consequences, and point of view.* The intellectual Standards describe the criteria used to evaluate the quality of the critical thinking.

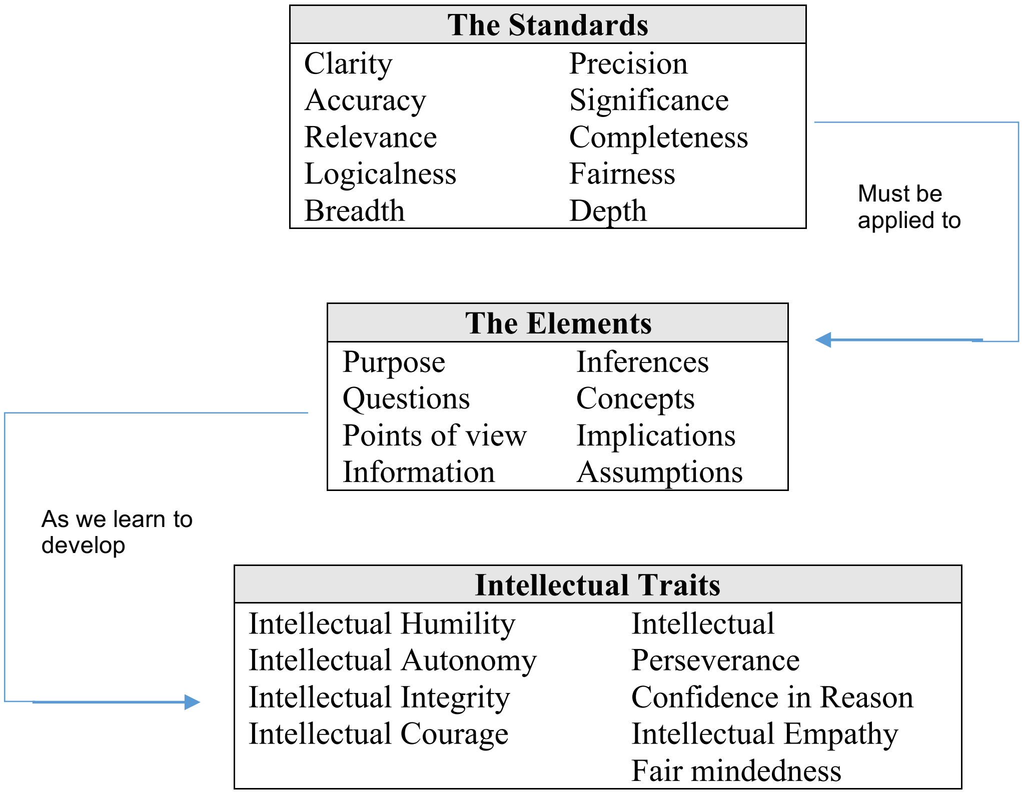



Figure 3. The Paul-Elder framework for critical thinking (Paul-Elder, 2009).

### D. Attitudes towards STEM

Attitude is a learned trait by an individual either actively or by vicarious Experiences and is receptive to change. Osborne defines attitude as, *"the feelings, beliefs, and values held about an object that may be the enterprise of science, school science, the impact of science on society or scientists themselves"* (Osborne, 2003, p. 1053). Zacharia and Barton (2004) suggested that there are literatures which reported researches on students' interest toward science in elementary and middle school level. It is main point must be considered that the fluctuation nature of an interest toward science is connected to its implementation (Wrightsman, 1977).

An attitude can be directed to a person, situation, group, policy, or an abstract idea. Even though attitude is changeable, it is not a random occurrence; a specific event or situation has to be the catalyst for a change (Zacharia and Barton, 2004). Papanastasiou & Papanastasiou (2004) claimed based on their research that students` environment, parental influence, private ambition, and beneficial instructional methods will influence to students' attitudes toward a specific content. Besides, the teacher is perceived as a significant part of the learning process also impact to students` attitudes in classroom (Agranovich, 2013).

A research (Tseng, Chang, Lou & Chen, 2013) state that students` toward science have to be reviewed in order to develop students` attitudes toward STEM because science is a main part of STEM. To promote of students` attitudes toward STEM have to begin early, because early children more positive attitudes in science than older students, and elementary or middle students express more positive attitudes than high school students (Jarvis and Pell, 2002). Sakariyau (2016) reported that a higher percentage of the students show positive attitude towards science and no significant difference between boys and girls students` attitudes towards science. Ali, M. Shabir & Asif Iqbal (2016) investigated about attitude of students towards science and its relationship with achievement score at intermediate level and the result showed that science related attitude had a significant and positive relationship with the achievement score of science students. The study reported that there was a significant difference between boy and girl points of perceptions in attitude towards sciences and technology, girl have lower averages than boy students (Najafi, Ebrahimitabass, Dehgani, & Rezaei, 2012). A Likert scale survey was developed to assess students' attitude.

Another study reported that high school students had positive attitudes toward engineering when attached engineering design project in learning process. This study was held during summer camp to investigation students` attitudes toward engineering (Chen, Tomsovic and Avdeniz, 2014). The study was used to investigated middle school students` attitudes towards technology. A great number of the students had positive attitudes towards technology. Furthermore, they found that following schools in city areas, having previous technology training, and if the parents with work related to technology had positive influence on students` attitudes towards technology. Students express technology in term of daily life application to make life easier (Nurettin, Emel, Sabahattin, 2015).

STEM Project Based Learning have an impacted student performance in mathematics by demographic backgrounds of students and students` achievement. Also, implementation of STEM Project Based Learning in schools profitable for low performing students to a greater performing and minimize the achievement gap (Han, Capraro & Capraro, 2015). Another research (Rice, Bart, Guadagno, Smith, & McCallum, 2013) about students` attitudes toward mathematics and science reported that students who recognize greater social support for mathematics and science from parents, friends, and teacher have more positive attitudes toward mathematics and science.

Students are directed to have a positive attitude towards STEM so that students have a passion and are stimulated to pursue a career related to STEM. A study investigated high school students and college students found they had not enthusiastic attitudes towards STEM careers, because students recognize scientific careers less creativity and social interaction (Masnick, Valentia, Cox & Osman, 2010). Another study about out-of-school time (OST) science activities as a means to foster STEM career interest. This study reported that students' who attended in OST activities, had significant role in university career interest in STEM. Besides, their interest in mathematics and science in middle school and gender, also play a role in career interest in STEM (Dabney, Tai, Almarode, Miller, Sonnert, Sadler, & Hazari, 2012).

# CHAPTER III

# METHODOLOGY

Chapter of methodology of research explain in depth information on the processes of this research involve a highlight of the research design, participants, instruments, and data analysis.

## A. Research Design

The study applied mixed methods research design. This method of research design is a procedure for collecting, analyzing, and "mixing" both quantitative and qualitative methods in a study or a series of studies to achieve purpose of research (Creswell & Plano Clark, 2011). In mixed method research there are qualitative data and quantitative data. Quantitative data, such as scores on instruments, result specific numbers that can be analyzed statistically, can generate result to judge the frequency and dimensions of trends, also can supply useful information to report trends about a large number of people. Besides, qualitative data, such as open-ended interviews that provide actual minds of people in the study, propose many diverse perspectives on the research and give a complex picture situation (Creswell, 2012). *"When one combines quantitative and qualitative data, we have a very powerful mix"* (Miles & Huberman, 1994). Creswell (2012) explained that there were six mixed methods designs commonly used in educational research:

- The convergent parallel design
- The explanatory sequential design
- The exploratory sequential design

- The embedded design
- The transformative design
- The multiphase design

This study focus applied mixed methods the convergent parallel research design. The goal of a convergent parallel mixed methods research design is to synchronously collect both quantitative and qualitative data, incorporation the data, and apply the results to solve a research problem (Creswell, 2012). The convergent parallel mixed methods research design can be show as figure 4.

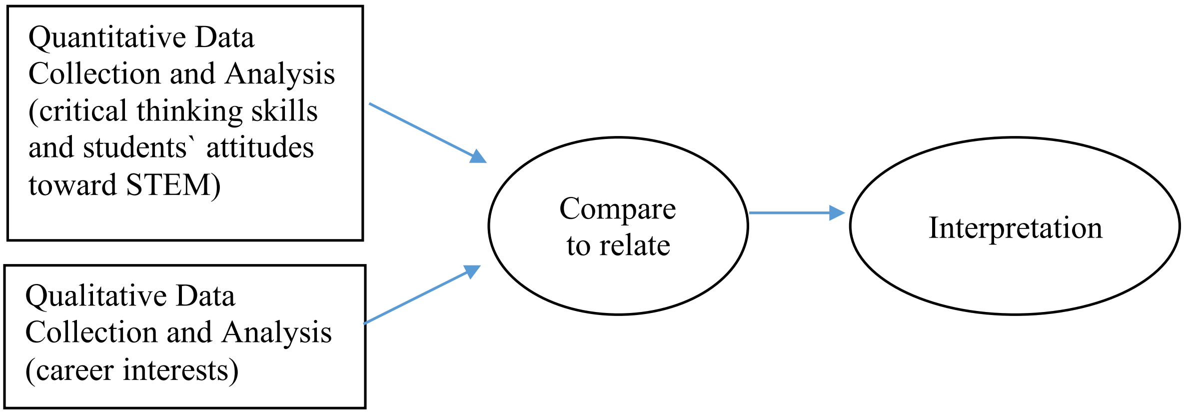



Figure 4. The convergent parallel mixed methods research design.

This study will describe completely in scheme of research. The scheme of research can be show as figure 5.

**B. Participants**

The participants were 160 first grade Japanese middle school students from four classes and 111 first grade Indonesian middle school students from three classes. They were divided into nine groups each class.

The students in the treatment group engaged in STEM education using project-based learning methods. The participants completed the critical thinking test (worksheet), and STEM attitude and career interest questionnaire.

## C. Instruments

The instruments were worksheets to explore students' critical thinking skills how to clean up wastewater and problem-solving processes. The questionnaire was developed by professional educational researcher in America (Faber, et. al., 2013). This questionnaire consisted of 26 questions about attitudes toward STEM and 12 about career selection. The collected data describe the percentage of students' responses. Besides, the instruments were wastewater, filter paper, beaker glass, plastic bottles, litmus paper, and some materials or tools which needed by students. Therefore, students had to think the materials in order to solve problems. In these lessons, students not only wrote worksheets, but also designed tools to clean up the wastewater. Students were given more than one chance to design the best product for wastewater treatment. The lessons consist of six lessons, first lesson was the introduction of colloid, solution, and suspension, and discussion about wastewater. From the second lesson to fourth lesson were to find solutions and design products. Fifth lesson is watch video of wastewater treatment in Japan and optimize the solutions or products. Last lesson was to make conclusion, presentation, and discussion. The lessons were started by explanation of different solution and colloid, furthermore, illustration problem about the need of wastewater system in our city to conserve the sea. And then, students had to find solutions to clean wastewater.

## D. Data Analysis

### 1. Analysis Indonesia and Japanese science textbooks

Science textbook is one of tool for identifying students' initial knowledge, although students' ability to understand each concept is different each other. At the minimum, students ever learn the topics that describe in the textbook. Indonesian and Japanese textbooks were analyzed to identify the topic that taught in first grade middle school students. This topic would be a fundamental consideration to develop the STEM education learning. Since STEM education learning in this study were a Project Based Learning that ask students to design solution, students need the basic content knowledge to solve problem.

For many science educators, textbooks offer a predefined scope and sequence of science content, access to scientific concepts and principles, and ways to present these concepts to their students (Ball & Feiman-Nemser, 1988). Moreover, science textbooks are frequently used as the main source of the subject matter that students are expected to understand and supply detailed explanations of subject to be taught (Chiappetta & Fillman, 2007). Although some researchers have been conducted on middle science textbooks, almost no research was found regarding STEM implementation in middle science textbooks.

Based on TIMSS 2011 research showed that 71% of teachers in Japan used textbooks as the major study material, but 29% used it as a supplement. In Indonesia these numbers are distinctly higher: 97% and 3%, respectively. Thus, textbooks most frequently are the ones deciding the content of science subjects, topics to examine, proportion of different subjects and how the subject is taught at school.

Therefore, it shows that implementation of STEM education can be analyzed through context of science textbook.

The science textbooks descriptively based on the presence of science, technology, engineering, and mathematic aspects and the categories of STEM education that proposed by Beers (2013) as follows:

a. *A variety of learning opportunities and activities* (are the contents of textbook which encourage students in STEM activities).
b. *The use of appropriate technology tools to accomplish learning goals* (Whether the used technologies in learning have correlation with the concepts taught or not?).
c. *Project based learning* (Whether the task for students has conditions for project-based learning or not?).
d. *Cross-curricular connections* (Are there overlapping concepts in science, technology, engineering, and mathematic?)
e. *A focus on inquiry and the student-led investigations* (Whether the tasks lead students to construct their understanding and increase their curiosity or not?).
f. *Collaborative learning environments, both within and beyond the classroom* (Whether the tasks provide students to discuss and work together or not?).
g. *High levels of visualization and the use of visuals to increase understanding* (The picture in textbook will give concepts and contexts for understanding).
h. *Self-assessment* (that provide students to assess their knowledge and understanding).

## 2. Critical Thinking Skills

The data were collected by worksheets and observation sheets during the lessons. The collected data were analyzed using critical thinking rubric that designed by Paul and Elder (2009) critical thinking framework. This Paul and Elder critical thinking framework is one of frameworks that have been used in some researches to analyze critical thinking, because this framework was general for engineering, natural science, social science, and linguistics. The collected data were analyzed using R in order to see different of critical thinking of each class. Before the data were analyzed statistically, and students' design solutions were scored by critical thinking rubric, so the students' design solution could convert to numeric data. Furthermore, the gained scores were compared with criteria of critical thinking based on stages of critical thinking development (Table 2).

Table 1. Critical Thinking Rubric
(base on the Paul-Elder critical thinking framework)

| **Dimension** | **Score** | | | |
|---|---|---|---|---|
| | **4** | **3** | **2** | **1** |
| Purpose and question | Clearly identifies the purpose including all complexities of relevant questions. | Clearly identifies the purpose including **some** complexities of relevant questions. | Identifies the purpose including **irrelevant** and/or **insufficient** questions. | Unclear purpose that does not includes questions. |
| Information | Accurate, complete information that is supported by relevant evidence. | Accurate, mostly complete information that is supported by evidence. | Accurate, but incomplete information that is not supported by evidence. | Inaccurate, incomplete information that is not supported by evidence. |
| Assumption and point of view | Complete, fair presentation | Complete, fair presentation | Simplistic presentation that ignores | Incomplete presentation that ignores |

| | | | | |
|---|---|---|---|---|
| | of all relevant assumptions and points of view. | of some relevant assumptions and points of view. | relevant assumptions and points of view. | relevant assumption and points of view |
| Implications and consequences | Clearly articulates significant, logical implications and consequences based on relevant evidence | Clearly articulates some implications and consequences based on evidence. | Articulates insignificant or illogical implications and consequences that are not supported by evidence. | Fails to recognize to generates invalid implications and consequences based on irrelevant evidence |

Table 2. Scoring of Critical Thinking Development Stages (Paul and Elder, 2009)

| | | | | | |
|---|---|---|---|---|---|
| Criteria of score: | 3.51 | - | 4.0 | : | Master Thinker |
| | 3.11 | - | 3.50 | : | Advanced Thinker |
| | 2.41 | - | 3.10 | : | Practicing Thinker |
| | 1.71 | - | 2.40 | : | Beginning Thinker |
| | 1.01 | - | 1.70 | : | Challenged Thinker |
| | 0 | - | 1.0 | : | Unreflective Thinker |

**3. Students` Attitudes Toward STEM and Career Interests**

Students' attitude toward STEM field consisted of 26 statements with five scales likert (strongly agree, agree, neutral, disagree, and strongly disagree). This questionnaire could be a reference that describe students' interests of science, mathematics, engineering and technology. The questionnaire, S-STEM Survey (Student Attitudes Toward STEM) was developed by professional educational researcher in America; (Faber, et. al., 2013).

For science category consisted of 9 statements with 8 positive statements and one negative statement. For mathematics category consisted of 8 statements with 5 positive statements and 3 negative statements. Further, for engineering and technology consisted of 9 positive statements. The scoring of positive and negative statements was different in which for strongly agree response of positive statement was given 5 points, while for negative statement was given one point. The detail questionnaire can be seen in appendix.

Table 3. S-STEM questionnaire sample items

| S-STEM Construct | Number of Item | Sample Items |
|---|---|---|
| Science Attitudes | 8 | I am sure of myself when I do science. |
| | | I will need science for my future work. |
| Mathematics Attitudes | 9 | I am the type of student who does well in math. |
| | | When I`m older, I might choose a job that uses math. |
| Technology and Engineering Attitudes | 9 | I like to imagine creating new product. |
| | | I believe I can be successful in a career in engineering |

Moreover, career interests of students consisted of 12 questions that ask what kinds of work you are desiring in the future. The careers divided into 12 field namely physic, environment, biology, veterinarian, mathematic, healthy, computer science, medical researcher, chemistry, energy, and engineering.

The questionnaire responses were convert to numerical data in order to analyze statistically. Further, the analyzed questionnaire data and critical thinking data were investigated in terms of the correlation among them. Because the attitude toward STEM fields correlated to motivation of learning, whether critical thinking skills are influenced by students' motivation learning. Besides that, project-based learning can motivate students who got lower motivation for learning.

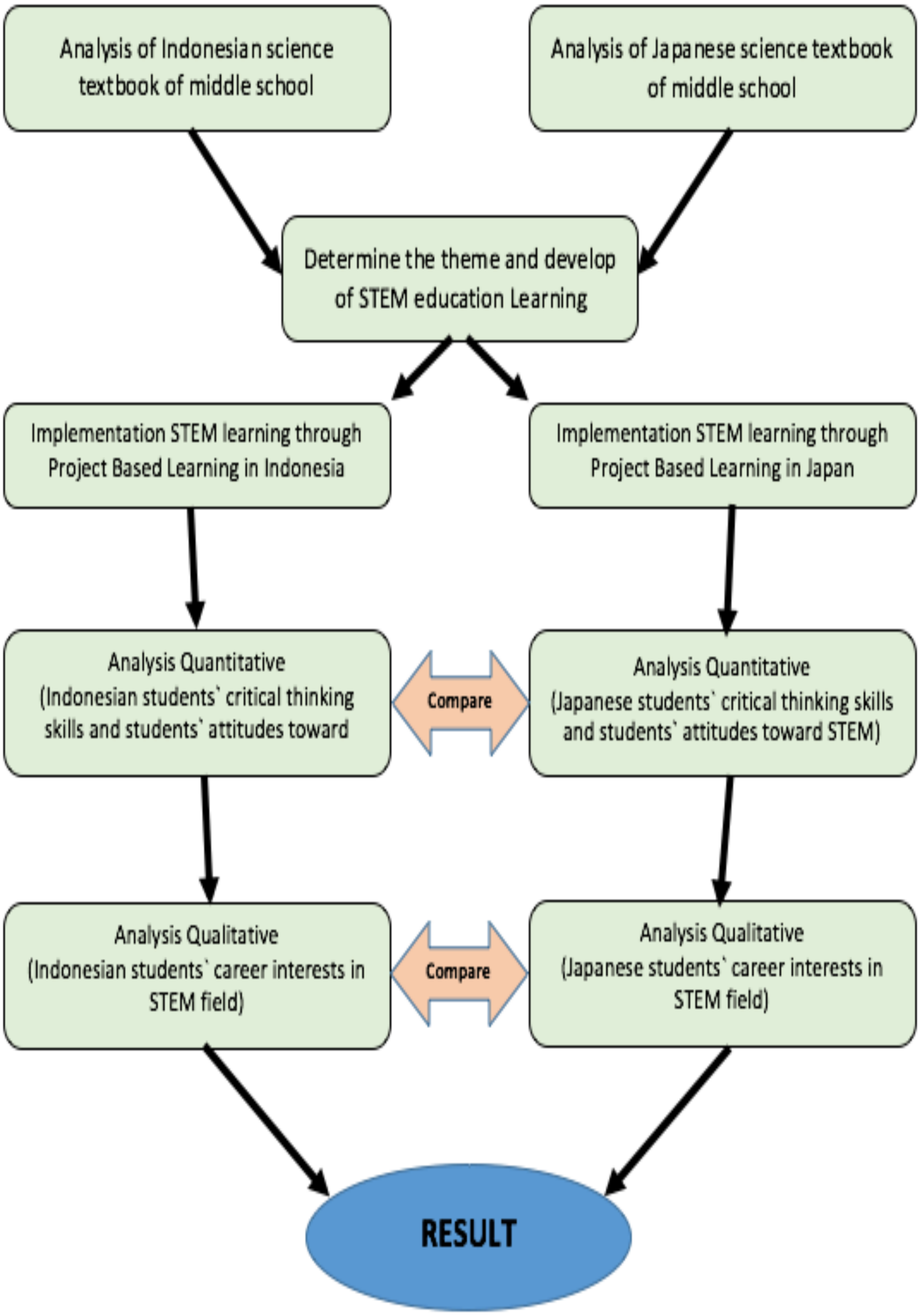



Figure 5. Scheme of Research

# CHAPTER IV
# RESULT AND DISCUSSION

In order to develop authentic learning and assessment system, students' initial knowledge should be identified for determining the theme will be challenged to students. Initial knowledge required to solve the problems or issues effectively and efficiently (Fischer, Greiff, Funke, 2012; Sherin, 2006). There are seven steps of problem solving consisted of defining the problem; to gather information and data; analysis data to identify why the problem is occurring; to identify, evaluate, and to select solution; to identify and implement action items; to monitor result; to adjust and sustain improvement (Minnesota Continuous Improvement, 2016). In gathering information and data process, initial knowledge support students to achieve higher order information and data. In order to identify the initial knowledge of students, it can be done through analysis of science textbook.

Furthermore, Japanese and Indonesian students are the next generation who must be prepared to solve problems and issues in the future of each country. Critical thinking skills required to solve problems or issues effectively and efficiently. Critical thinking skills in terms of students' levels are influenced by motivation of students. Therefore, they have correlated each other. Japanese and Indonesian students' profiles of critical thinking skill, motivation (attitude) of STEM fields, and career interests. The results of Japanese and Indonesian science textbooks, critical thinking skills, attitude toward STEM field, and career interests are described in this chapter.

## A. Analysis Science Textbook

This study compared science textbooks between Japanese and Indonesian middle school level. This study analyzed one Japanese textbook and one Indonesian textbook published by private printing company. This study analyzed the science textbooks descriptively based on the presence of science, technology, engineering, and mathematic aspects and the categories of STEM education that proposed by Beers (2013).

### 1. Analysis Contents of Indonesian and Japanese Science Textbook

The first stage in analysis textbook is analyze the contents of textbook itself. In analyzing the contents reviewed several aspects, there are about content knowledge, learning process, tools and connection with daily life. Each chapter in middle school science textbook was described in the following table.

a. Organization of life

| Country | Aspect | | | | |
|---|---|---|---|---|---|
| | Grade | Knowledge | Learning Process | Tools | Connection with daily life |
| Indonesia | 7 | • Function of cell part.<br>• The differences between animal and plant cells.<br>• Organ system of plant, animal, and human. | Experiment about animal and plant cells, and explanation through text and some pictures (black and white). | Micro scope | - |
| Japan | 7 and 8 | • Structure and part of many flowers.<br>• Differences of | Experiment to observe structure and part of flower. | Micro scope, loop, tweez ers, | - |

| | | | | | |
|---|---|---|---|---|---|
| | | angiosperm and gymnosperm.<br>• Differences between animal and plant cell.<br>• Different shape of cell each part of body. | Experiment about plant and animal cell.<br><br>Experiment about shape of plant cell of each part. | coloring solution. | |

b. Characteristic and states of matter

| Country | Aspect | | | | |
|---|---|---|---|---|---|
| | Grade | Knowledge | Learning Process | Tools | Connection with daily life |
| Indonesia | 7 | Characteris-tics of matter. Change state of matter. Adhesion, cohesion, capillarity, density. Mixtures (acid, base, salt, and indicator) | Experiment, explanation through text and some pictures (black and white). | • Analytical scale<br>• Beaker glass<br>• Test tube<br>• Erlenmeyer<br>• Burner<br>• Pipette<br>• Gauze and tripod<br>• Filter paper<br>• Litmus paper<br>• Universal indicator<br>• pH meter | Density, changing states of matter, and acid-base indicator |
| Japan | 7 | • Characteristics of solid, liquid, and gas matters.<br>• Correlation among volume, | Experiment to find characteristic and change state of matters. | Gas burner, scale, thermometer, loop, filter paper. | Make coffee, tea, and salt water using hot water.<br><br>Produce salt from sea. |

| | | | | | |
|---|---|---|---|---|---|
| | | temperature, and particle of matters.<br>• Density.<br><br>• Mixtures (solution "salt, acid and base", colloid).<br>• Solubility and re-crystallization. | Measure weight and volume of objects.<br>Time to dissolve solid objects in water.<br>Test acid-base using litmus paper, BTB, conductivity, and magnesium.<br>Evaporate the water of solution. | | Vinegar and toilet cleaner. |

c. Energy and transformation of energy

| Country | Aspect | | | | |
|---|---|---|---|---|---|
| | Grade | Knowledge | Learning Process | Tools | Connection with daily life |
| Indonesia | 7 | Form of energies.<br>Transformation energy.<br>Source of non-renewable and renewable energies.<br>Law of energy conservation.<br>Work and power. | Experiment, observation, explanation through text and some pictures (black and white). | • Oil lamp<br>• Paper<br>• Beaker glass<br>• Test tube<br>• Tripod and gauze<br>• Petri dish<br>• Pipette<br>• Polybag<br>• Tube clamp<br>• Burner | Transformation of energy (making flashlight) |
| Japan | 9 | Force, work, and power. | Pull and push some objects in some elevations. | Metal ball, scale, speed recorder, | Use pulley to lift object.<br>Jet coaster. |

| | | | | | |
|---|---|---|---|---|---|
| | | Form of energies. Transformation energy. Conservation energy. | Experiment about speed of moving. Experiment about variable that affect to potential energy. | battery, lamp, wood, cable. | Lamp. Battery. Heater. |

d. Ecosystem

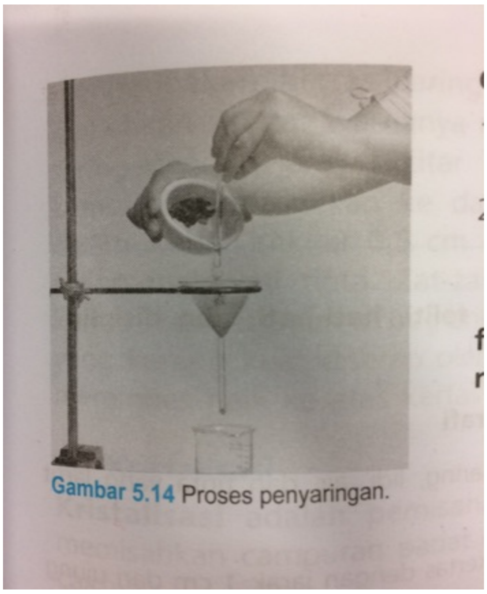
| Country | Aspect | | | | |
|---|---|---|---|---|---|
| | Grade | Knowledge | Learning Process | Tools | Connection with daily life |
| Indonesia | 7 | Definition of ecosystem and units of ecosystem. Component of ecosystem. Type of interaction and food chain. | Observation, explanation through text and some pictures (black and white). | | Distribution of food and animal feed, developing farm system. |
| Japan | 9 | Definition of ecosystem. Component of ecosystem. Food chain. | Explanation through pictures and graphics. Experiment to observe organism in soil. | Filter paper, lamp, beaker glass | Distribution of food and animal feed, developing farm system. |

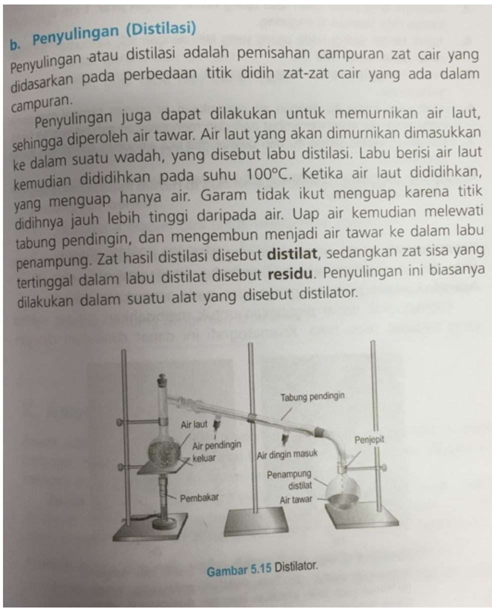
**2. Analysis of implementation STEM education on Japanese and Indonesian science textbooks for middle school.**

STEM education is a model learning that integrate science, technology, engineering, and mathematics in learning. In Indonesian science textbook, for the explanation of concepts it is very rare to use the pictures, then the application of concepts in contextual situation or daily life is very small part showing in Indonesian textbook. According to this condition, Indonesian students are predicted could not solve contextual problems in daily life, however, they could answer the questions of end year examination. In contrast, Japanese science textbook always attach the applications of each scientific concept. It means Japanese science textbook has already inserted the value of STEM integrated learning implicitly, although there was no explanation of STEM at all.

1. Indonesian science middle school textbook

| Aspect | Science | Technology | Engineering | Mathematics |
|---|---|---|---|---|
| A variety of learning opportunities and activities | Very High | Low | Very Low | Low |
| The use of appropriate technology tools to accomplish learning goals | | Very Low | | |
| Project based learning | No | Very low | Very low | No |
| Cross-curricular connections | Low | Very low | No | Low |
| A focus on inquiry and the student-led investigations | High | No | No | No |
| Collaborative learning environments, both within and beyond the classroom | Very low | No | No | No |
| High levels of visualization and the use of visuals to increase understanding | Very Low | Very Low | No | No |
| Self-assessment | No | No | No | No |


Gambar 5.14 Proses penyaringan.


b. Penyulingan (Distilasi)

Penyulingan atau distilasi adalah pemisahan campuran zat cair yang didasarkan pada perbedaan titik didih zat-zat cair yang ada dalam campuran.

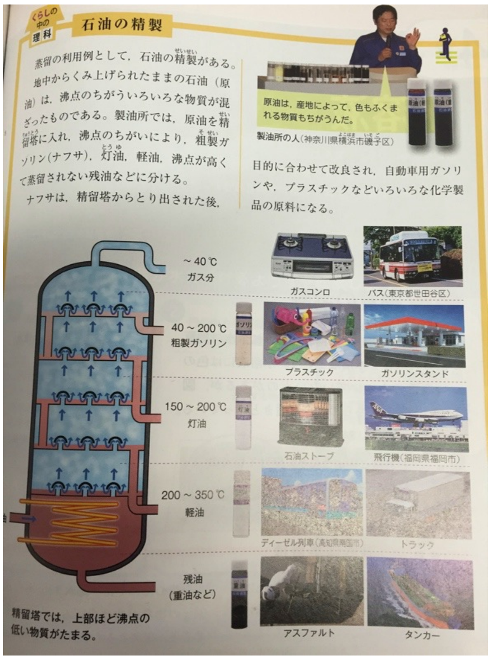
Penyulingan juga dapat dilakukan untuk memurnikan air laut, sehingga diperoleh air tawar. Air laut yang akan dimurnikan dimasukkan ke dalam suatu wadah, yang disebut labu distilasi. Labu berisi air laut kemudian dididihkan pada suhu 100°C. Ketika air laut dididihkan, yang menguap hanya air. Garam tidak ikut menguap karena titik didihnya jauh lebih tinggi daripada air. Uap air kemudian melewati tabung pendingin, dan mengembun menjadi air tawar ke dalam labu penampung. Zat hasil distilasi disebut **distilat**, sedangkan zat sisa yang tertinggal dalam labu distilat disebut **residu**. Penyulingan ini biasanya dilakukan dalam suatu alat yang disebut distilator.

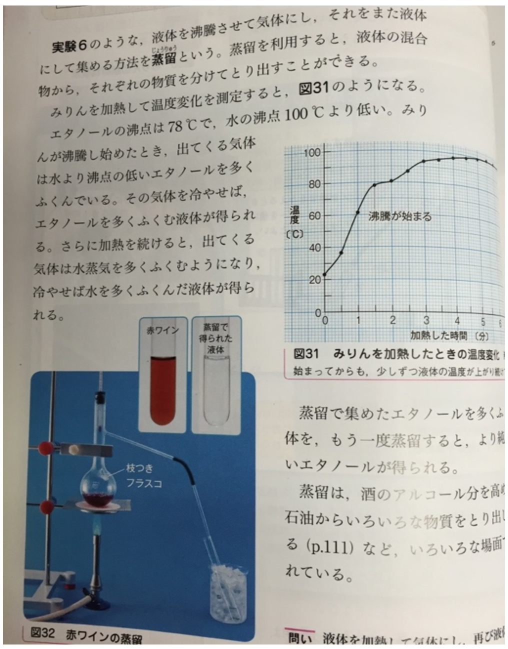

Gambar 5.15 Distilator.

Picture 1. Indonesian Middle School Science Textbook about distillation processes (Erlangga).

2. Japanese Science Middle School Textbook

| Aspect | Science | Technology | Engineering | Mathematics |
|---|---|---|---|---|
| A variety of learning opportunities and activities | Very high | Low | No | Low |
| The use of appropriate technology tools to accomplish learning goals | | Very low | | |
| Project based learning | High | No | No | No |
| Cross-curricular connections | Intermediate | Very low | | |
| A focus on inquiry and the student-led investigations | Very high | No | No | Low |
| Collaborative learning environments, both within and beyond the classroom | Very high | No | No | No |
| High levels of visualization and the use of visuals to increase understanding | Very high | Very high | No | No |
| Self-assessment | High | No | No | No |






Picture 2. Japanese Middle School Science Textbook about distillation processes and its' application in daily life (Dainippon)

According to the analysis of Indonesian and Japanese science textbooks, there are similarities in learning processes of some contents. However, there are many differences between Indonesian and Japanese science textbook as follows:

- Indonesian textbook consisted of explanation using texts to transfer knowledge, whereas Japanese textbook are using experiments and observations more, and some texts to explain scientific concepts clearly.
- Indonesian textbook includes much more concepts that must be studied by students, but each concept does not study deeply. This situation contrasts with Japanese textbooks that have some concepts, but each concept studied deeply.

The study has tried to analyze Indonesian and Japanese science textbooks for first grade middle school based on eight aspects in terms of connections to STEM education. Based on the result of analysis textbooks, this study concludes as follows:

- Both Japanese and Indonesian science textbook have variety of learning opportunities and activities, the uses of appropriate technology tools to accomplish learning goals, cross-curricular connections in science textbook, and a focus on inquiry-based and the student-led investigations with the biggest percentage of scientific fields only. It is mean that technology, engineering, and mathematics fields need to be developed further to integrate STEM education on science textbook.
- Aspects of high levels of visualization and the uses of visuals to increase understanding, and self-assessment are consisted in Japanese science textbook

only. Nevertheless, Japanese science textbook needs supplement contents of technology, engineering, and mathematics fields.

- Both Indonesian and Japanese science textbooks in terms of the connections to the STEM education aspects on science textbooks for first grade middle school needs modification especially in technology and engineering aspects in order to implement STEM education in classroom.

Limitations of this study includes no analysis of American science textbook as reference, whereas, America is one of the advanced country with highly organized in STEM education. Furthermore, the textbooks analysis was done for only first grade middle school because the samples of this study are first grade middle school students.

**B. STEM Learning through Project Based Learning**

STEM learning through Project Based Learning (PBL) was developed by NGSS (*Next Generation Science Standard*) framework. Some studies suggest that STEM education learning more effectively through PBL approach. In order to develop STEM learning, the cross-cutting concepts aspects should be considered in learning processes. Because cross-cutting concepts can help students better understanding of a nature, common vocabulary, core ideas and practices of science and engineering. Cross-cutting concepts should be assessed dependently from practices or core ideas (NGSS, 2013). In this study, the lessons consisted of six lessons, first lesson was the introduction of colloid, solution, suspension, and discussion about wastewater. From the second lesson to fourth lesson were to find solutions and design products. The fifth lesson was to watch video of wastewater treatment in Japan and to optimize the solutions or products. Last lesson was to make conclusion, presentation, and discussion. Each learning was described in the following Table 4.

Table 4. STEM lessons processes of wastewater treatment

| **Activity** | **Crosscutting Concepts** | **Scientific and Engineering Practices (NGSS Framework)** | **Disciplinary Core Ideas** |
|---|---|---|---|
| **First Lesson** | | | |
| Introduction of the theme of lessons and dividing the groups. (9 groups) | | | |
| Provide students to mention examples of solid, liquid, and gas (states of matter) in their daily life. (**Physics**) | Molecules pattern of solid, liquid, and gas. (CCs 1) | Asking questions and defining problems. (SEPs 1) | **Structure and Properties of Matter** The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter. (PSs 1.A) |
| Students observe the demonstration and determine the colloid. (**Chemistry**) | Pattern, Cause and Effect, Scale. (CCs 1, CCs 2, CCs 3) | Asking questions and defining problems. (SEPs 1) Engaging in argument from evidence. (SEPs 7) | |
| Teacher introduce wastewater treatment plant/ cleaning water system and asks students to find any information about how to clean wastewater. (**Science, Technology, Engineering, and Mathematics**). | Matter is conserved because atoms are conserved in physical and chemical processes. (CCs 5) | Constructing explanations and design solutions. (SEPs 6) | **Type of Interaction** Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (PSs 2.B) |
| Students search information in internet, books, and so on. | | | |

| | | | |
|---|---|---|---|
| **Second, Third, and Fourth Lesson** | | | |
| Students design wastewater treatment system.<br>Students determine what they need to clean wastewater.<br>Student check water clarity by their eyes. (**Science, Technology, Engineering, and Mathematics**).<br>Students check pH before and after cleaning processes.<br>Students redesign the wastewater treatment system. **(Science, Technology, Engineering, and Mathematics**). | Influence of S.E.T on society and the natural world (CCs 7).<br>System and model system (CCs 4).<br>Structure and function (CCs 6). | Asking questions and defining problems. (SEPs 1)<br>Developing and using models. (SEPs 2)<br>Planning and carrying out investigations. (SEPs 3)<br>Analyzing and interpreting data. (SEPs 4)<br>Using mathematics and computational thinking. (SEPs 5)<br>Constructing explanation and designing solutions. (SEPs 6)<br>Engaging in argument from evidence. (SEPs 7) | Defining and delimiting engineering problems. (ETSs 1.A)<br>Developing possible solutions. (ETSs 1.B)<br>Optimizing the design solution. (ETSs 1.C) |
| **Fifth Lesson** | | | |
| Students watch video about wastewater treatment plant.<br><br>Students redesign wastewater treatment by drawing or if the time is available, students can redesign their prototype. (**Science, Technology, Engineering, and Mathematics**). | Influence of science, engineering, and technology on society and the natural world. (CCs 7) | Developing and using models. (SEPs 2)<br>Planning and carrying out investigations. (SEPs 3)<br>Analyzing and interpreting data. (SEPs 4)<br>Using mathematics and computational thinking. (SEPs 5)<br>Constructing explanation and designing solutions. (SEPs 6)<br>Engaging in argument from evidence. (SEPs 7) | Defining and delimiting engineering problems. (ETSs 1.A)<br>Developing possible solutions. (ETSs 1.B)<br>Optimizing the design solution. (ETSs 1.C) |
| **Sixth Lesson** | | | |
| Students present and explain their prototype of wastewater treatment system.<br>**(Science, Technology, Engineering, and Mathematics**). | Influence of science, engineering, and technology on society and the natural world. (CCs 7) | Obtaining, evaluating, and communicating information. (SEPs 8) | Defining and delimiting engineering problems. (ETSs 1.A)<br>Developing possible solutions. (ETSs 1.B)<br>Optimizing the design solution. (ETSs 1.C) |

In these lessons, aspect system and system models and structure and function of cross-cutting concepts were not explained explicitly in these lessons. Students have to think more critically to understand system and functions of each objects.

## C. Analysis of Japanese Students

### 1. Japanese Students` Critical Thinking Skills

Collected data were from the worksheets involving design solutions, results, and conclusions. The problem was defined by students almost same, that was how to clean wastewater before moving to the sea, because if the sea becomes dirty, it would damage the environment. Some examples of students' designed solution can see in table 5. Most of the students had ideas about distillation and filtering system to clean the wastewater.

Table 5. Japanese Students` design solution and classify stages of critical thinking

| Design Solution | Result | Conclusion | Stage CT |
|---|---|---|---|
| Boil wastewater in isolated system will keep water in the system.<br>S: physic<br>T: evaporation kit<br>E: design evaporation kit from beaker glasses (small and big).<br>M: not used | Dirty water to be clean, but it more consumes time. | Boiling water is effective method to clean water. | Challenged Thinker (Lower Thinker) |
| Biological<br>Using water (microorganism) from turtle pond (surface, middle, bottom), and leave for one day, after that stir the wastewater. Avoid the sunlight. | No significant different of each sample, but after stirred, the sample to be little clean. | Stirring was needed for better result. Pond water did not work to clean wastewater. Perhaps, there no microorganism who can clean the water. | Beginning Thinker (Average Thinker) |

| | | | |
|---|---|---|---|
| S: biology and physic<br>T: cleaning system using micro organism<br>E: design bath of biological cleaning system.<br>M: not used | | | |
| Physical filtering<br>1st experiment used filter paper, stone, leaf, and charcoal.<br>2nd experiment did not use leaf.<br>3rd experiment did not use filter paper.<br>S: physic<br>T: filtering kit<br>E: design filtering system by various materials.<br>M: not used | 1st experiment: the water be clean.<br>2nd experiment: result not different with 1st experiment.<br>3rd experiment: after two times filtering, the water be clean. | The leaf does not have role in cleaning system, but filter paper has role it. | Practicing Thinker (Average Thinker) |
| Distillation<br>Identify effectiveness based on volume of samples 10 ml, 20 ml, and 30 ml.<br>Biological system (using euglena).<br>Mix pond water and sample, and then store for a day.<br>S: physic and biology<br>T: distillation kit<br>E: design distillation kit from tubes, pipe, and rubber stopper.<br>M: calculate the volume of sample | Distillation: the water become clean but consume energy.<br>Using Euglena: no change anything, but environmental friendly. | The combination of distillation and using euglena would become effective and environmental friendly solution. | Advanced Thinker (Higher Thinker) |

According to students` worksheets, some of groups cleaned wastewater using simple distillation system or boiling. However, students realized that boiling consumed more energy and could not be an efficient solution. In this case, students evaluated their solution, it meant that they had critical thinking skills (Elder and Paul, 2003). Furthermore, students use euglena to clean wastewater. Unfortunately, the results did not like their predictions, wastewater were still dirty. Based on their experiment results, they thought that distillation method could clean wastewater and using Euglena would not contaminate environment. Finally, students concluded that the combination of distillation and euglena would be an effective, efficient, and environmental friendly solution. According to these statements, students were still lack of logical thinking and made conclusion from the data. Distillation used heating for boiling the water, so it could not be an efficient solution.

Another one of sample of students' solution was evaporation. They provide 3 samples of wastewater and each sample was boiled in different length time. Their thinking was similar to scientific researchers and they tried to investigate the result based on lengths of boiling time. However, they tried the experiments in opened condition. So, the clean water would evaporate to atmosphere. Even though 15 minutes boiling showed the cleanest result than others and pH of wastewater were most acidic than others. According to this, 15 minutes boiled sample was not fresh water, because range of pH was too large. If this acid water goes to the sea, it would make the sea be acidic. They did not analysis and evaluate the data, it means they lack in critical knowledge and thinking skill.

These worksheets analyzed using critical thinking rubric (Table.1) and the result of critical thinking each group in all classes showed in Figure 6

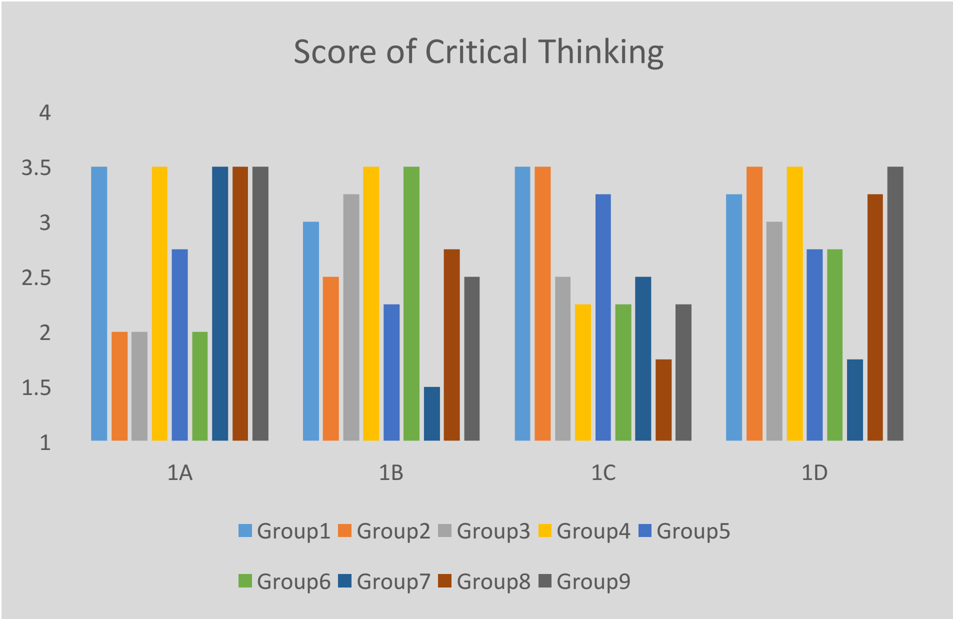



Figure 6. Score of Critical Thinking

Based on measures T test, the mean scores of critical thinking skill for each class can be compared in order to see the significance of difference. The results show that the mean critical thinking score for class 1A was 2.92 (SD 0.72); accordingly; 1B was 2.75 (SD 0.65); 1C was 2.67 (SD 0.62); 1D was 3.03 (SD 0.62), and mean score of critical thinking all of the students was 2.82. The highest students` critical thinking skill is class 1D, and the lowest was 1C. But, after the scores were analyzed statistically with T-test multiple comparison, there was no different significantly.

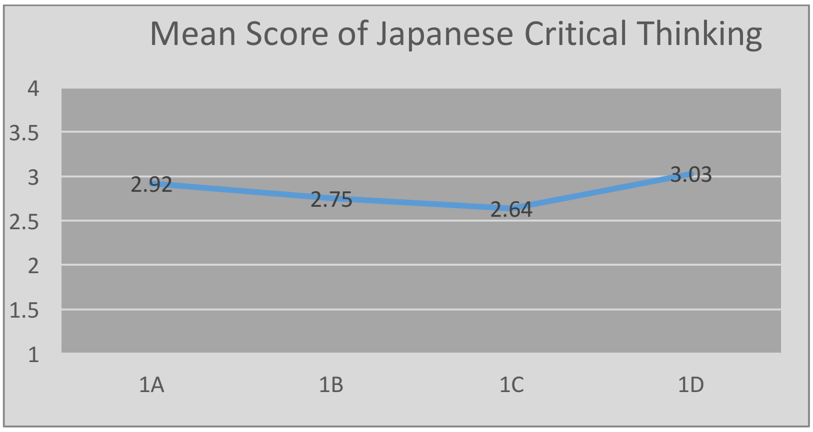



Figure 6. Critical Thinking Skill's Mean Scores

Table 6. T-test Multiple Comparison of Critical Thinking Score

| (I) CLASS | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|---|---|
| 1A | 1B | .16667 | .30979 | .949 | -.6727 | 1.0060 |
| | 1C | .27778 | .30979 | .807 | -.5615 | 1.1171 |
| | 1D | -.05556 | .30979 | .998 | -.8949 | .7838 |
| 1B | 1A | -.16667 | .30979 | .949 | -1.0060 | .6727 |
| | 1C | .11111 | .30979 | .984 | -.7282 | .9504 |
| | 1D | -.22222 | .30979 | .889 | -1.0615 | .6171 |
| 1C | 1A | -.27778 | .30979 | .807 | -1.1171 | .5615 |
| | 1B | -.11111 | .30979 | .984 | -.9504 | .7282 |
| | 1D | -.33333 | .30979 | .706 | -1.1727 | .5060 |
| 1D | 1A | .05556 | .30979 | .998 | -.7838 | .8949 |
| | 1B | .22222 | .30979 | .889 | -.6171 | 1.0615 |
| | 1C | .33333 | .30979 | .706 | -.5060 | 1.1727 |

In order to determine of *q score* of T- test, q calculate is mean difference divided with standard error. Furthermore, q critical score can see from table of q score in which k (number of class) is 2, df (number of data – k) is 16. The calculation to determine the significant of difference can see in table 6. According to calculation T- test, the score of critical thinking skill of each class, there are no significant different of performance one class to other classes, because $q_{cal}$ is lower than $q_{critical}$

(Hochberg, 1987). It means that the learning processes of each class are same, so critical thinking skill of each class no gap each other.

Table 7. Significance difference each class

| Class | Q calculate | Q critical (alpha = 0.05) | hypothesis |
|---|---|---|---|
| 1A – 1B | 0.539 | 3.00 | No different significantly |
| 1A – 1C | 0.897 | 3.00 | No different significantly |
| 1A – 1D | 0.181 | 3.00 | No different significantly |
| 1B – 1C | 0.358 | 3.00 | No different significantly |
| 1B – 1D | 0.716 | 3.00 | No different significantly |
| 1C – 1D | 1.074 | 3.00 | No different significantly |

Critical thinking score was compare with criteria of critical thinking development based on stage of critical thinking development (Table 2.). Criteria of students` critical thinking skill were advanced thinker (41.6%), practicing thinker (30.6%), beginning thinker (25%), and challenged thinker (2.8%). In simple word, challenged thinker included in lower thinker, beginning and practicing thinker included in average thinker, and advanced thinker included in higher thinker (Figure 7).

Unreflective thinkers and challenged thinkers included in lower thinker. Finding indicates that only 1 group have lower thinker stage of critical thinking. Lower thinkers had very limited skills in thinking, they only focus on one solution, and they did not try to give better solutions. As shown in Table 4, lower thinkers` design solution was simple isolated cleaning wastewater isolated evaporation system kit from beaker glasses. There was no separation between clean water and wastewater.

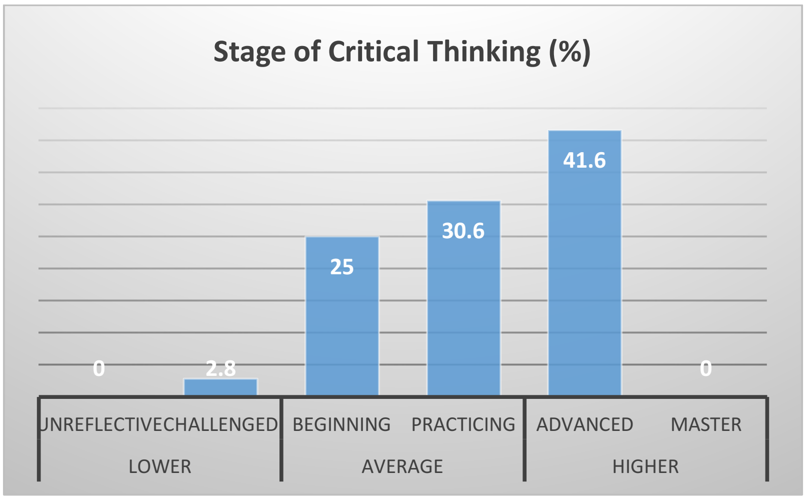


Figure 7. Percentage of stage of critical thinking

The lower thinker group conducted one experiment only and they did not evaluate at all. Whereas learning activities were conducted in 6 lessons, it was possible to evaluate their own experiment. However, they might have developed a diversity of skills in thinking without being aware of them, and these skills may serve as barriers for the development and their future. "*At this stage of critical thinking with some implicit critical thinking abilities may deceive themselves easily into believing that their thinking was better than what actually was, they were making it more difficult to recognize the problems inherent in poor thinking"* (Paul and Elder, 2008).

Average thinker has 2 stages of critical thinking, there were beginning thinker and average thinker. Thinkers at this stage had a sense of the habits which they needed to develop to take charge of their thinking. Base on Table 4, average thinkers` design solutions were cleaning wastewater system by filtering kit. They tried some experiments to get better solution. This method was effective to clean water, but it was not efficient. In engineering solution, efficiency and effectiveness must be concerned. However, average thinkers were only starting to approach the development of their thinking in a structured way. *"Average thinkers had enough skills in thinking to critique their own plan for systematic practices, and to construct a realistic critique of their powers of thought"* (Paul and Elder, 2009). Moreover, average thinkers had sufficient skills to start to systematically monitor their own idea. Therefore, they could effectively articulate the power and weaknesses in their thinking. Paul and Elder (2009) said that *"practicing thinkers could often recognize their own egocentric thinking as well as egocentric thinking on the part of others"*.

Advanced thinker (higher thinker) systematically critiqued their own strategy for systematic practices and correct it thereby, they and had accepted great practices of thought. As shown in Table 4, higher thinkers` design solution were cleaning wastewater system by combining 2 methods, biological and distillation kit. They tried various methods and combined the methods to get best solutions. The combination methods of distillation and biological would became effective and environmental friendly solutions. Students in this stage became advanced thinkers not only examining their thinking in all the important domains of their lives, but also having significant insights into issues at deeper levels of thought. Although advanced thinkers were competent to think proficiency across the necessary aspects of their lives, they were not yet capable to think at a constantly high level across all of these dimensions. *Advanced thinkers had good general commands over their egocentric nature. They continually strived to be fair-minded. Of course, they sometimes lapsed into egocentrism and reason in a one-sided way* (Paul and Elder, 2008).

Table 8. T-test between mean scores lower-average-higher thinker

| | Test Value = 0 | | | | | |
|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | |
| | t | df | Sig. (2-tailed) $P_{value}$ = ½ Sig | Mean Difference | Lower | Upper |
| Score (lower-average) | 25.092 | 19 | .000 | 2.32500 | 2.1311 | 2.5189 |
| Score (average-higher) | 27.700 | 34 | .000 | 2.85714 | 2.6475 | 3.0668 |

T-test are used to determine significant differences between mean score lower thinkers-average thinkers, and average thinkers-higher thinkers. Table 8 reports there are significant differences between mean lower thinkers and average thinkers ($P_{value} < 0.05$). Also, based on table 8, there are significant differences between mean average thinkers and higher thinkers ($P_{value} < 0.05$). In overall, the findings of differences among mean scores lower thinker-average and thinker-higher thinker suggest that STEM learning through Project Based Learning could differentiate among lower thinker, average thinker, and higher thinker.

**2. Japanese Students` Attitudes Toward STEM**

Students` attitudes toward STEM were collected by questionnaire consisted of 26 statements with five Likert scales. The questionnaire divided by 3 categories; namely; mathematics filed, science field, and technology and engineering field. Table 9 presents the mean scores of attitudes towards STEM among Japanese students. The dimension of Technology and Engineering came in the first rank with a mean of (3.698) and standard deviation of (0.18) followed by Science with a mean of (3.455) and standard deviation of (0.403). Meanwhile, the last rank by Mathematics with a mean of (3.345) and standard deviation of (0.506).

Technology and Engineering performed greater than the grand mean (3.49). These results indicated that Technology and Engineering became the dominant preference among student and following by Science compared to Mathematics. This result represents the proportion of students` attitudes in Technology and Engineering in Japanese middle school students which is greater than others.

Table 9. Summary of degree students` attitudes toward STEM

| | M | SD | Rank |
|---|---|---|---|
| Mathematics | 3.345 | 0.506 | 3 |
| Science | 3.455 | 0.403 | 2 |
| Technology and Engineering | 3.698 | 0.183 | 1 |
| Total | 3.499 | 0.403 | |

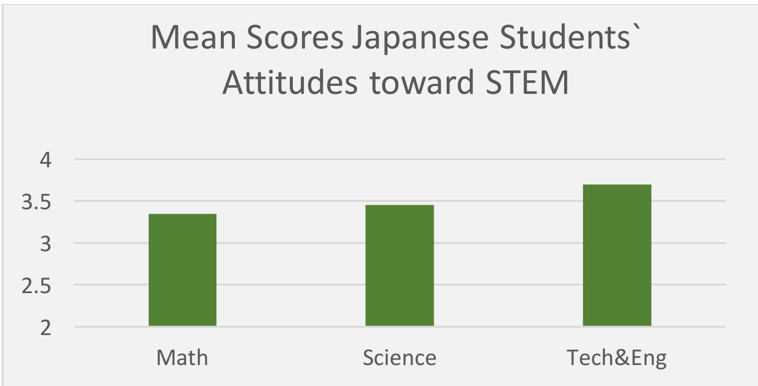



Figure 8. Mean scores Japanese students` attitudes toward STEM

Figure 8 shows that Japanese students have more positive attitudes towards technology and engineering field than mathematics field and science field. According to analysis of data among students` attitudes toward STEM fields by gender, the male students have more positive attitudes than the female students (Figure 1). Figure 1 shows that the male students have the greatest positive attitudes toward technology and engineering fields and the lowest attitudes in mathematics fields. However, the female students have almost equal attitudes toward all STEM fields.

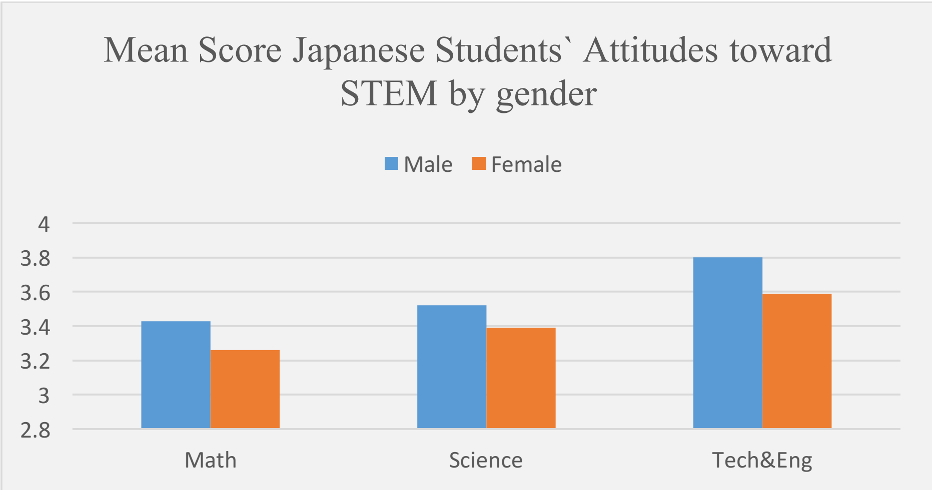



Figure 8. Mean score Japanese students` attitudes toward STEM by gender

Analysis R statistic were used to identify significant differences in term of attitudes between the male students and the female students, and the result show in Table 9.

Table 10. T-test between the male and the female students` attitudes toward STEM

| Subject | Mean Score Male | Mean Score Female | t | df | P-value | Interval | |
|---|---|---|---|---|---|---|---|
| Mathematics | 3.43 | 3.26 | -0.63821 | 14 | 0.533 | -0.718 | 0.389 |
| Science | 3.52 | 3.38 | -0.68215 | 16 | 0.504 | -0.540 | 0.277 |
| Technology and engineering | 3.80 | 3.59 | -2.8196 | 16 | 0.012 | -0.358 | 0.051 |

Because p-value of science and mathematics is more than 0.025, therefore there are not significant differences in term of attitude between the male students and the female students in science and mathematics field. P-value of technology and engineering is less than 0.012, then there are differences attitudes between the male students and the female students towards technology and engineering field. Japanese students' attitudes toward STEM fields between the male and the female were different slightly, however statistically speaking, they is not different. Japanese male students have slightly positive attitudes toward STEM fields. However, the lowest attitudes are toward mathematics fields.

### 3. Japanese Students` Career Interests

Students were asked to show their interest in 12 STEM career areas. Histograms displaying students' interest level in each of the 12 careers are illustrated in Figure 9.

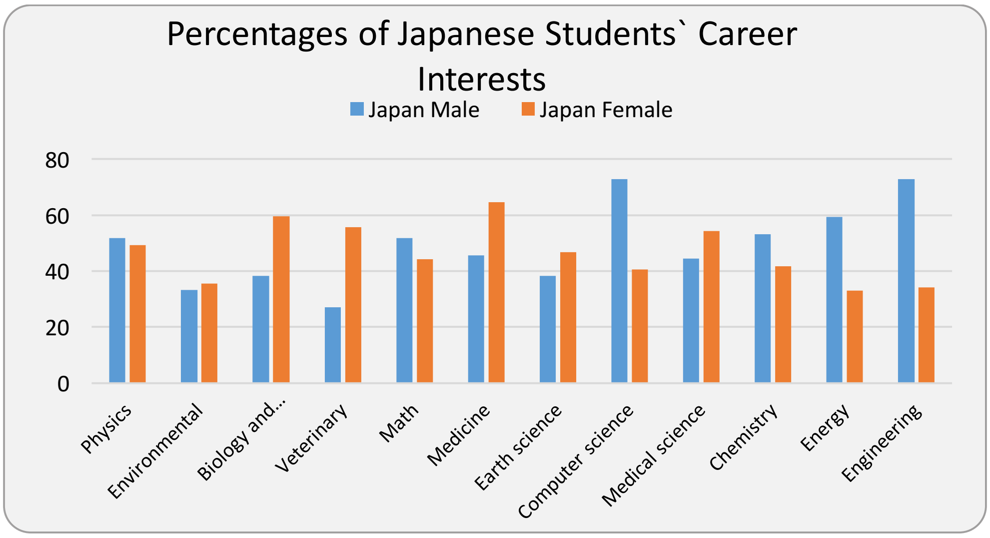



Figure 9. Percentages of Japanese students` Career Interest

The results from survey of students` career interests showed that students had mostly interests in STEM careers (Figure 2). However, the highest percentage of female students indicated that they were "interested" or "very interested" in medicine (64.56%), while the lowest percentage of female students showed that in careers in energy (32.91%). Moreover, the highest percentage of male students showed that they were "interested" and "very interested" in engineering and computer science (72.84%), while the lowest percentage of male students' interest in careers in veterinary (27.16%).

### D. Analysis of Indonesian Students

#### 1. Critical Thinking Skills

Collected data from the worksheets involved design solutions, results, and conclusions. The problems were defined by students almost the same, which was how to clean wastewater before moving to the sea, because if the sea dirty, it would damage the environment. Some examples of Indonesian students' design solutions can be seen in Table 11.

Table 11
Indonesian Students` design solution and classify stages of critical thinking

| Design Solution | Result | Conclusion | Stage CT |
|---|---|---|---|
| Physical Filtering using sponge, ink, sand, gravel, carbon active, coconut husk, and cotton. | 3 times filtering<br>1st filtration: still dirty (pH 6,0)<br>2nd filtration: cleaner (pH 6,83)<br>3rd filtration: cleaner (pH 6.93) | Dirty water becomes cleaner water by filtration process. | **Practicing Thinker** |
| Physical Filtering using zeolite, cotton, coconut husk, and filter paper | 3 times filtering:<br>1st filtration: still dirty<br>2nd filtration: more clean<br>3rd filtration: cleaner | The result of filtering cannot clean because materials of filtration is too much | **Beginning Thinker** |
| Physical Filtering using: cotton, carbon, gravel, sand, and coconut husk. | 1-time filtration | We got knowledge about water filtration. | **Challenged Thinker** |

According to students` worksheets, all of groups cleaned wastewater using filtration system. In this case, students solved their solution based on their daily life.

In order to clean dirty water, Indonesian people usually buy a chemical in shop. Cleaner dirty water very popular in Indonesia and it can be found in the market. People used that tool because the low quality of water in Indonesia, so they used purifier water to get clean water.  In this case, some students evaluated their solution, they tried 2 times until 4 times filtration, it meant that they had critical thinking skills (Elder and Paul, 2003).

These worksheets analyzed using critical thinking rubric (Table.1) and the results of critical thinking of each group in all classes showed in Figure 10.

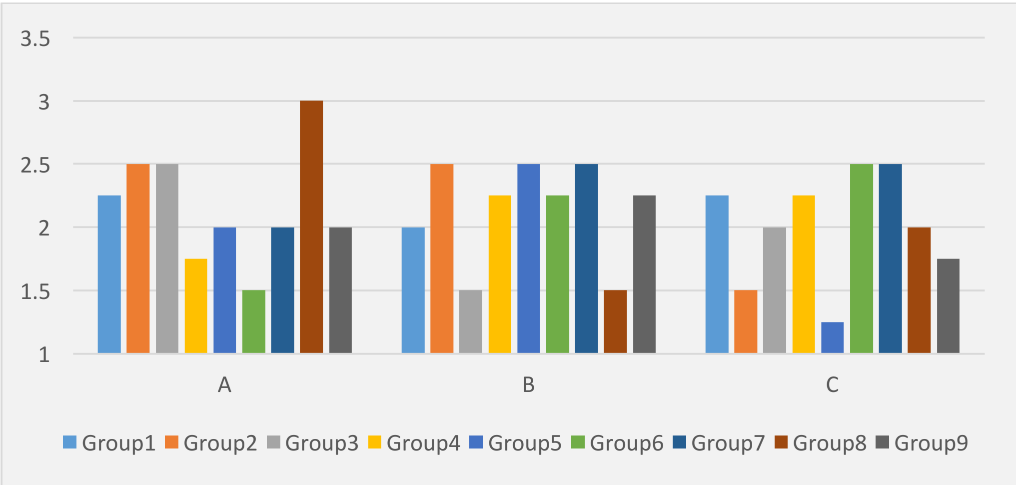



Figure 10. Score of Indonesian Students` Critical Thinking Skills

Based on measures of T test, the mean scores of critical thinking skill for each class can be compared in order to see the significant of difference. The result show that the mean critical thinking score for class A was 2.17 (SD 0.45); B was 2.14 (SD 0.39); C was 2.00 (SD 0.43), and mean score of critical thinking all of the students was 2.10. The highest students` critical thinking skill is class A, and the lowest is C.

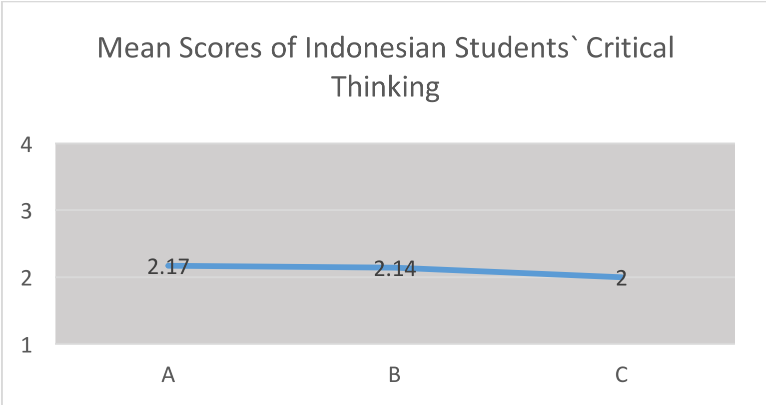



Figure 11. Mean Score of Indonesian Students` Critical Thinking Skills

There was no significantly with reports the T-test multiple comparison for the critical thinking skills score. The results of T-test multiple comparison are showed in Table 12.

Table 12. T-test Multiple Comparison of Critical Thinking Score

| (I) Class | | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|
| 1A | 1B | .02778 | .20159 | .892 | -.3883 | .4438 |
| | 1C | .16667 | .20159 | .417 | -.2494 | .5827 |
| 1B | 1A | -.02778 | .20159 | .892 | -.4438 | .3883 |
| | 1C | .13889 | .20159 | .497 | -.2772 | .5549 |
| 1C | 1A | -.16667 | .20159 | .417 | -.5827 | .2494 |
| | 1B | -.13889 | .20159 | .497 | -.5549 | .2772 |

In order to determine of *q score* of T- test, q calculate is mean difference divided with standard error. Furthermore, q critical can see from table q score in which k (number of class) is 2, df (number of data – k) is 16. The calculation to determine the significant of differences can see in table 13. According to calculation T- test, the score of critical thinking skills of each class, there are no significant different of Indonesian students' performance one class to other classes, because $q_{cal}$ is lower than $q_{critical}$ (Hochberg, 1987). It means that the learning processes of each class are the same, so critical thinking skill of each class were no gap each other.

Table 13. Significance difference each class

| Class | Q calculate | Q critical (alpha = 0.05) | hypothesis |
|---|---|---|---|
| A – B | 0.539 | 3.00 | No different significantly |
| A – C | 0.897 | 3.00 | No different significantly |
| B – C | 0.358 | 3.00 | No different significantly |

Critical thinking score was compared with criteria of critical thinking development based on stage of critical thinking development (Table 2.). Criteria of students` critical thinking skill were practicing thinker (29.62%), beginning thinker (51.85%), and challenged thinker (18.51%). In simple word, challenged thinker included in lower thinker, beginning and practicing thinker included in average thinker, and advanced thinker included in higher thinker (Figure 12).

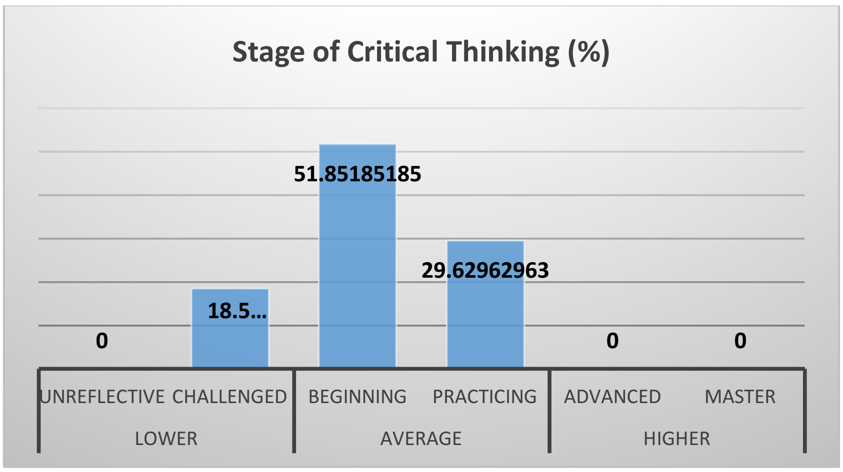



Figure 12. Indonesian Students` Stage of Critical Thinking Skills

Unreflective thinkers and challenged thinkers included in lower thinker. Finding indicates that 18.51% has lower thinker stage of critical thinking. Lower thinkers had very limited skills in thinking, they only focus on one solution, and they did not try to give better solutions. As shown in Table 11, lower thinkers` design solution was simple filtration wastewater system. The lower thinker group conducted one experiment only and they did not evaluate at all. Whereas learning activities were conducted in 6 lessons, it was possible to evaluate their own experiment. However, they may have expanded many skills in thinking without being aware of them, and these skills might provide as barriers for the development. *"At this stage of critical thinking with some implicit critical thinking abilities may deceive themselves easily into believing that their thinking was better than what actually was, they were making it more difficult to recognize the problems inherent in poor thinking"* (Paul and Elder, 2008).

Average thinker has 2 stages of critical thinking, there were beginning thinker and average thinker. Thinkers at this stage had a sense of the practices which they needed to improve to take charge of their thinking. Base on Table 11, average thinkers` design solutions were cleaning wastewater system by filtering system. They tried some experiments to get better solution. And also, they tried to check the pH of solution. This method was effective to clean water, but it was not efficient. In engineering solution, efficiency and effectiveness must be concerned. However, since average thinkers were only beginning to approach the improvements of their thinking in a systematic way. *"Average thinkers had enough skills in thinking to critique their own plan for systematic practices, and to construct a realistic critique* *of their powers of thought"* (Paul and Elder, 2009). Furthermore, average thinkers had enough skills to begin to regularly monitor their own thoughts. Thus, they could effectively articulate the strengths and weaknesses in their thinking. Paul and Elder (2009) said that *"practicing thinkers could often recognize their own egocentric thinking as well as egocentric thinking on the part of others"*.

Table 14. T-test between mean scores lower-average-higher thinker

| | Test Value = 0 | | | | | |
|---|---|---|---|---|---|---|
| | | | | | 95% Confidence Interval of the Difference | |
| | t | df | Sig. (2-tailed) $P_{value}$ = ½ Sig | Mean Difference | Lower | Upper |
| Score (lower-average) | 25.092 | 19 | .000 | 2.32500 | 2.1311 | 2.5189 |
| Score (average-higher) | 27.700 | 34 | .000 | 2.85714 | 2.6475 | 3.0668 |

To determine significant differences between mean score of lower thinkers-average thinkers, and average thinkers-higher thinkers are used T-test are used. Table 7 reports that there are significant differences between the means of lower thinkers and average thinkers ($P_{value} < 0.05$). Also, based on table 7, there are significant differences between mean average thinkers and higher thinkers ($V_{alue} < 0.05$). In overall, the findings of differences among mean scores of lower thinker-average thinker-higher thinker suggest that STEM learning through Project Based Learning could differentiate among lower thinker, average thinker, and higher thinker.

## 2. Indonesian Students` Attitudes Toward STEM

Students` attitudes toward STEM were collected by questionnaire consisted of 26 statements with five Likert scales. The questionnaire divided by 3 categories; mathematics filed, science field, and technology and engineering field. Table 9 presents the mean score of attitudes towards STEM among Indonesian students. The first rank with the mean of (3.298) with the standard deviation of (0.261) is Technology and Engineering aspect, and then the second rank followed by Science with the mean of (3.478) with the standard deviation of (0.213). Meanwhile, the last rank is Mathematics with the mean of (3.604) with standard deviation of (0.338).

Technology and Engineering performed greater than the grand mean (3.460). This result indicated that Technology and Engineering became the dominant preference among student and following by Science compared to Mathematics. This result represents that the proportion of students` attitudes in Technology and Engineering in Indonesian middle school is greater than others.

Table 15. Summary of degree students` attitudes toward STEM

| | M | SD | Rank |
|---|---|---|---|
| Mathematics | 3.345 | 0.506 | 3 |
| Science | 3.455 | 0.403 | 2 |
| Technology and Engineering | 3.698 | 0.183 | 1 |
| Total | 3.499 | 0.403 | |

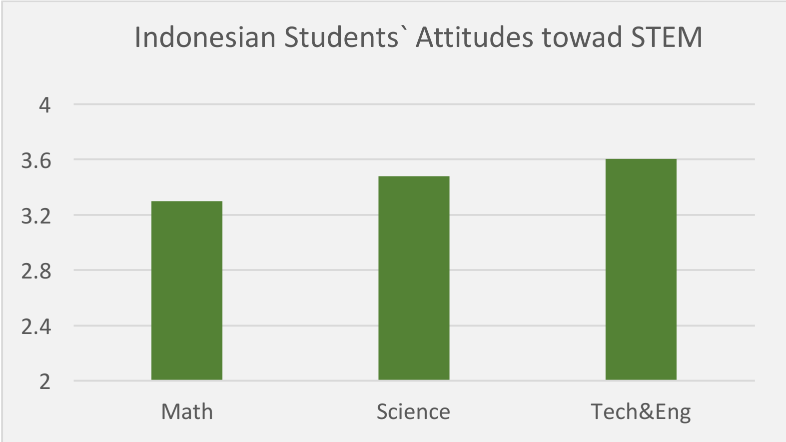



Figure 13. Indonesian students` attitudes toward STEM

According to analyzed data of student attitudes toward STEM by gender, male students have more positive attitudes than female students (Figure 14). Figure 14 shows that male students have the greatest positive attitudes exist in technology and engineering fields and the lowest attitudes in mathematics fields. However, female students have almost equal attitudes toward all STEM fields.

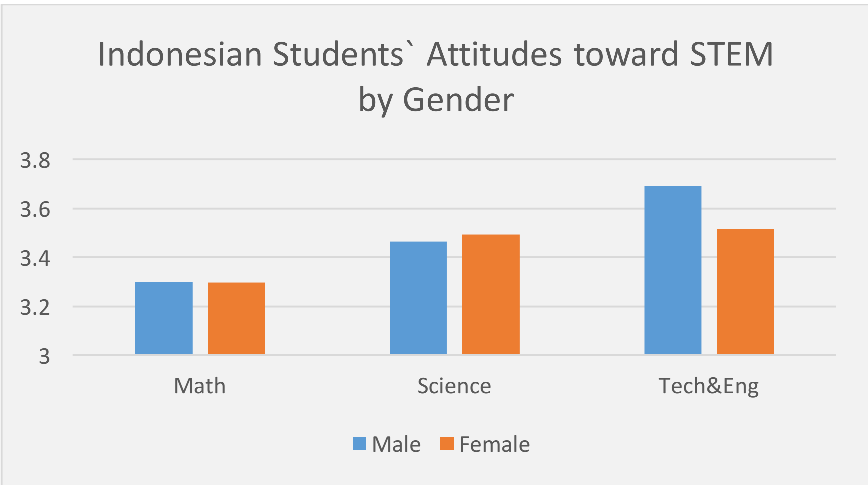



Figure 14. Indonesian students` attitudes toward STEM by gender

Table 16. T-test male and female students` attitudes toward STEM by gender

| Subject | Mean Score Male | Mean Score Female | t | df | P-value | Interval | |
|---|---|---|---|---|---|---|---|
| Science | 3.47 | 3.49 | -0.2589 | 16 | 0.799 | -0.246 | 0.192 |
| Mathematics | 3.30 | 3.29 | 1.1054 | 16 | 0.989 | -0.288 | 0.292 |
| Technology and engineering | 3.69 | 3.51 | 0.0138 | 14 | 0.285 | -0.161 | 0.512 |

Because p-value of science, engineering, and mathematic more than 0.025, therefore, there are not differences in terms of attitudes toward STEM field between male students and female students. Indonesian students' attitudes toward STEM fields between male and female were different slightly, however statistically it is not different.

Indonesian male students have slightly more positive attitudes toward technology and engineering fields. However, the lowest attitudes in mathematics fields. This result different with Australian, Ghana, and Kenyan students in which the male students have more interest toward mathematic than the female students (Mutai, 2016; Lee & Anderson, 2015). The female students are almost equal attitudes toward all STEM fields.

### 3. Indonesian Students` Career Interests

Students were asked to show their interests in 12 STEM career areas. Histograms displaying students' interests level in each of the 12 careers are illustrated in Figure 15.

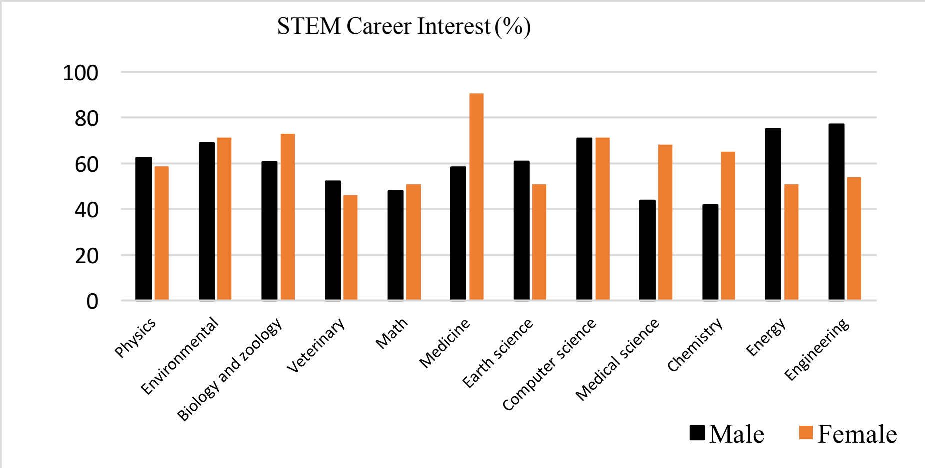


Figure 15. Indonesian students` career interests in STEM field

Results from the survey of students` career interests showed that students had mostly moderate interest in STEM careers (Figure 15). However, the highest percentage of the female students showed that they were “interested” or “very interested” in medicine (90.5%), while the lowest percentage of the female students reported that in careers in veterinary work (46%). Furthermore, the highest percentage of the male students showed that they were “interested” and “very interested” in engineering and energy (77.1% and 75%), while the lowest percentage of the male students interests reported interest in careers in chemistry and medical science (41.7% and 43.8%).

## E. Comparison of Indonesian students and Japanese students in critical thinking skills, attitudes toward STEM, and career interest in STEM field

### 1. Critical Thinking Skills

Students skills of students each country are different, because government of each country has different policy of education system depend on visions and interest of each country. Furthermore, the conditions of economic, industry, agriculture, natural resources, and geographical location have strong influences to attitudes and interests toward STEM fields and careers (Joseph, 2015; Ntibi & Edoho, 2017). Indonesia has more natural resources than Japan, so Indonesia sales the natural resources to other countries for getting income. While Japan possesses less natural resources, so the Japanese have to think more than the Indonesian. Finally, Japan can afford create more science and technology than Indonesia. Based on the conditions of a country, Japanese government has to encourage students to be an expert in science and technology with thinking skills.

Result of Indonesian and Japanese students` critical thinking skills statistically using t-test showed in table 17. Because P-value less than 0.025 (p-value > $\alpha/2$), the answers for third research question ***"Are there some differences of Japanese and Indonesian students in critical thinking skills?"***, $H_0$ = accepted, $H_1$ = rejected. It means there are differences between Japanese and Indonesian students in critical thinking skills. Japanese students master than Indonesian students in critical thinking skills, because the problems in these lessons related to daily life. The range of mean scores in critical thinking skills between Japanese students and Indonesian students are 0.717, this gap point is big enough. Based on the solutions that designed by students, Japanese students have more variety of solutions and they could evaluate their own solutions.

Table 17. Calculation results of two sample t-test in critical thinking skills

| **Sample** | **N** | **Mean score** | **t** | **df** | **p-value** | **95% confidence interval** | |
|---|---|---|---|---|---|---|---|
| Japanese students | 160 | 2.819 | -5.053 | 61 | 0.000 | -1.00159 | -0.43359 |
| Indonesian students | 111 | 2.102 | | | | | |

There are several factors that influence to differences of Japanese and Indonesian students in critical thinking skills:

**Curriculum**

Indonesia educational curriculum had go through changes in several times since 1945 (Independence Year), there were curriculum revised 1947, 1952, 1964, 1988, 1975, 1984, 1994, 2004, KTSP 2006, curriculum 2013, and then curriculum 2013 had revise in 2016 namely National Curriculum (kurikulum nasioal). Policy of those curriculum were based on condition of government systems, social cultural, politic issues, economic, and also science and technology influence in change in the living of community (Soekisno, 2007). consequently, the curriculum as a set of main educational program should be developed dynamically in agreement with the command and that apply a society. All of curriculum in Indonesia were created based on the same national foundation, the foundation namely Pancasila (Philosophical foundation Republic of Indonesian) and the 1945 Constitution. The primary differences among those curriculums were only on underline of educational aims and approaches to achieve it. Those curriculums could be revise based on the ministry of education.

Japanese curriculum revised every eight to ten years, the vision of curriculum (course of study) should pursued for about eight to ten years. MEXT has policies for educating the Japanese next generations as follows (MEXT, 2009):

a. *Lifelong learning (promotion of educational reform, perceive education in which schools, families, and society participate together in collaboration,* *providing lifelong learning opportunities, and promoting information-oriented education);*

b. *Elementary and secondary education (development of academic competence, improvement of the quality of teachers, reinforce impressiveness in minds, responding to problem behavior, encourage career education, improvement of school management, promoting of special needs education, promoting of early childhood education, and promoting international education);*

c. *Higher education (encourage universities and graduate schools, programs for scholarship loan, promoting private schools, promoting of internationalization of universities and student exchange);*

d. *Science and Technology (proposal for basic policies regarding science and technology, research and coordination on science and technology policy, developing human resources in science and technology, strategic promotion of international activities, promotion of science and technology in regions, ensuring the safety of radiation and nuclear energy);*

e. *Research promotion (promotion of basic research, enhancing and equipping the research and development infrastructure, promotion of research and development in important fields, promotion of industry-academia-government cooperation);*

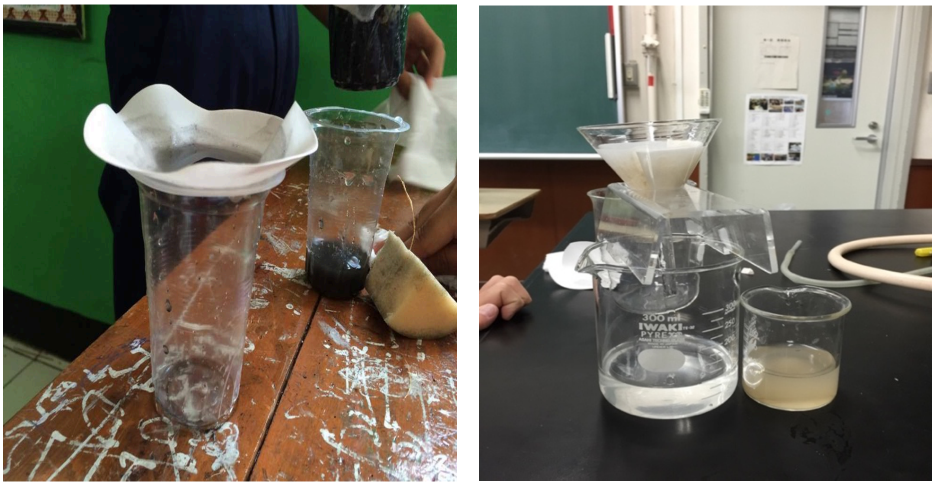
f. *Research and Development (promotion research and development in aerospace, promoting research and development in the field of nuclear and energy, in the environment and energy field, in the oceans and the earth field, for earthquake and disaster prevention studies) .*

According to some policies of MEXT, Japanese government has visions to develop the quality of human resources to improve science and technology. Therefore, Japanese students must possess advance thinking skills to support and improve the condition of Japan. While Indonesian students have to adapt to unstable educational policy and prepare for the national examination. In Indonesia, the quality gap of schools and universities are too big, so Indonesian students focus on more contents knowledge than context knowledge and skills for preparing entrance examination to high quality schools and universities.

Table 18. Comparison of Japanese and Indonesian national curriculum

| Aspect | Indonesia | Japan |
|---|---|---|
| **National curriculum standards** | Minimum national standards | Course of study |
| **Agency initiating curriculum development** | Ministry of Education (Mendiknas) | Ministry of Education (MEXT) |
| **Agencies consulted for curriculum development** | Senior officials from relevant institutions, subject specialists, universities and institutes, senior subject teachers, headmasters, representatives from the National Education Advisory Board, private companies | Central Council for Education (board aims), Curriculum Council, committee for making the course of study. |
| **Input of stakeholders in curriculum development** | Using committees of principals, parents, teachers, students, industry representatives, and stakeholders. | Publishing of draft papers, collecting opinions, conducting hearings of parents and specialists, before submission of final report by the council. |
| **Description of National Framework** | National curriculum for training teachers of each level of education. | National guidelines |

| | | |
|---|---|---|
| **Community support for curriculum development** | Parents: PTA<br>Local community: local government<br>Business community: private business<br>NGOs: many different groups, depends on district<br>Others: religious groups assist in schools | Parents: PTA<br>Local community: use of local environment as resources |
| **Students assessment for curriculum monitoring** | Type: Year-end, national<br>Frequency: 2 times a year for each grade | Type: National assessment<br>Frequency: every 10 years |

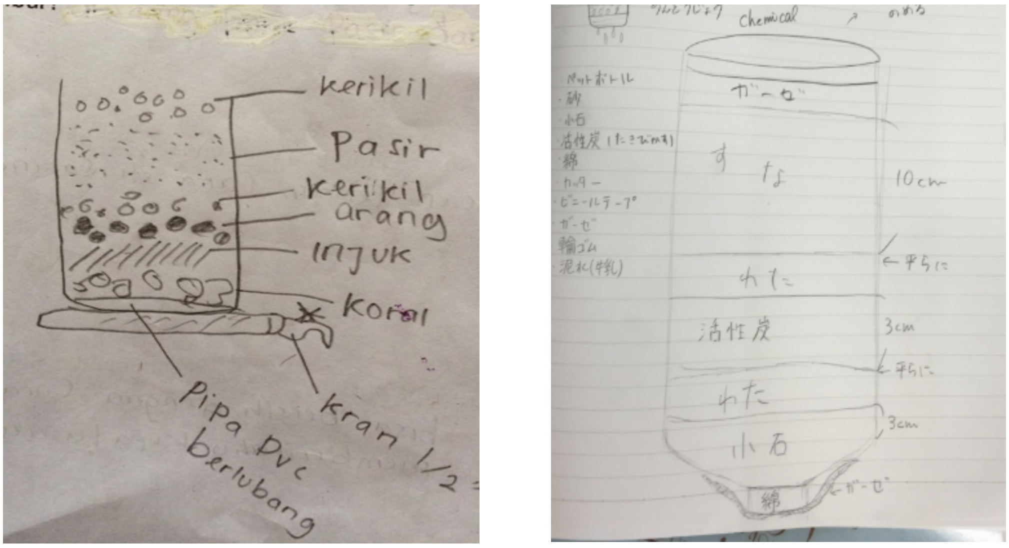



a b

Picture 3 filtering use paper: Indonesian students (a) and Japanese students (b)

Picture 3 shows that Indonesian students have less of experimental equipment than Japanese, and also Indonesian schools do not consider the contextual knowledge and skills. Therefore, Indonesian students are not familiar with experimental equipment and they did not know how what the good methods was to filter using paper.

Furthermore, Japanese students possess more advancement in scientific methods than Indonesian students. In picture 4, Japanese student designs in detail wastewater filtering system with a usage of mathematics and engineering aspects. Based on this phenomenon, Japanese students realized and evaluated the important ratio of composition of materials to clean water. While Indonesian students consider the materials only without thinking the ratio of composition. It means Japanese students' critical thinking skills have more advancement than Indonesian students. Scientists and engineers usually use ratio of composition to determine the experiments and products (technology) through mathematical formulas. The effectiveness and efficiency of results and products cannot be evaluated without mathematics.




a b

Picture 4. Design of wastewater treatment (a) Indonesian students (b) Japanese students

### 2. Attitudes toward STEM and Career Interest

Attitudes toward STEM fields related to motivation for learning STEM fields, because the questions of attitudes toward STEM questionnaire consisted of interests to STEM fields, abilities and knowledge in STEM fields, and future in STEM fields. If students are interested in STEM fields, automatically they have motivation in learning of STEM subjects (science, technology, engineering, and mathematics). Learning possess not only to understand the contents and contexts knowledge, but also to improve the skills life. In other word, motivation or attitudes toward STEM are important to improve the comprehension of knowledge and skills. In this study, attitudes toward STEM fields of Japanese and Indonesian students collected using MISO (Maximizing the Impact of STEM Outreach).

The results of Indonesian and Japanese students` attitudes toward STEM statistically (R) using t-test showed in table 19. Because P-value more than 0.025 (p-value $> \alpha/2$), the answers for fourth research question ***"Are there some differences of Japanese and Indonesian students` attitudes toward STEM and career interest?"***, $H_0$ = accepted, $H_1$ = rejected ($H_0$ = there are not differences between Japanese and Indonesian attitudes` toward STEM; $H_1$ = there are differences between Japanese and Indonesian attitudes` toward STEM). It means there are not differences between Japanese and Indonesian students` attitudes toward STEM in all aspect (Mathematics, Science and Technology and Engineering).

The aspect of Technology and Engineering (mean score 3.689 and 3.604) became the first rank both Japanese students` and Indonesian students` attitudes toward STEM followed by Science with mean score 3.455 and 3.478. Meanwhile, the last rank by Mathematics with a mean score are 3.345 and 3.298. The result of calculation by R statistics can be showed in Figure 16. It showed that both Japanese and Indonesian students have same attitudes toward STEM.

Table 19. Two sample t-test in students` attitudes toward STEM

| **Aspect** | **Mean score** | | **t** | **df** | **p-value** | **95% confidence interval** | |
|---|---|---|---|---|---|---|---|
| Mathematics | Japan | 3.345 | 0.326 | 30 | 0.746 | -0.2443 | 0.3373 |
| | Indonesia | 3.298 | | | | | |
| Science | Japan | 3.455 | -0.216 | 34 | 0.830 | -0.2417 | 0.1951 |
| | Indonesia | 3.478 | | | | | |
| Technology and Engineering | Japan | 3.689 | 1.039 | 34 | 0.306 | -0.0901 | 0.2786 |
| | Indonesia | 3.604 | | | | | |

The countries in Asian have low self-confidence and interest in mathematics, and much lower if compared with American and European countries and also much lower with OECD average within the results of 2015. But this case did not find in Singapore and Hong Kong, the students chose mathematics as interest subject, those of the other Asian countries did consider mathematics as somewhat valuable, although it was also much lower than American, European countries and the OCDE average (Khine, 2015).

```
data:  At_JVSI$Math_J and At_JVSI$Math_I
t = 0.32652, df = 30, p-value = 0.7463
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.2443674  0.3373758
sample estimates:
mean of Math_J mean of Math_I
 3.345053  3.298549

data:  At_JVSI$Science_J and At_JVSI$Science_I
t = -0.21636, df = 34, p-value = 0.83
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.2417030  0.1951904
sample estimates:
mean of Science_J mean of Science_I
 3.455414  3.478671

data:  At_JVSI$TE_J and At_JVSI$TE_I
t = 1.039, df = 34, p-value = 0.3061
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.09011511  0.27866136
sample estimates:
mean of TE_J mean of TE_I
 3.698715  3.604442
```

Figure 16. Result of calculation R statistics for comparison students` attitudes toward STEM

There are several factors that influence to students` attitudes toward STEM. One of important role in the interrelation of attitudes toward STEM is cultural aspect. Cultural influence has been different between countries because cultural context, including demographic, social, linguistic, political, government system, and philosophical ways of thinking, those would be affected to determine and shape attitudes toward science.

Another factor besides culture that would influence to students` attitudes toward STEM is families. Families are the core and basic units of the culture. Families raise their children with their cultural essences, so culture is embedded into children's lives. In consequence, family has an important influence on students' choice (Örnek, 2015). Families powerfully have an impact on students' attitudes towards STEM. In several researches, the result showed that there were positive relationships between children's attitudes towards science and science-related choices and parents' attitudes towards science and science-related careers (Talton & Simpson, 1985; Talton & Simpson, 1986; Breakwell & Beardsell, 1992; Osborne, Simon, & Collins, 2003).

Motivation or attitude tend to be influenced to career interests among students. Knowledge and skills that needed of each career must be prepared since early stage. As mentioned in NGSS, the new framework considers science and engineering practices from kindergarten level until high school (K-12). In the future, students already possess skills and knowledge in workplace. Therefore, they can adapt rapidly to solve problems or tasks that faced to them.

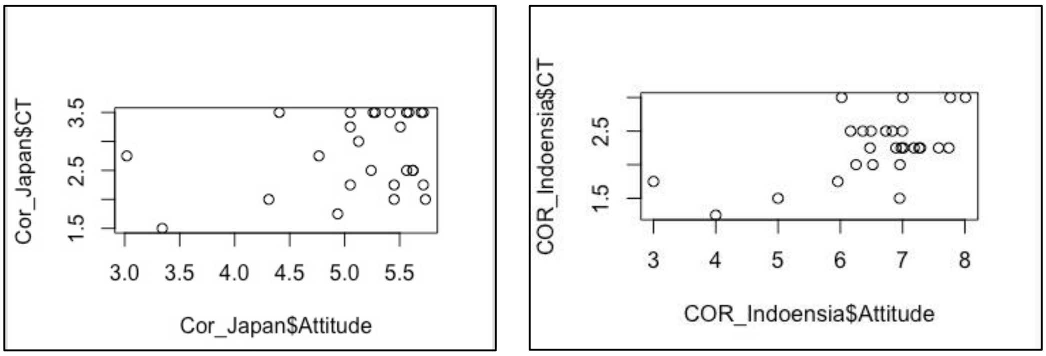
According to questionnaire results, both Japanese female students` and Indonesian female students` were more interested in career in medicine. Japanese male students` career interests were more interested in careers in computer science and engineering, but Indonesian male students` career interested in energy and engineering careers.

**F. Correlation between students` critical thinking skills and attitudes toward STEM**

Correlation between students` critical thinking skills and attitudes toward STEM were analyzed using R statistical method (Pearson correlation) showed in table 17. The result of P-value correlation between students` critical thinking skills and attitudes toward STEM for both Japanese and Indonesian is less than 0.025 (P value < $\alpha/2$), the answers for fifth research question ***"Is there correlation between students` critical thinking skills and students' attitudes toward STEM and career interests using STEM education through Project Based Learning?",*** is accepted in term of Ho, and oppositely, $H_1$ is rejected ($H_0$ ; there is not correlation between students` critical thinking skills and attitudes toward STEM; $H_1$; there is correlation between students` critical thinking skills and attitudes toward STEM). It means there are correlations between Japanese and Indonesian students` critical thinking skills and attitudes toward STEM.

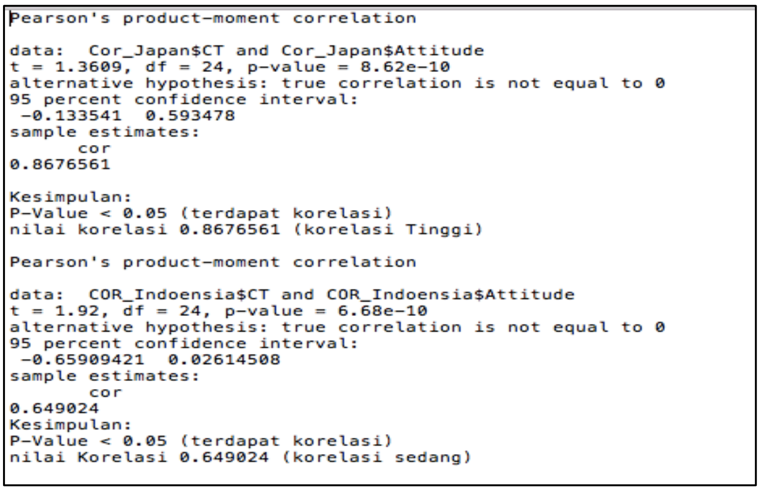
For Japanese students`, P-value of the correlation between students` critical thinking skills and attitudes toward STEM is 8.6e-10 and correlation score is 0.867. It is mean Japanese students have higher correlation score between critical thinking skills and attitudes toward STEM. And then, P-value of the correlation between Indonesian students` critical thinking skills and attitudes toward STEM is 6.6e-10 and correlation score is 0.649 (Figure 18). It is mean Indonesian students have moderate correlation between critical thinking skills and attitudes toward STEM.

Graphic of correlation between critical thinking skills and attitudes toward STEM can be showed in Figure 17.




(a) (b)

Figure 17. Correlation between critical thinking skills and attitudes toward STEM (a) Japan (b) Indonesia



```
Pearson's product-moment correlation

data:  Cor_Japan$CT and Cor_Japan$Attitude
t = 1.3609, df = 24, p-value = 8.62e-10
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.133541  0.593478
sample estimates:
      cor
0.8676561

Kesimpulan:
P-Value < 0.05 (terdapat korelasi)
nilai korelasi 0.8676561 (korelasi Tinggi)

Pearson's product-moment correlation

data:  COR_Indoensia$CT and COR_Indoensia$Attitude
t = 1.92, df = 24, p-value = 6.68e-10
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.65909421  0.02614508
sample estimates:
      cor
0.649024
Kesimpulan:
P-Value < 0.05 (terdapat korelasi)
nilai Korelasi 0.649024 (korelasi sedang)
```

Figure 18. Results of calculation R statistic for comparison students` attitudes toward STEM

# CHAPTER V
# CONCLUSIONS

## A. Summary of Findings

According to the findings of study in STEM education through Project Based Learning to encourage critical thinking, there are some results as follows:

- The result showed that mean score of Japanese students` critical thinking skill was 2.82. Using criteria analysis, Japanese students` critical thinking skills consisted of advanced thinker: 41.6%, practicing thinker: 30.6%, beginning thinker: 25%, and challenged thinker: 2.8%. And the average criteria of Japanese students` critical thinking were *practicing thinker.* The results of Japanese students` analysis showed that the attitudes toward STEM fields of Japanese male students and female students were not different significantly. Students` career interests showed that both male and female students had generally moderate interests in STEM careers. Female students were more interested in careers in medicine, but the male students were more interested in computer science and engineering careers.
- The result showed that mean score of Indonesian students` critical thinking skills were 2.10. Criteria analysis of Indonesian students` critical thinking skills consist of practicing thinker: 29.63%; beginning thinker 51.85%; and challenged thinker 18.52%. Also, the average result using criteria of Indonesian students` critical thinking was *beginning thinker*. The result of Indonesian students` showed that the male students had more positive attitudes toward STEM than the female students. Findings indicated that the attitudes

toward STEM fields of Indonesian male students and female students were not different significantly. Students` career interests showed that both male and female students had generally moderate interests in STEM careers. Female students were more interested in careers in medicine, but male students were more interested in careers in engineering.

- There were differences between Japanese and Indonesian students in critical thinking skills (p-value > $\alpha/2$). Japanese students have mastered than Indonesian students in critical thinking skills, because the identification of problem in these lessons related to daily life. The range of mean scores in critical thinking skills between Japanese students and Indonesian students was 0.717, this gap point was big enough. Based on the solutions that designed by students, Japanese students had more variety of solutions and they did evaluate their solutions.
- There were not differences between Japanese and Indonesian students` attitudes toward STEM in all aspect; Mathematics, Science and Technology and Engineering (p-value < $\alpha/2$). It is mean that both Japan and Indonesia have same attitudes toward STEM. Both the Japanese female students` and the Indonesian female students` were more interested in careers in medicine. The Japanese male students` career interests were more interested in careers in computer science and engineering, but the Indonesian male students` career were interested in careers in energy and engineering.
- There was correlation between Japanese and Indonesian students` critical thinking skills and attitudes toward STEM. The Japanese students had high

correlation between critical thinking skills and attitudes toward STEM. Moreover, the Indonesian students have moderate correlation between critical thinking skills and attitudes toward STEM.

## B. Implication for Teaching and Learning

Achieved information of this study are given benefits to students in experiences learning, ideas for teacher to design learning, higher education practitioners to improve students' skills, and higher learning institutions to educate pre-service teacher to prepare to be a good teacher. The results of this study can be a guidance for students that critical thinking can be implemented in the classroom through STEM education Project Based Learning, and also provides information about students` attitudes toward STEM and career interests. The teachers and higher education practitioners may design STEM Project Based Learning method completely in encouraging the development of these skills. Furthermore, stakeholders and higher learning institutions can recognize if any method within the integration of critical thinking skill and STEM education in the middle school syllabus or science textbooks. Moreover, the findings also make a significant contribution to the body of knowledge concerning Project Based Learning, critical thinking and STEM education.

## C. Limitation of Study

- The present study has some limitations that it is needed some continuous studies to complete the contextual information and then, higher contributions will be conformed to stakeholders, students in particular. The participants in this study were not randomly selected, therefore, they were not being arranged in the groups according to skills and knowledge.

- The division of groups should consist of higher thinker who can be a leader to guide lower thinker.
- In this study, only one of each Japanese and Indonesian science textbooks only were analyzed. However, STEM education has been developed in mainly in the America, so it will be better if US science textbooks are analyzed too.

**D. Future Work**

There is many uncompleted information in these studies, especially samples size and variety are too limited in Japan (Shizuoka city) and Indonesia (Sukabumi city). Where, it compares two Asian countries only that have similarity in many aspects. The study will provide more information if it is compared among three or more countries from different continents that have different needs, cultures, and education systems. Idea of problems can be applied for elementary, middle, senior, and university levels, so it will be more interesting in the comparisons for each level. Moreover, these studies could not collect data about improvement of students' understanding and critical thinking skills that are very important to develop learning processes in classrooms (formal or informal). Besides, interviewing is highly needed to make sure students' works and thinking. In the case of STEM education programs, students still need guidance to avoid misconceptions in scientific knowledge.

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# APPENDIX 1

# INSTRUMENT

Appendix 1.1 Worksheet and guide questions for STEM-PBL

NAME: CLASS:

1. According to news, who are need clean water? What they have to do? Why it must be done?

- Who:
- What:
- Why:

2. In this activity, what the problems must be solved?

   Problem:

   Questions will be answer in this activity:

3. What kinds of solution (solution more than one are allowed)? Design your solution? Please illustrate and explain your solution using drawings and words!
4. Explain your results that obtained in your experiment!
5. Explain your findings?
6. What kinds of strains that make your solution not work effectively?
7. What should you do to solve that strains?
8. What your conclusions in this activity?
9. Please mention your opinions and impressions of this learning?

Appendix 1.2 Prolog of Issues STEM Project Based Learning

**Important News from Gevernor and Major City**

Gevernor and major of city announced that our area particularly Shizuoka (Japan)/ Sukabumi (Indonesia) has problem deficient clean water, rivers are contaminated, and oceans are contaminated too. Population animals and plants around contaminated area have been decresed. Furthermore, diseases increased because rivers and seas were contaminated.

According to above announcement, governor and major of city engage the citizen to solve this problem (deficient clean water). Please give your ideas to solve this probem!

Appendix 1.3 Questionnaire for Indonesian Students (Students` attitudes and career interests)

Kelas: Jenis kelamin:

**KUISIONER SIKAP TERHADAP STEM (SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATIC)**

| No | | Sangat tidak setuju | Tidak setuju | Ragu-ragu | Setuju | Sangat setuju |
|---|---|---|---|---|---|---|
| MATHEMATICS | | | | | | |
| 1 | Matematika hal yang paling tidak disukai. | | | | | |
| 2 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan matematika. | | | | | |
| 3 | Matematika sangat sulit bagi saya. | | | | | |
| 4 | Saya termasuk siswa yang bagus dalam matematika | | | | | |
| 5 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan matematika. | | | | | |
| 6 | Saya yakin saya dapat bekerja dengan baik dalam matematika. | | | | | |
| 7 | Saya dapat nilai bagus dalam matematika. | | | | | |
| 8 | Saya ahli dalam matematika. | | | | | |
| SCIENCE | | | | | | |
| 9 | Saya percaya diri ketika saya melakukan hal yang berhubungan dengan sains | | | | | |
| 10 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan sains. | | | | | |
| 11 | Saya berharap untuk menggunakan sains setelah pulang dari sekolah. | | | | | |
| 12 | Pengetahuan sains akan menolong saya dalam mendapatkan kehidupan. | | | | | |
| 13 | Saya akan membutuhkan sains untuk masa depan karir saya. | | | | | |
| 14 | Saya tahu bahwa saya dapat bekerja baik dalam sains. | | | | | |
| 15 | Sains akan menjadi hal yang penting dalam karir saya di masa depan. | | | | | |
| 16 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan sains. | | | | | |
| 17 | Saya yakin dapat bekerja dengan baik dalam sains. | | | | | |
| ENGINEERING and TECHNOLOGY | | | | | | |
| 18 | Saya senang berimajinasi umtuk membuat suatu produk yang baru. | | | | | |
| 19 | Jika saya belajar teknik, kemudian saya akan membuat suatu barang yang dapat | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | digunakan semua orang untuk kebutuhan sehari-hari. | | | | | |
| 20 | Saya dapat membuat atau memperbaiki suatu barang. | | | | | |
| 21 | Saya tertarik untuk membuat mesin. | | | | | |
| 22 | Mendesain produk atau struktur akan menjadi hal yang penting dalam karir saya. | | | | | |
| 23 | Saya ingin tahu bagaimana suatu mesin elektronik dapat bekerja. | | | | | |
| 24 | Saya akan menggunakan kreativitas dan inovasi dalam karir saya di masa depan. | | | | | |
| 25 | Pengethauan bagaimana mengkombinasikan matematika dan siains akan berguna dalam menguasai teknologi. | | | | | |
| 26 | Saya yakin karir saya akan sukses dibidak teknik. | | | | | |

KUISIONER TENTANG KARIR DI MASA DEPAN

| No | Pertanyaan | SAngat tidak tertarik | Tidak tertarik | Tertarik | Sangat Tertarik |
|---|---|---|---|---|---|
| 1 | Fisika (tekniksi penerbangan, teknisi alternative energy, teknisi laboratorium, ahli astronomi) | | | | |
| 2 | Lingkungan (analis pengontrol polusi, teknisi lingkungan atau ilmuan, ahli pengontrol erosi, teknisi system energy) | | | | |
| 3 | Biologi (teknisi biologi, peneliti dibidang biologi, pemuliaan tanaman, ahli binatang,pembibitan tanaman, ahli genetic) | | | | |
| 4 | Ahli hewan (ahli penyakit hewan, dokter hewan, pengurus kebun binatang) | | | | |
| 5 | Matematika (akuntan, ahli aplikasi matematika, analis keuangan, ahli statistic, peneliti pasar, analis perdagangan). | | | | |
| 6 | Kesehatan (dokter, terapis, psikiater, ahli gizi, suter, bidan, dokter gigi) | | | | |
| 7 | Ilmu bumi (ahli geologi, peramal cuaca, ahli barang kuno) | | | | |
| 8 | Komputer Sains (ahli teknik informasi, ahli pembuat program, ahmi pembuat game, programmer) | | | | |
| 9 | Peneliti dibidang kesehatan (apoteker, teknik laboratorium kesehatan, ahli kesehatan kulit, peneliti penyakit menular) | | | | |
| 10 | Kimia (analis kimia, teknisi kimia, ahli kimia terapan) | | | | |
| 11 | Energy (ahli elektronik, ahli nuklir, ahli alternative energy) | | | | |
| 12 | Teknik (teknik sipil, teknik pertanian, teknik automitif, teknik knstruksi, teknik industry) | | | | |

Appendix 1.4 Questionnaire for Japanese Students (Students` attitudes and career interest)

年生:　　　　　　　　　　　　　性別:

# 科学・技術・工学・数学に対する姿勢のアンケート

| | | 強く反対する | 反対する | どちらでもない | 同意する | 強く同意する |
|---|---|---|---|---|---|---|
| 数学 | | | | | | |
| 1 | 数学は一番嫌いな科目です。 | | | | | |
| 2 | 私は将来、数学と関係ある仕事を検討します。 | | | | | |
| 3 | 数学は私にとって難しいです。 | | | | | |
| 4 | 私は数学では得意な生徒タイプに含まれます。 | | | | | |
| 5 | 私は数学の問題以外の他の科目については問題解決がうまくできます。 | | | | | |
| 6 | 私は数学の応用した学習でもうまくできたと確信できます。 | | | | | |
| 7 | 私は数学におけて、良い成績をとれます。 | | | | | |
| 8 | 私は数学が得意です。 | | | | | |
| 科学 | | | | | | |
| 9 | 科学と関係する学習をするとき、自信をもってできます。 | | | | | |
| 10 | 私は科学と関連した仕事を考えています。 | | | | | |
| 11 | 学校から帰ってきたら、科学知識を応用することを求めています。 | | | | | |
| 12 | 科学知識は生きていく糧（かて）となります。（お給料をしっかりいただけること） | | | | | |
| 13 | 私の未来の仕事の為、科学が必要となるでしょう。 | | | | | |
| a14 | 私は科学と関係ある学習ではうまく出来ます。 | | | | | |
| 15 | 私の一生にとって、科学は大切なものになるでしょう。 | | | | | |
| 16 | 理科という科目以外、全科目の問題をうまく解決ができます。 | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 17 | 理科に関連したより難しい学習を上手くできるます | | | | | |
| 工学と技術 | | | | | | |
| 18 | 私は新製品を造るのを想像することが大好きです。 | | | | | |
| 19 | 私は工学を学ぶことで、人々が生活日常で使用するものを改善できるようになります。 | | | | | |
| 20 | 私はものが造ったり、修理したりすることが得意です。 | | | | | |
| 21 | 私は機械造りに興味があります。 | | | | | |
| 22 | プロダクト（製品）あるいは建設物を設計することは私の未来の仕事のために重要でしょう。 | | | | | |
| 23 | 私はエレクトロニクスがどのように機能しているか知りたいです。 | | | | | |
| 24 | 私は将来、創造する力や革新的な能力を使っていきたい。 | | | | | |
| 25 | どのように数学と科学を使うべきか知ることは、私が有用なものを発明することを可能にするでしょう。 | | | | | |
| 26 | 私はエンジニアリング（工学）におけるキャリアにおいて成功を収め得ると信じています | | | | | |

## 未来のキャリアのアンケート

| No | 質問 | まったく興味がない | 興味がない | 興味がある | すごく興味がある |
|---|---|---|---|---|---|
| 1 | 物理学関連の仕事（航空工学、代替エネルギー技術者、検査技師、物理学者、天文学者）。 | | | | |
| 2 | 環境関連の仕事（汚染管理アナリスト、環境エンジニア又は科学者、地滑制御専門家、エネルギーシステムとメンテナンスエンジニア）。 | | | | |
| 3 | 生物関連の仕事（生物学技術者、生物科学者、植物育種家、収穫物検査技師、動物科学者、遺伝学者、動物学者）。 | | | | |
| 4 | 獣医関連の仕事（獣医師；動物の病気を予防するか治療する科学を伴います) | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 5 | 数学関連の仕事（会計士、応用数学者、エコノミスト、金融アナリスト、数学者、統計学者、市場調査員、株式市場アナリスト）。 | | | | |
| 6 | 健康関連の仕事（看護師、医者、栄養士、救急救助隊員、理学療法士、歯科医）。 | | | | |
| 7 | 地学業務（地球科学者、天気予報、考古学者、地質学者）。 | | | | |
| 8 | 情報科学関連の仕事（コンピュータサポート専門家,コンピュータプログラマ,コンピュータおよびネットワーク技術者,ゲームデザイナー,コンピュータソフトウェアエンジニア、情報技術専門家）。 | | | | |
| 9 | 医学関連の仕事（臨床検査技師、医学者、生物医学のエンジニア、疫学者、薬理学者）。 | | | | |
| 10 | 化学関連の仕事（化学技師、化学者、化学エンジニア）。 | | | | |
| 11 | エネルギー関連の仕事（電気工、電気エンジニア、加熱、通風と空気条件付け（HVAC）テクニシャン、核エンジニア、システムエンジニア、代替エネルギーシステム設置者あるいは技術者）。 | | | | |
| 12 | 工学関連の仕事（土木技師、産業技術者、農業技術者、機械エンジニア、溶接機、自動車メカニック、建設マネージャー）。 | | | | |

Appendix 1.5 Lesson Plan

STEM Lessons through Project Based Learning

| **Activity** | **Crosscutting Concepts** | **Scientific and Engineering Practices (NGSS Framework)** | **Disciplinary Core Ideas** |
|---|---|---|---|
| | | **First Lesson** | |
| Introduction of the theme of lessons and dividing the groups. (9 groups) | | | |
| Provide students to mention examples of solid, liquid, and gas (state of matter) in their daily life. (**Physics**) | Molecules pattern of solid, liquid, and gas. (CCs 1) | Asking questions and defining problems. (SEPs 1) | **Structure and Properties of Matter** The fact that matter is composed of atoms and molecules can be used to explain the properties of substances, diversity of materials, states of matter, phase changes, and conservation of matter. (PSs 1.A) |
| Students observe the demonstration and determine the colloid. (**Chemistry**) | Pattern, Cause and Effect, Scale. (CCs 1, CCs 2, CCs 3) | Asking questions and defining problems. (SEPs 1) Engaging in argument from evidence. (SEPs 7) | |
| Teacher introduce wastewater treatment plant/ cleaning water system and asks students to find any information about how to clean wastewater. (**Science, Technology, Engineering, and Mathematics**). | Matter is conserved because atoms are conserved in physical and chemical processes. (CCs 5) | Constructing explanations and design solutions. (SEPs 6) | **Type of Interaction** Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. (PSs 2.B) |
| Students search information in internet, books, and so on. | | | |
| | | **Second, Third, and Fourth Lesson** | |
| Students design wastewater treatment system. Students determine what they need to clean wastewater. | Influence of science, engineering, and technology on society | Asking questions and defining problems. (SEPs 1) Developing and using models. (SEPs 2) | Defining and delimiting engineering problems. (ETSs 1.A) Developing possible solutions. (ETSs 1.B) |

| | | | |
|---|---|---|---|
| Student check water clarity by their eyes. (**Science, Technology, Engineering, and Mathematics**). Students check pH before and after cleaning processes. Students redesign the wastewater treatment system. **(Science, Technology, Engineering, and Mathematics**). | and the natural world. (CCs 7) | Planning and carrying out investigations. (SEPs 3)<br>Analyzing and interpreting data. (SEPs 4)<br>Using mathematics and computational thinking. (SEPs 5)<br>Constructing explanation and designing solutions. (SEPs 6)<br>Engaging in argument from evidence. (SEPs 7) | Optimizing the design solution. (ETSs 1.C) |
| **Fifth Lesson** | | | |
| Students watch video about wastewater treatment plant.<br><br>Students redesign wastewater treatment by drawing or if the time is available, students can redesign their prototype. (**Science, Technology, Engineering, and Mathematics**). | Influence of science, engineering, and technology on society and the natural world. (CCs 7) | Developing and using models. (SEPs 2)<br>Planning and carrying out investigations. (SEPs 3)<br>Analyzing and interpreting data. (SEPs 4)<br>Using mathematics and computational thinking. (SEPs 5)<br>Constructing explanation and designing solutions. (SEPs 6)<br>Engaging in argument from evidence. (SEPs 7) | Defining and delimiting engineering problems. (ETSs 1.A)<br>Developing possible solutions. (ETSs 1.B)<br>Optimizing the design solution. (ETSs 1.C) |
| **Sixth Lesson** | | | |
| Students present and explain their prototype of wastewater treatment system. | Influence of science, engineering, and technology | Obtaining, evaluating, and communicating information. (SEPs 8) | Defining and delimiting engineering problems. (ETSs 1.A)<br>Developing possible solutions. (ETSs 1.B) |

| | | | |
|---|---|---|---|
| **(Science, Technology, Engineering, and Mathematics**). | on society and the natural world. (CCs 7) | | Optimizing the design solution. (ETSs 1.C) |

Appendix 1.6 Critical Thinking Skills Rubric

Critical Thinking Skills Rubric

(base on the Paul-Elder critical thinking framework)

| **Dimension** | **Score** | | | |
|---|---|---|---|---|
| | **4** | **3** | **2** | **1** |
| Purpose and question | Clearly identifies the purpose including all complexities of relevant questions. | Clearly identifies the purpose including some complexities of relevant questions. | Identifies the purpose including irrelevant and/or insufficient questions. | Unclear purpose that does not includes questions. |
| Information | Accurate, complete information that is supported by relevant evidence. | Accurate, mostly complete information that is supported by evidence. | Accurate, but incomplete information that is not supported by evidence. | Inaccurate, incomplete information that is not supported by evidence. |
| Assumption and point of view | Complete, fair presentation of all relevant assumptions and points of view. | Complete, fair presentation of some relevant assumptions and points of view. | Simplistic presentation that ignores relevant assumptions and points of view. | Incomplete presentation that ignores relevant assumption and points of view |
| Implications and consequences | Clearly articulates significant, logical implications and consequences based on relevant evidence | Clearly articulates some implications and consequences based on evidence. | Articulates insignificant or illogical implications and consequences that are not supported by evidence. | Fails to recognize to generates invalid implications and consequences based on irrelevant evidence |

# APPENDIX
# 2
## DATA

Appendix 2.1 Result of Analysis Science Middle School Textbook (first grade)

1. variety activities

| | Indonesia | Japan |
|---|---|---|
| Science | 100 | 100 |
| Technology | 50 | 69 |
| Engineering | 20 | 7 |
| Mathematics | 40 | 62 |

2. Tech Tools

| | Indonesia | Japan |
|---|---|---|
| Science | | |
| Technology | 50 | 62 |
| Engineering | | |
| Mathematics | | |

3. Project Based Learning

| | Indonesia | Japan |
|---|---|---|
| Science | 0 | 100 |
| Technology | 0 | 0 |
| Engineering | 0 | 0 |
| Mathematics | 0 | 25 |

4. Cross-cullar connection

| | Indonesia | Japan |
|---|---|---|
| Science | 80 | 23 |
| Technology | 50 | 46 |
| Engineering | 20 | 7 |
| Mathematics | 40 | 53 |

5. Inquiry

| | Indonesia | Japan |
|---|---|---|
| Science | 100 | 100 |
| Technology | 10 | 0 |
| Engineering | 0 | 0 |
| Mathematics | 20 | 0 |

6. Collaborative

| | Indonesia | Japan |
|---|---|---|
| Science | 80 | 100 |
| Technology | 50 | 7 |
| Engineering | 20 | 0 |
| Mathematics | 30 | 0 |

7. Level visualization

| | Indonesia | Japan |
|---|---|---|
| Science | 0 | 100 |
| Technology | 0 | 69 |
| Engineering | 0 | 0 |
| Mathematics | 0 | 23 |

8. Self assessment

| | Indonesia | Japan |
|---|---|---|
| Science | 0 | 100 |
| Technology | 0 | 0 |
| Engineering | 0 | 0 |
| Mathematics | 0 | 7 |

Appendix 2.2 Result of Wastewater Treatment System Project Japanese Students

Wastewater Treatment System Project (First Grade Middle School Student)-Japan

Problem: Everyday, the water use has been increased, and wastewater also became increased. In addition, the unfriendly chemicals used for cleaning wastewater in many wastewater treatment plan. Therefore, the government need to solve these problems. Please help government to solve these problem!

Class 1D

| Group | Solution | Result | Conclusion | Comment |
|---|---|---|---|---|
| 1 | Physical Filtering | In first filtering, the particles colloid still detected by flash. In second filtering, the water more clear. | The number of filtering will impact to number of particle colloid. | Students did not think to real situation. How many water come to wastewater treatment plan? |
| 2 | Physical Filtering | 4 times filtering clean wastewater | The more filtering wastewater, the water will be clean | This method is effective to clean water, however it is not efficient. In engineering solution, efficiency and effectiveness must be concerned. |
| 3 | Physical Filtering | 10 times filtering clean wastewater. | If the filtering is added fabric will clean wastewater more. | This method will consume much time in wastewater treatment system plan. |
| 4 | Distillation and biological system (using euglena) | Distillation: the water become clean, but consume energy. Using Euglena: no change anything, but environmental friendly. | The combination of distillation and using euglena will become effective and environmental friendly solution. | The conclusion is not logic. Overheating will kill Euglena and distillation still consume energy (not environmental friendly). |

| | | | | |
|---|---|---|---|---|
| 5 | Physical Filtering | 5 times filtering can clean the water, but if it compared with suido water, it still dirty. | The number of filtering will impact to number of particle colloid. | Bacteria will be killed by filtering only or not? |
| 6 | Rotate the sample about 20 minutes, the dirt particles will accumulated in center, and then take the water. Do same thing until third day. | The water colors fade. Increasing volume of clean water. After three times treatments, the pollution particles precipitate in the bottom. | Number of rotation influence to water cleanliness and the sedimentation of pollution particles. | They realize that the solution will consume more energy. It is mean that they can evaluate the solution by themselves. This is the important starting to be good problem solver. |
| 7 | Physical Filtering and Boiling to kill the bacteria | Five times filtering clean the water. | More filtering can clean the water. | This solution will consume more energy and time. |
| 8 | Evaporation<br>3 samples were evaporated in different times 5, 10, and 15 minutes. Furthermore, each sample was checked the pH. | 3 samples still dirty, but 15 minutes evaporated samples slightly clear than others. Test pH results showed that 5 minutes sample is 4.22, 10 minutes is 3.90, 15 minutes is 3,84, water is 6.28, and wastewater 4.38. | Evaporation make wastewater become clear. | Which will evaporate first between water and waste particles? How much the energy will be consumed in evaporation process? |
| 9 | Using micro organism from pond and three conditions (dark – sealed, sunlight – sealed, sunlight – not sealed). | Condition 1: 19.7 gram<br>Condition 2: 19.7 gram<br>Condition 3: 19.6 gram<br>No change of the water color. | Micro organism need air and sunlight in working. | The information about experiments are required to design effective and efficient solutions. Whether the micro organism in pond can clean the wastewater? |

Class 1A

| Group | Solution | Result | Conclusion | Comment |
|---|---|---|---|---|
| 1 | Physical Filtering<br>1st experiment: using gauze, cotton, stone, charcoal, and gravel.<br>2nd experiment: Using gauze only.<br>3rd experiment:<br>Using cotton only.<br>4th experiment: using gauze and cotton | 1st result: water still dirty, but almost clean.<br>2nd result: water still dirty.<br>3rd result: water still dirty<br>4th result: water still dirty | Gauze and cotton not enough to clean the dirty water, so combination of some materials are needed to clean the water. | How much time are needed to process one litter clean water? However, they were tried to identify effectiveness of gauze and cotton. This showed that they have analytic thinking skill as the foundation of critical thinking (Elder and Paul, 2003) |
| 2 | Physical Filtering<br>1st experiment: Rotate wastewater in the bottle with 60 rpm during 30 minutes, and then let stand for 30 minutes. Filter the water using paper filtering.<br>2nd experiment: filtered water from 1st experiment pour into big beaker glass and in the middle put the small beaker glass. Seal the big beaker glass and put a load right above the small beaker glass. | In 1st experiment, the precipitation can be seen on filtering, the water looked slightly clean.<br>In 2nd experiment, there were no water in small beaker glass. | 1st experiment has better effectiveness than 2nd experiment. If the method in 1st experiment is continued, the water will be clean. | Creative thinking is not enough to solve the problem, however, creative and critical thinking are needed to solve problem effectively and efficiently. |

| | | | | |
|---|---|---|---|---|
| 3 | Physical filtering<br>Using charcoal, big and small stones, sand, leaf, and paper filtering. | The water still dirty, but little clean. | Sand and leaf to filter small particles and charcoal to kill the bacteria | How to identify the roles of each material? No experiments in order to identify them. |
| 4 | Physical filtering<br>$1^{st}$ experiment: using fabric (2 cm), small stone (6 cm), charcoal (3 cm).<br>$2^{nd}$ experiment: fabric added 3 cm more, and charcoal added 3 cm more.<br>$3^{rd}$ experiment: fabric (3 locations, 5 pieces filter paper (2 locations), and charcoal (1 location). | Filtering $1^{st}$ experiment:<br>$1^{st}$ : dirty, $2^{nd}$ : dirty, $3^{rd}$ : dirty, $4^{th}$ : slightly clean, $5^{th}$ : clean.<br>Filtering $2^{nd}$ experiment:<br>$1^{st}$ and $2^{nd}$ : better than $1^{st}$ experiment. $3^{rd}$ and $4^{th}$ : slightly clean, $5^{th}$ : clean.<br>Filtering $3^{rd}$ experiment:<br>$1^{st}$ : better than $1^{st}$ experiment, $2^{nd}$ : slightly clean, $3^{rd}$ : clean slightly dirty, $4^{th}$: clean but not like suido water. | Filter paper has role to clean the water more than others. | Efficiency of solution was not concerned, whereas efficiency and effectiveness are key in science and technology. |
| 5 | Physical filtering<br>$1^{st}$ experiment used filter paper, stone, leaf, and charcoal.<br>$2^{nd}$ experiment did not use leaf.<br>$3^{rd}$ experiment did not use filter paper. | $1^{st}$ experiment: the water be clean.<br>$2^{nd}$ experiment: result not different with $1^{st}$ experiment.<br>$3^{rd}$ experiment: after two times filtering, the water be clean. | The leaf do not has role in cleaning system, but filter paper has role it. | Clean water is not necessarily no bacteria. Bacteria in the water not be concerned as solution. |
| 6 | Evaporated by sunlight<br>Wastewater pour on big beaker glass, and then put on small beaker glass in the | $1^{st}$ experiment: the water still dirty.<br>$2^{nd}$ experiment: the water be clean. | The number of load effect to cleanliness of water. Black sheet has | They can evaluate their solution effectively, but still efficiency was not concerned. |

| | | | | |
|---|---|---|---|---|
| | middle big beaker glass. Furthermore, Big one is sealed by black sheet with load in the middle. 1st experiment used one load and 2nd experiment used two loads. | | role in collecting sunlight. | |
| 7 | Filtering and evaporation.<br>1st experiment: wastewater was filtered by filter paper only.<br>2nd experiment: wastewater was boiled every 2 minutes. This treatment was conducted 3 times (A, B, C). | 1st experiment<br>1st filtering decrease black dots, 2nd filtering was cleaned the water.<br>2nd experiment<br>A: no water<br>B and C: there are water with neutral pH. | Filtering use filter paper can clean the water. Evaporation has effective method to clean the water. | Filter paper can filter the big particles, but not for small particles. This solution has effectiveness and less material for small scale.<br>The water start evaporated after 2 minutes. |
| 8 | Filtering<br>Wastewater was filtered using two pieces' filter papers, charcoal, and stones. They modified number of charcoal and stone. | Number of stone and charcoal did not influence significantly to cleanness of wastewater. | Stone and charcoal not influence in wastewater cleaning system. However, filter paper influence. | Clean stone and charcoal were not washed before used. They did not predict it. Perhaps, they have been tried to apply their experiences. This activity encourage students to be scientist and engineering. |
| 9 | Okra (coagulation)<br>Sliced okra insert in wastewater, and let stand for one day. The amount of okra as variable (10 slices, 20 slices, and 30 slices). | Wastewater still dirty for each sample. Even the samples leave for one week. The pollutant particles spread in all solution. | Okra not affect in water cleaning system. However, the wastewater to be slimy from okra. Perhaps, the pollutant particles are trapped in the mucus of okra. | They have different idea from other groups. It means they challenge their creative thinking. However, they did know how to processes okra before used as flocculants. |

Class 1C

| Group | Solution | Result | Conclusion | Comment |
|---|---|---|---|---|
| 1 | Physical filtering.<br>Using gravel and 6-piece fabrics. After filtering, the water were tested the luminance. | Clean water = 4600 LX<br>Dirty water = 1500 LX<br>$1^{st}$ filtering = 3800 LX<br>$2^{nd}$ filtering = 4400 LX | The luminance value increase by filtering. | Students could conduct the good method in experiments. They had standard to test the result. |
| 2 | Filtering.<br>Use 3 layers of fabric and 2 paper cups (big and small). The sequence from bottom is big cup, fabric, and small cup (perforated). $1^{st}$ experiment used ice, and $2^{nd}$ experiment not. | $1^{st}$ experiment.<br>The color of colloid become sallow (5 level) and there are white particles on surface of ice and fabric.<br>$2^{nd}$ experiment.<br>The color of colloid not change (10 level), but there are particles on fabric | Using ice can filter colloid particles better than not use. | Creative idea. This is starting for innovation in technology. However, their solution is to small scale, they did not think how in real life. |
| 3 | Physical Filtering.<br>Using filter paper only, but the filtering was conducted under different conditions (room temperature and $100^{o}$C). | Result of filters in room temperature and 100oC were no different significantly. | Temperature of wastewater did not effect to result, but filter paper influence to clean wastewater. | Good thinking to conclude the data and investigate the factor that influence in cleaning system. Good starting to be scientist and engineering. |
| 4 | Biological<br>Using water (micro organism) from turtle pond (surface, middle, bottom), and leave for one day, after that stir the wastewater. Avoid the sunlight. | No significant different of each sample, but after stirred, the sample to be little clean. | Stirring is needed for better result. Pond water did not work to clean wastewater. Perhaps, there no micro organism who can clean the water. | Before use pond water, make sure what kind of bacteria in there. At least the sharp of bacteria. However, they were create new idea than other group who use physical filtering. |

| | | | | |
|---|---|---|---|---|
| 5 | Evaporation.<br>Exp 1st: Water is boiled, and the steam go to tube (not use pipe), and then store in refrigerator.<br>Exp 2nd: using mirror to collect the sunlight, and boil the water. So, fire is not used (environmentally friendly). | Experiment 1st.<br>Not environmentally friendly.<br>The steam goes to atmosphere, so no water in tube.<br>Experiment 2nd.<br>No enough sunlight, so the water cannot be boiled. | Experiment 2nd can be the best solution, because use natural energy (sunlight). If the sunlight enough, water will evaporate. So, only clean water will go to tube. | In order to achieve environmentally friendly and efficient result is difficult for middle school level. However, they could assess their solutions by themselves is good point in education (critical thinking skills). |
| 6 | Evaporated by sunlight<br>Wastewater pour on big beaker glass, and then put on small beaker glass in the middle big beaker glass. Furthermore, Big one is sealed by black sheet with load in the middle. 1st experiment used one load and 2nd experiment used two loads. | 1st experiment: the water still dirty.<br>2nd experiment: the water be clean. | The number of load effect to cleanliness of water. Black sheet has role in collecting sunlight. | They can evaluate their solution effectively, but still efficiency was not concerned. |
| 7 | Evaporation.<br>Wastewater in test tube evaporated for 10 minutes, close the test tube use the little finger. Move the water on little finger to another test tube. | The evaporated water cleaner than wastewater. The evaporated water checked under microscope, there are no stains. | Evaporation is the effective way to clean the wastewater. | How energy needed to evaporate the wastewater in real life? However, they found the effective solution. |

| | | | | |
|---|---|---|---|---|
| 8 | Physical Filtering.<br>Using filter paper only, but the filtering was conducted under different conditions (room temperature and 100oC). | Result of filters in room temperature and 100oC were no different significantly. | Temperature of wastewater did not effect to result, but filter paper influence to clean wastewater. | Good thinking to conclude the data and investigate the factor that influence in cleaning system. Good starting to be scientist and engineering. |
| 9 | Physical Filtering | 7 times filtering clean wastewater. | If the filtering is added fabric will clean wastewater more. | This method will consume much time in wastewater treatment system plan. |

Class 1B

| Group | Solution | Result | Conclusion | Comment |
|---|---|---|---|---|
| 1 | Physical Filtering.<br>Using filter paper only. Compare the use of one and two sheets of filter. | Filtering use two sheets filter show the water cleaner than use one sheet filter. However, there are no stains on second layer. Then, the pH of filtered water are checked, | More layer of filter, the water will be cleaner. Furthermore, the water poured little by little will show better result. | This group was conducted inquiry, science (check the pH of water) and engineering practices (compare the use one and two sheets filter). |
| 2 | Evaporation.<br>Wastewater in test tube evaporated for 10 minutes, close the test tube use the little finger. Move the water on little finger to another test tube. | The evaporated water cleaner than wastewater. The evaporated water checked under microscope, there are no stains. | Evaporation is the effective way to clean the wastewater. | How energy needed to evaporate the wastewater in real life? However, they found the effective solution. |
| 3 | Evaporation | Evaporated water cleaner than waste water. | Evaporation is the effective way to clean | They conduct STEM activities. However, they did not think the |

| | | | | |
|---|---|---|---|---|
| | Evaporate the wastewater in beaker glass that closed by plastic. The water that collected on plastic, move to test tube. Compare with wastewater. Compare effectiveness by volume of wastewater (100, 300, and 500 mL). | Small volume water easier to evaporate than big volume.<br>100mL => 8.5 mL<br>300mL => 7 mL<br>500mL => 1.5 mL | water, and then the volume of wastewater that evaporated influence to effectiveness of evaporation. | how much energy must be consumed to evaporate water. |
| 4 | Biological (euglena).<br>Euglena enter to colloid (pH milk 5), and then stored for 1 day. After that, check the pH. | pH of colloid change to 6. It means the pH close to water's pH. | Euglena can clean the water, because they will increase the oxygen in the water. | pH is one of condition for clean water. How to check the other conditions? However, this idea different with other groups. |
| 5 | Evaporation<br>Insert wastewater into 500 mL beaker glass, and then put the smaller beaker glass in the center. 500 mL beaker glass closed by plastic sheet and put ballast in the center plastic sheet. Boil the wastewater, and then the clean water will flow to smaller beaker glass. | This method generates clean water. Weight of ballast influences to number of collected clean water. | Evaporation is one of effective method to clean water. Weight of ballast influence to efficiency of collection water. However, does this method can be used in real wastewater treatment? | They aware that this method cannot be used in reality. They begin to correlate experiment to reality. If they are given more time, I hope they will think the method that can be used in reality. |
| 6 | Evaporation<br>Boil wastewater using big fire and small fire. | Using big fire, wastewater did not be clean. However, small fire could be clean water effectively. | Boiling use small fire can clean water effectively. However, this method need more cost. | They have critical thinking to evaluate the value their solution. It will more useful, if the experiment not be conducted. First think other solutions, evaluate solutions, and conduct the best method. |

| | | | | |
|---|---|---|---|---|
| 7 | Evaporation<br>Boil wastewater in isolated system will keep water in the system. | Dirty water to be clean, but it more consumes time. | Boiling water is effective method to clean water. | No demerit value of method is evaluated. It means no critical thinking. |
| 8 | Evaporation<br>Boil wastewater in small amount and big amount (50 mL, 100 mL, and 200 mL). Using 1 L beaker glass and 250 mL beaker glass put in 1 L beaker glass for collecting clean water. 1 L beaker glass was sealed and put coin for flowing evaporated water into 250 mL beaker glass. | 50 ml sample evaporate quickly than others. All of evaporated water are clean. | Evaporation is effective method to clean water. Evaporate little by little is better in efficiency of time. | They did not think critically how much this method consume energy. And the amount of water will effect on evaporating time. However, they taught creatively using seal and coin to flow the water into 250 mL beaker glass. |
| 9 | Physical Filtering.<br>Using filter paper only, but the filtering was conducted under different conditions (room temperature and 100$^{o}$C). | Result of filters in room temperature and 100oC were no different significantly. | Temperature of wastewater did not effect to result, but filter paper influence to clean wastewater. | Good thinking to conclude the data and investigate the factor that influence in cleaning system. Good starting to be scientist and engineering. |

Appendix 2.3 Result of Wastewater Treatment System Project Indonesian Students

Wastewater Treatment System Project (First Grade Middle School Student)-Indonesia

Problem: Everyday, the water use has been increased, and wastewater also became increased. In addition, the unfriendly chemicals used for cleaning wastewater in many wastewater treatment plan. Therefore, the government need to solve these problems. Please help government to solve these problem!

Class 1B

| Group | Solution | Result | Conclusion | Comment |
|---|---|---|---|---|
| 1 | Physical Filtering | 2 times filtering using cotton, sponge, zeolite, gravel, and sand. 1st filtration: water still dirty (pH 4) 2nd filtration: water more clean (pH 7) | Wastewater become clean water by filtering. | They did not focus to redesign the materials. it means they did not evaluate the solution. So, they lack in critical thinking. |
| 2 | Physical Filtering | 4 times filtering use carbon active, zeolite, cotton, sponge, and coconut husk can clean the water. | The more filtering wastewater, the water will be clean | They did not focus to redesign the materials. it means they did not evaluate the solution. So, they lack in critical thinking. |
| 3 | Physical Filtering | 4 times filtering use coconut hush, tissue paper, cotton, sand, and gravel could clean the water. | We achieve new knowledge about wastewater treatment. | They not familiar with scientific method. |
| 4 | Physical Filtering | Using zeolite only could not clean the water. | In order to clean wastewater needed filtering processes. | They not familiar with scientific method and lack in critical thinking. |

| | | | | |
|---|---|---|---|---|
| 5 | Physical Filtering<br>2 times filtering use filter paper, sand, carbon active, zeolite, sponge, and tissue. | Water be clean with pH 7. | Clean water important for daily life, so we have to conserve the environment. | They not familiar with scientific method and lack in critical thinking. |
| 6 | Physical Filtering | 5 times filtering use sand, gravel, and ijuk fibers (*arenga pinnata*) could clean wastewater with pH 7. | If pH decrease, water still dirty.<br>If pH increase, water is clean. | They did not focus to redesign the materials. So, they lack in critical thinking. They not familiar with scientific method. |
| 7 | Physical Filtering | Filter wastewater use gravel, ijuk fibers, carbon active, zeolite, sand, sponge, and cotton make water becomes black. | Wastewater can be cleaned by filtering. | They cannot conclude the experiment. |
| 8 | Physical Filtering<br>1st experiment: 2 times filtering use ijuk fiber, zeolite, and sand.<br>2nd experiment: 2 times filtering use tissue, cotton, ijuk fiber, zeolite, and sand. | 1st result: water still dirty.<br>2nd result: water becomes clean. Cotton and tissue support to clean wastewater. | Filtering use tissue, cotton, ijuk fiber, zeolite, and sand can clean the wastewater. | They start to know scientific method and evaluate the solutions with redesign the solution. |
| 9 | Physical Filtering<br>4 times filtering use zeolite, carbon active, sand, coconut hush, and tissue. Check ph water before and after filtering. | Water slightly dirty. pH not change before (4) and after filtering (4). | Filtering can clean the wastewater. | They do not know what is the conclusion. No redesign solution. |

Class 1F

| Group | Solution | Result | Conclusion | Comment |
|---|---|---|---|---|
| 1 | Physical Filtering | 3 times filtering using carbon active, gravel, cotton, and coconut husk.<br>1st filtration: water still dirty (pH 5)<br>2nd filtration: water still dirty (pH 4.2)<br>3rd filtration: water more clean (pH 4.3) | Wastewater become clean water by 3 times filtering. | They did not focus to redesign the materials.<br>it means they did not evaluate the solution. |
| 2 | Physical Filtering | 2 times filtering use carbon active, zeolite, cotton, sponge, and coconut husk can clean the water.<br>1st filtration: water still dirty (pH 7.13)<br>2nd filtration: water more clean (pH 6.6) | Dirty water can be clean water by filtering used simple materials. | They did not focus to redesign the materials. it means they did not evaluate the solution. They cannot conclude the experiment. |
| 3 | Physical Filtering | Water filtration use: sponge, carbon, gravel, and sand. | We must able to create useful things, one of which is water filtration. | They not familiar with scientific method. They did not focus to redesign the materials. it means they did not evaluate the solution. They cannot conclude the experiment. |
| 4 | Physical Filtering | 2 times filtering using gravel, sand, carbon active, coconut husk, and sponge | In order to clean wastewater needed filtering processes. | They not familiar with scientific method and lack in critical thinking. |
| 5 | Physical Filtering | 3 times filtering using sponge, ijuk, sand, gravel, carbon active, coconut husk, and cotton. | Dirty water becomes clean water by filtration process. | They not familiar with scientific method and lack in |

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|---|---|---|---|---|
| | | 1st filtration: still dirty (pH 6,0)<br>2nd filtration: more clean (pH 6,83)<br>3rd filtration: more clean (pH 6.93) | | critical thinking. They did not focus to redesign the materials |
| 6 | Physical Filtering | 2 times filtering using sponge, cotton, gravel, and carbon. | We got clean water from dirty water by filtration. | They did not focus to redesign the materials. So, they lack in critical thinking. They not familiar with scientific method. |
| 7 | Physical Filtering | 3 times filtering using sponge, cotton, gravel, sand, and carbon. | Wastewater can be clean water by filtering. | They not familiar with scientific method. They did not focus to redesign the materials. it means they did not evaluate the solution. They cannot conclude the experiment. They cannot conclude the experiment. |
| 8 | Physical Filtering | Water filtration using: cotton, carbon, gravel, sand, and coconut husk. | We got knowledge about water filtration. | They not familiar with scientific method. They did not focus to redesign the materials. it means they did not evaluate the solution. They cannot conclude the experiment. They cannot conclude the experiment. |
| 9 | Physical Filtering | 2 times filtering using sponge, ijuk, carbon, gravel, sand, and cotton.<br>1st filtration: water still dirty<br>2nd filtration: water more clean | Wastewater can be clean water by filtering. | They did not focus to redesign the materials. So, they lack in critical thinking. They not familiar with scientific method. |

Class 1I

| Group | Solution | Result | Conclusion | Comment |
|---|---|---|---|---|
| 1 | Physical Filtering | 3 times filtering using zeolite, cotton, coconut husk, and filter paper.<br>1st filtration: still dirty<br>2nd filtration: more clean<br>3rd filtration: more clean | The result of filtering can not clean because materials of filtration is too much | They did not focus to redesign the materials. So, they lack in critical thinking. They not familiar with scientific method. |
| 2 | Physical Filtering | Water filtration use: cotton, filter paper, zeolite, and and. | Wastewater can be clean water by filtering. | They not familiar with scientific method. They did not focus to redesign the materials. it means they did not evaluate the solution. They cannot conclude the experiment. They cannot conclude the experiment. |
| 3 | Physical Filtering | 2 times filtering, 1st filtration dirty, and then 2nd filtration became clean but still dirty | We got clean water from dirty water by filtration. | They did not focus to redesign the materials. So, they lack in critical thinking. They not familiar with scientific method. |
| 4 | Physical Filtering | Water becomes clean after filtering by using bottle. | We should go together for anything. | They not familiar with scientific method. They did not focus to redesign the materials. it means they did not evaluate the solution. They cannot conclude the experiment. They cannot conclude the experiment. |
| 5 | Physical Filtering | Dirty water becomes clean water | Dirty water can be broken into clean water | They not familiar with scientific method. They did not focus to redesign the materials. it means |

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| | | | | they did not evaluate the solution. They cannot conclude the experiment. They cannot conclude the experiment. |
| 6 | Physical Filtering | Dirty water becomes clean water by filtration, using: filter paper, coconut husk, zeolite, and carbon active. | Wastewater can be clean water by filtering. | They did not focus to redesign the materials. So, they lack in critical thinking. They not familiar with scientific method. |
| 7 | Physical Filtering | Water filtration using: coconut husk, sand, gravel, and cotton.. | To get clean water from dirty water must be filtered first. | They not familiar with scientific method and lack in critical thinking. |
| 8 | Physical Filtering | Wastewater becomes clean water by filtration using: cotton, gravel, carbon active, | We can manage dirty water becomes clean water by filtration. | They do not know what is the conclusion. No redesign solution. |
| 9 | Physical Filtering | Dirty water becomes clean water by filtration, using: cotton, sand, gravel, and carbon. | We got new knowledge about water filtration. | They not familiar with scientific method. |

Appendix 2.4 Result of Critical Thinking Skills Indonesian Students

| Class | Group | Score of Dimension | | | | Total Score | Score |
|---|---|---|---|---|---|---|---|
| | | Purpose and question | Information | Assumptions and point of view | Implications and consequences | | |
| 1B (A) | 1 | 2 | 3 | 2 | 2 | **9** | 2.25 |
| | 2 | 3 | 3 | 2 | 2 | **10** | 2.5 |
| | 3 | 3 | 3 | 2 | 2 | **10** | 2.5 |
| | 4 | 2 | 2 | 1 | 2 | **7** | 1.75 |
| | 5 | 1 | 3 | 2 | 2 | **8** | 2 |
| | 6 | 1 | 2 | 2 | 1 | **6** | 1.5 |
| | 7 | 2 | 2 | 2 | 2 | **8** | 2 |
| | 8 | 3 | 3 | 3 | 3 | **12** | 3 |
| | 9 | 2 | 2 | 2 | 2 | **8** | 2 |
| 1F (B) | 1 | 2 | 2 | 2 | 2 | **8** | 2 |
| | 2 | 3 | 2 | 2 | 3 | **10** | 2.5 |
| | 3 | 2 | 2 | 1 | 1 | **6** | 1.5 |
| | 4 | 2 | 3 | 2 | 2 | **9** | 2.25 |
| | 5 | 3 | 3 | 2 | 2 | **10** | 2.5 |
| | 6 | 2 | 3 | 2 | 2 | **9** | 2.25 |
| | 7 | 3 | 3 | 2 | 2 | **10** | 2.5 |
| | 8 | 2 | 2 | 1 | 1 | **6** | 1.5 |
| | 9 | 2 | 3 | 2 | 2 | **9** | 2.25 |
| 1I (C) | 1 | 2 | 3 | 2 | 2 | **9** | 2.25 |
| | 2 | 2 | 2 | 1 | 1 | **6** | 1.5 |
| | 3 | 3 | 3 | 1 | 1 | **8** | 2 |
| | 4 | 4 | 3 | 1 | 1 | **9** | 2.25 |
| | 5 | 1 | 2 | 1 | 1 | **5** | 1.25 |
| | 6 | 3 | 3 | 2 | 2 | **10** | 2.5 |
| | 7 | 3 | 3 | 2 | 2 | **10** | 2.5 |
| | 8 | 3 | 2 | 1 | 2 | **8** | 2 |
| | 9 | 2 | 3 | 1 | 1 | **7** | 1.75 |

| | A | B | C |
|---|---|---|---|
| Group1 | **2.25** | **2** | **2.25** |
| Group2 | **2.5** | **2.5** | **1.5** |
| Group3 | **2.5** | **1.5** | **2** |
| Group4 | **1.75** | **2.25** | **2.25** |
| Group5 | **2** | **2.5** | **1.25** |
| Group6 | **1.5** | **2.25** | **2.5** |
| Group7 | **2** | **2.5** | **2.5** |
| Group8 | **3** | **1.5** | **2** |
| Group9 | **2** | **2.25** | **1.75** |
| mean | 2.166666667 | 2.138888889 | 2 |

R-statistic:

```
data:  Kelas_CT_Ind$A and Kelas_CT_Ind$B
t = 0.13868, df = 16, p-value = 0.8914
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.3968571  0.4524126
sample estimates:
mean of A mean of B
 2.166667  2.138889

data:  Kelas_CT_Ind$A and Kelas_CT_Ind$C
t = 0.8, df = 16, p-value = 0.4354
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.2749803  0.6083136
sample estimates:
mean of A mean of C
 2.166667  2.000000

data:  Kelas_CT_Ind$B and Kelas_CT_Ind$C
t = 0.70888, df = 16, p-value = 0.4886
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -0.2764576  0.5542353
sample estimates:
mean of B mean of C
 2.138889  2.000000
```

Appendix 2.5 Result of Indonesian attitudes toward STEM

Class A

| No | Boy | Sangat tidak setuju | Tidak setuju | Ragu-ragu | Setuju | Sangat setuju |
|---|---|---|---|---|---|---|
| MATHEMATICS | | | | | | |
| 1 | Matematika hal yang paling tidak disukai. | 5 | 8 | 3 | 2 | 1 |
| 2 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan matematika. | 0 | 5 | 8 | 6 | 0 |
| 3 | Matematika sangat sulit bagi saya. | 0 | 9 | 6 | 4 | 0 |
| 4 | Saya termasuk siswa yang bagus dalam matematika | 1 | 5 | 10 | 3 | 0 |
| 5 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan matematika. | 0 | 9 | 6 | 4 | 0 |
| 6 | Saya yakin saya dapat bekerja dengan baik dalam matematika. | 0 | 1 | 9 | 9 | 0 |
| 7 | Saya dapat nilai bagus dalam matematika. | 0 | 3 | 5 | 10 | 1 |
| 8 | Saya ahli dalam matematika. | 1 | 4 | 12 | 1 | 1 |
| SCIENCE | | | | | | |
| 9 | Saya percaya diri ketika saya melakukan hal yang berhubungan dengan sains | 0 | 5 | 5 | 8 | 1 |
| 10 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan sains. | 0 | 3 | 6 | 9 | 1 |
| 11 | Saya berharap untuk menggunakan sains setelah pulang dari sekolah. | 0 | 7 | 10 | 1 | 1 |
| 12 | Pengetahuan sains akan menolong saya dalam mendapatkan kehidupan. | 0 | 1 | 7 | 10 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 13 | Saya akan membutuhkan sains untuk masa depan karir saya. | 0 | 4 | 4 | 11 | 0 |
| 14 | Saya tahu bahwa saya dapat bekerja baik dalam sains. | 0 | 4 | 10 | 5 | 0 |
| 15 | Sains akan menjadi hal yang penting dalam karir saya di masa depan. | 1 | 3 | 12 | 1 | 2 |
| 16 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan sains. | 1 | 7 | 10 | 1 | 0 |
| 17 | Saya yakin dapat bekerja dengan baik dalam sains. | 0 | 4 | 10 | 4 | 1 |
| ENGINEERING and TECHNOLOGY | | | | | | |
| 18 | Saya senang berimajinasi umtuk membuat suatu produk yang baru. | 0 | 2 | 5 | 10 | 2 |
| 19 | Jika saya belajar teknik, kemudian saya akan membuat suatu barang yang dapat digunakan semua orang untuk kebutuhan sehari-hari. | 0 | 0 | 4 | 12 | 3 |
| 20 | Saya dapat membuat atau memperbaiki suatu barang. | 0 | 4 | 7 | 8 | 0 |
| 21 | Saya tertarik untuk membuat mesin. | 0 | 4 | 7 | 6 | 2 |
| 22 | Mendesain produk atau struktur akan menjadi hal yang penting dalam karir saya. | 0 | 5 | 8 | 5 | 1 |
| 23 | Saya ingin tahu bagaimana suatu mesin elektronik dapat bekerja. | 0 | 0 | 2 | 13 | 4 |
| 24 | Saya akan menggunakan kreativitas dan inovasi dalam karir saya di masa depan. | 0 | 0 | 11 | 4 | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 25 | Penethauan bagaimana mengkombinasikan matematika dan siains akan berguna dalam menguasai teknologi. | 0 | 1 | 12 | 6 | 0 |
| 26 | Saya yakin karir saya akan sukses dibidak teknik. | 0 | 3 | 9 | 6 | 1 |

Female Students

| No | Girl | Sangat tidak setuju | Tidak setuju | Ragu-ragu | Setuju | Sangat setuju |
|---|---|---|---|---|---|---|
| MATHEMATICS | | | | | | |
| 1 | Matematika hal yang paling tidak disukai. | 3 | 6 | 5 | 4 | 2 |
| 2 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan matematika. | 0 | 2 | 15 | 2 | 1 |
| 3 | Matematika sangat sulit bagi saya. | 0 | 8 | 5 | 5 | 2 |
| 4 | Saya termasuk siswa yang bagus dalam matematika | 0 | 3 | 11 | 6 | 0 |
| 5 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan matematika. | 1 | 5 | 5 | 6 | 3 |
| 6 | Saya yakin saya dapat bekerja dengan baik dalam matematika. | 1 | 3 | 7 | 8 | 1 |
| 7 | Saya dapat nilai bagus dalam matematika. | 0 | 3 | 8 | 8 | 1 |
| 8 | Saya ahli dalam matematika. | 0 | 7 | 10 | 3 | 0 |
| SCIENCE | | | | | | |
| 9 | Saya percaya diri ketika saya melakukan hal yang berhubungan dengan sains | 0 | 1 | 7 | 11 | 1 |
| 10 | Saya akan mempertimbangkan dalam memilih karir | 0 | 2 | 7 | 10 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | yang berhubungan dengan sains. | | | | | |
| 11 | Saya berharap untuk menggunakan sains setelah pulang dari sekolah. | 0 | 4 | 7 | 7 | 2 |
| 12 | Pengetahuan sains akan menolong saya dalam mendapatkan kehidupan. | 1 | 0 | 3 | 14 | 2 |
| 13 | Saya akan membutuhkan sains untuk masa depan karir saya. | 1 | 3 | 5 | 8 | 3 |
| 14 | Saya tahu bahwa saya dapat bekerja baik dalam sains. | 0 | 3 | 7 | 9 | 1 |
| 15 | Sains akan menjadi hal yang penting dalam karir saya di masa depan. | 1 | 1 | 7 | 9 | 2 |
| 16 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan sains. | 2 | 7 | 5 | 5 | 1 |
| 17 | Saya yakin dapat bekerja dengan baik dalam sains. | 1 | 3 | 6 | 8 | 2 |
| ENGINEERING and TECHNOLOGY | | | | | | |
| 18 | Saya senang berimajinasi umtuk membuat suatu produk yang baru. | 0 | 2 | 4 | 13 | 1 |
| 19 | Jika saya belajar teknik, kemudian saya akan membuat suatu barang yang dapat digunakan semua orang untuk kebutuhan sehari-hari. | 1 | 1 | 4 | 11 | 3 |
| 20 | Saya dapat membuat atau memperbaiki suatu barang. | 1 | 2 | 8 | 8 | 1 |
| 21 | Saya tertarik untuk membuat mesin. | 0 | 9 | 6 | 5 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 22 | Mendesain produk atau struktur akan menjadi hal yang penting dalam karir saya. | 0 | 7 | 5 | 7 | 1 |
| 23 | Saya ingin tahu bagaimana suatu mesin elektronik dapat bekerja. | 0 | 3 | 1 | 13 | 3 |
| 24 | Saya akan menggunakan kreativitas dan inovasi dalam karir saya di masa depan. | 0 | 1 | 4 | 14 | 1 |
| 25 | Penethauan bagaimana mengkombinasikan matematika dan siains akan berguna dalam menguasai teknologi. | 1 | 1 | 9 | 5 | 4 |
| 26 | Saya yakin karir saya akan sukses dibidang teknik. | 0 | 4 | 5 | 9 | 2 |

Class B

| No | Boy | Sangat tidak se | Tidak setuju | Ragu-ragu | Setuju | Sangat setuju |
|---|---|---|---|---|---|---|
| MATHEMATICS | | | | | | |
| 1 | Matematika hal yang paling tidak disukai. | 4 | 5 | 0 | 1 | 3 |
| 2 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan matematika. | 1 | 6 | 1 | 5 | 0 |
| 3 | Matematika sangat sulit bagi saya. | 2 | 3 | 3 | 4 | 1 |
| 4 | Saya termasuk siswa yang bagus dalam matematika | 0 | 1 | 8 | 3 | 1 |
| 5 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan matematika. | 0 | 7 | 1 | 5 | 0 |
| 6 | Saya yakin saya dapat bekerja dengan baik dalam matematika. | 0 | 1 | 3 | 8 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | Saya dapat nilai bagus dalam matematika. | 0 | 0 | 4 | 9 | 0 |
| 8 | Saya ahli dalam matematika. | 1 | 1 | 7 | 4 | 0 |
| SCIENCE | | | | | | |
| 9 | Saya percaya diri ketika saya melakukan hal yang berhubungan dengan sains | 0 | 1 | 3 | 8 | 1 |
| 10 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan sains. | 0 | 0 | 5 | 7 | 1 |
| 11 | Saya berharap untuk menggunakan sains setelah pulang dari sekolah. | 1 | 3 | 5 | 4 | 0 |
| 12 | Pengetahuan sains akan menolong saya dalam mendapatkan kehidupan. | 0 | 0 | 4 | 5 | 4 |
| 13 | Saya akan membutuhkan sains untuk masa depan karir saya. | 0 | 0 | 4 | 5 | 4 |
| 14 | Saya tahu bahwa saya dapat bekerja baik dalam sains. | 0 | 0 | 6 | 6 | 1 |
| 15 | Sains akan menjadi hal yang penting dalam karir saya di masa depan. | 0 | 1 | 5 | 5 | 2 |
| 16 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan sains. | 0 | 4 | 5 | 4 | 0 |
| 17 | Saya yakin dapat bekerja dengan baik dalam sains. | 0 | 0 | 5 | 8 | 0 |
| ENGINEERING and TECHNOLOGY | | | | | | |
| 18 | Saya senang berimajinasi umtuk membuat suatu produk yang baru. | 0 | 1 | 2 | 6 | 4 |
| 19 | Jika saya belajar teknik, kemudian saya akan membuat suatu barang yang dapat digunakan semua orang untuk kebutuhan sehari-hari. | 0 | 0 | 1 | 9 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 20 | Saya dapat membuat atau memperbaiki suatu barang. | 0 | 0 | 3 | 8 | 2 |
| 21 | Saya tertarik untuk membuat mesin. | 0 | 1 | 3 | 5 | 4 |
| 22 | Mendesain produk atau struktur akan menjadi hal yang penting dalam karir saya. | 0 | 1 | 3 | 9 | 0 |
| 23 | Saya ingin tahu bagaimana suatu mesin elektronik dapat bekerja. | 0 | 0 | 2 | 9 | 2 |
| 24 | Saya akan menggunakan kreativitas dan inovasi dalam karir saya di masa depan. | 0 | 0 | 2 | 7 | 4 |
| 25 | Penethauan bagaimana mengkombinasikan matematika dan siains akan berguna dalam menguasai teknologi. | 0 | 2 | 6 | 4 | 1 |
| 26 | Saya yakin karir saya akan sukses dibidak teknik. | 0 | 0 | 5 | 6 | 2 |

| No | Girl | Sangat tidak setuju | Tidak setuju | Ragu-ragu | Setuju | Sangat setuju |
|---|---|---|---|---|---|---|
| MATHEMATICS | | | | | | |
| 1 | Matematika hal yang paling tidak disukai. | 1 | 6 | 8 | 7 | 1 |
| 2 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan matematika. | 0 | 2 | 10 | 9 | 2 |
| 3 | Matematika sangat sulit bagi saya. | 2 | 9 | 6 | 5 | 1 |
| 4 | Saya termasuk siswa yang bagus dalam matematika | 0 | 5 | 15 | 3 | 0 |
| 5 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan matematika. | 4 | 3 | 9 | 7 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 6 | Saya yakin saya dapat bekerja dengan baik dalam matematika. | 0 | 2 | 6 | 14 | 1 |
| 7 | Saya dapat nilai bagus dalam matematika. | 0 | 0 | 10 | 10 | 3 |
| 8 | Saya ahli dalam matematika. | 1 | 6 | 13 | 2 | 1 |
| SCIENCE | | | | | | |
| 9 | Saya percaya diri ketika saya melakukan hal yang berhubungan dengan sains | 0 | 3 | 5 | 14 | 1 |
| 10 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan sains. | 0 | 3 | 9 | 10 | 1 |
| 11 | Saya berharap untuk menggunakan sains setelah pulang dari sekolah. | 0 | 6 | 5 | 11 | 1 |
| 12 | Pengetahuan sains akan menolong saya dalam mendapatkan kehidupan. | 1 | 0 | 4 | 14 | 4 |
| 13 | Saya akan membutuhkan sains untuk masa depan karir saya. | 0 | 0 | 7 | 11 | 5 |
| 14 | Saya tahu bahwa saya dapat bekerja baik dalam sains. | 0 | 0 | 9 | 13 | 1 |
| 15 | Sains akan menjadi hal yang penting dalam karir saya di masa depan. | 1 | 1 | 10 | 10 | 1 |
| 16 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan sains. | 0 | 14 | 8 | 1 | 0 |
| 17 | Saya yakin dapat bekerja dengan baik dalam sains. | 1 | 1 | 5 | 12 | 4 |
| ENGINEERING and TECHNOLOGY | | | | | | |
| 18 | Saya senang berimajinasi umtuk membuat suatu produk yang baru. | 0 | 1 | 4 | 14 | 4 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 19 | Jika saya belajar teknik, kemudian saya akan membuat suatu barang yang dapat digunakan semua orang untuk kebutuhan sehari-hari. | 0 | 1 | 3 | 16 | 3 |
| 20 | Saya dapat membuat atau memperbaiki suatu barang. | 0 | 2 | 11 | 5 | 5 |
| 21 | Saya tertarik untuk membuat mesin. | 0 | 11 | 9 | 2 | 1 |
| 22 | Mendesain produk atau struktur akan menjadi hal yang penting dalam karir saya. | 0 | 3 | 11 | 8 | 1 |
| 23 | Saya ingin tahu bagaimana suatu mesin elektronik dapat bekerja. | 1 | 1 | 7 | 13 | 1 |
| 24 | Saya akan menggunakan kreativitas dan inovasi dalam karir saya di masa depan. | 0 | 1 | 6 | 12 | 4 |
| 25 | Penethauan bagaimana mengkombinasikan matematika dan siains akan berguna dalam menguasai teknologi. | 0 | 3 | 6 | 10 | 4 |
| 26 | Saya yakin karir saya akan sukses dibidak teknik. | 0 | 0 | 12 | 9 | 2 |

Class C

| No | Boy | Sangat tidak setuju | Tidak setuju | Ragu-ragu | Setuju | Sangat setuju |
|---|---|---|---|---|---|---|
| MATHEMATICS | | | | | | |
| 1 | Matematika hal yang paling tidak disukai. | 3 | 7 | 5 | 1 | 0 |
| 2 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan matematika. | 0 | 3 | 6 | 7 | 0 |
| 3 | Matematika sangat sulit bagi saya. | 3 | 7 | 0 | 6 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | Saya termasuk siswa yang bagus dalam matematika | 0 | 3 | 5 | 8 | 0 |
| 5 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan matematika. | 2 | 5 | 2 | 7 | 0 |
| 6 | Saya yakin saya dapat bekerja dengan baik dalam matematika. | 0 | 1 | 7 | 3 | 5 |
| 7 | Saya dapat nilai bagus dalam matematika. | 1 | 1 | 5 | 6 | 3 |
| 8 | Saya ahli dalam matematika. | 0 | 2 | 9 | 5 | 0 |
| SCIENCE | | | | | | |
| 9 | Saya percaya diri ketika saya melakukan hal yang berhubungan dengan sains | 0 | 1 | 5 | 8 | 2 |
| 10 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan sains. | 0 | 1 | 6 | 8 | 1 |
| 11 | Saya berharap untuk menggunakan sains setelah pulang dari sekolah. | 0 | 5 | 3 | 8 | 0 |
| 12 | Pengetahuan sains akan menolong saya dalam mendapatkan kehidupan. | 0 | 1 | 0 | 9 | 6 |
| 13 | Saya akan membutuhkan sains untuk masa depan karir saya. | 1 | 0 | 4 | 8 | 3 |
| 14 | Saya tahu bahwa saya dapat bekerja baik dalam sains. | 0 | 1 | 5 | 10 | 0 |
| 15 | Sains akan menjadi hal yang penting dalam karir saya di masa depan. | 0 | 0 | 7 | 6 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 16 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan sains. | 3 | 6 | 6 | 1 | 0 |
| 17 | Saya yakin dapat bekerja dengan baik dalam sains. | 0 | 1 | 7 | 8 | 0 |
| ENGINEERING and TECHNOLOGY | | | | | | |
| 18 | Saya senang berimajinasi umtuk membuat suatu produk yang baru. | 0 | 1 | 1 | 9 | 5 |
| 19 | Jika saya belajar teknik, kemudian saya akan membuat suatu barang yang dapat digunakan semua orang untuk kebutuhan sehari-hari. | 0 | 0 | 2 | 8 | 6 |
| 20 | Saya dapat membuat atau memperbaiki suatu barang. | 1 | 0 | 1 | 10 | 4 |
| 21 | Saya tertarik untuk membuat mesin. | 0 | 1 | 7 | 5 | 3 |
| 22 | Mendesain produk atau struktur akan menjadi hal yang penting dalam karir saya. | 1 | 1 | 6 | 7 | 1 |
| 23 | Saya ingin tahu bagaimana suatu mesin elektronik dapat bekerja. | 0 | 1 | 3 | 7 | 5 |
| 24 | Saya akan menggunakan kreativitas dan inovasi dalam karir saya di masa depan. | 0 | 1 | 2 | 10 | 3 |
| 25 | Pengetahauan bagaimana mengkombinasikan matematika dan siains akan berguna dalam menguasai teknologi. | 0 | 0 | 11 | 4 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 26 | Saya yakin karir saya akan sukses dibidak teknik. | 1 | 0 | 9 | 5 | 1 |

Female Students

| No | Girl | Sangat tidak setuju | Tidak setuju | Ragu-ragu | Setuju | Sangat setuju |
|---|---|---|---|---|---|---|
| MATHEMATICS | | | | | | |
| 1 | Matematika hal yang paling tidak disukai. | 5 | 9 | 2 | 3 | 1 |
| 2 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan matematika. | 0 | 5 | 5 | 8 | 2 |
| 3 | Matematika sangat sulit bagi saya. | 3 | 10 | 0 | 7 | 0 |
| 4 | Saya termasuk siswa yang bagus dalam matematika | 0 | 6 | 7 | 5 | 2 |
| 5 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan matematika. | 4 | 11 | 3 | 1 | 1 |
| 6 | Saya yakin saya dapat bekerja dengan baik dalam matematika. | 0 | 0 | 7 | 6 | 7 |
| 7 | Saya dapat nilai bagus dalam matematika. | 0 | 0 | 9 | 6 | 5 |
| 8 | Saya ahli dalam matematika. | 0 | 1 | 12 | 5 | 2 |
| SCIENCE | | | | | | |
| 9 | Saya percaya diri ketika saya melakukan hal yang berhubungan dengan sains | 1 | 3 | 5 | 11 | 0 |
| 10 | Saya akan mempertimbangkan dalam memilih karir yang berhubungan dengan sains. | 0 | 2 | 7 | 10 | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 11 | Saya berharap untuk menggunakan sains setelah pulang dari sekolah. | 1 | 5 | 8 | 6 | 0 |
| 12 | Pengetahuan sains akan menolong saya dalam mendapatkan kehidupan. | 1 | 0 | 6 | 8 | 5 |
| 13 | Saya akan membutuhkan sains untuk masa depan karir saya. | 1 | 1 | 4 | 11 | 3 |
| 14 | Saya tahu bahwa saya dapat bekerja baik dalam sains. | 1 | 1 | 11 | 5 | 2 |
| 15 | Sains akan menjadi hal yang penting dalam karir saya di masa depan. | 0 | 3 | 7 | 6 | 4 |
| 16 | Saya dapat menyelesaikan masalah dalam semua mata pelajaran, kecuali yang berhubungan dengan sains. | 0 | 8 | 9 | 2 | 1 |
| 17 | Saya yakin dapat bekerja dengan baik dalam sains. | 0 | 1 | 10 | 6 | 3 |
| ENGINEERING and TECHNOLOGY | | | | | | |
| 18 | Saya senang berimajinasi umtuk membuat suatu produk yang baru. | 1 | 4 | 2 | 11 | 2 |
| 19 | Jika saya belajar teknik, kemudian saya akan membuat suatu barang yang dapat digunakan semua orang untuk kebutuhan sehari-hari. | 0 | 0 | 4 | 10 | 6 |
| 20 | Saya dapat membuat atau memperbaiki suatu barang. | 0 | 2 | 11 | 6 | 1 |
| 21 | Saya tertarik untuk membuat mesin. | 2 | 8 | 6 | 4 | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 22 | Mendesain produk atau struktur akan menjadi hal yang penting dalam karir saya. | 2 | 6 | 4 | 6 | 2 |
| 23 | Saya ingin tahu bagaimana suatu mesin elektronik dapat bekerja. | 1 | 2 | 3 | 13 | 1 |
| 24 | Saya akan menggunakan kreativitas dan inovasi dalam karir saya di masa depan. | 0 | 1 | 3 | 9 | 7 |
| 25 | Pengetahauan bagaimana mengkombinasikan matematika dan siains akan berguna dalam menguasai teknologi. | 0 | 2 | 7 | 2 | 9 |
| 26 | Saya yakin karir saya akan sukses dibidak teknik. | 0 | 0 | 12 | 4 | 4 |

Score total of Indonesian students' attitudes

| Boy | | | | | | |
|---|---|---|---|---|---|---|
| | Sangat tidak setuju | Tidak setuju | Ragu | Setuju | Sangat setuju | Total |
| Math | | | | | | |
| 1 | 12 | 20 | 8 | 4 | 4 | 48 |
| 2 | 1 | 14 | 15 | 18 | 0 | 48 |
| 3 | 5 | 19 | 9 | 14 | 1 | 48 |
| 4 | 1 | 9 | 23 | 14 | 1 | 48 |
| 5 | 2 | 21 | 9 | 16 | 0 | 48 |
| 6 | 0 | 3 | 19 | 20 | 6 | 48 |
| 7 | 1 | 4 | 14 | 25 | 4 | 48 |
| 8 | 2 | 7 | 28 | 10 | 1 | 48 |
| Science | | | | | | |
| 9 | 0 | 7 | 13 | 24 | 4 | 48 |
| 10 | 0 | 4 | 17 | 24 | 3 | 48 |
| 11 | 1 | 15 | 18 | 13 | 1 | 48 |
| 12 | 0 | 2 | 11 | 24 | 11 | 48 |
| 13 | 1 | 4 | 12 | 24 | 7 | 48 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 14 | 0 | 5 | 21 | 21 | 1 | 48 |
| 15 | 1 | 4 | 24 | 12 | 7 | 48 |
| 16 | 4 | 17 | 21 | 6 | 0 | 48 |
| 17 | 0 | 5 | 22 | 20 | 1 | 48 |
| Technology and Engineering | | | | | | |
| 18 | 0 | 4 | 8 | 25 | 11 | 48 |
| 19 | 0 | 0 | 7 | 29 | 12 | 48 |
| 20 | 1 | 4 | 11 | 26 | 6 | 48 |
| 21 | 0 | 6 | 17 | 16 | 9 | 48 |
| 22 | 1 | 7 | 17 | 21 | 2 | 48 |
| 23 | 0 | 1 | 7 | 29 | 11 | 48 |
| 24 | 0 | 1 | 15 | 21 | 11 | 48 |
| 25 | 0 | 3 | 29 | 14 | 2 | 48 |
| 26 | 1 | 3 | 23 | 17 | 4 | 48 |

| **Girls** | | | | | | |
|---|---|---|---|---|---|---|
| **No** | **Sangat tdk setuju** | **Tidak setuju** | **Ragu** | **Setuju** | **Sangat setuju** | **Total** |
| **Math** | | | | | | |
| 1 | 9 | 21 | 15 | 14 | 4 | 63 |
| 2 | 0 | 9 | 30 | 19 | 5 | 63 |
| 3 | 5 | 27 | 11 | 17 | 3 | 63 |
| 4 | 0 | 14 | 33 | 14 | 2 | 63 |
| 5 | 9 | 19 | 17 | 14 | 4 | 63 |
| 6 | 1 | 5 | 20 | 28 | 9 | 63 |
| 7 | 0 | 3 | 27 | 24 | 9 | 63 |
| 8 | 1 | 14 | 35 | 10 | 3 | 63 |
| **Science** | | | | | | |
| 9 | 1 | 7 | 17 | 36 | 2 | 63 |
| 10 | 0 | 7 | 23 | 30 | 3 | 63 |
| 11 | 1 | 15 | 20 | 24 | 3 | 63 |
| 12 | 3 | 0 | 13 | 36 | 11 | 63 |
| 13 | 2 | 4 | 16 | 30 | 11 | 63 |
| 14 | 1 | 4 | 27 | 27 | 4 | 63 |
| 15 | 2 | 5 | 24 | 25 | 7 | 63 |
| 16 | 2 | 29 | 22 | 8 | 2 | 63 |
| 17 | 2 | 5 | 21 | 26 | 9 | 63 |
| **Tech and Engineering** | | | | | | |
| 18 | 1 | 7 | 10 | 38 | 7 | 63 |
| 19 | 1 | 2 | 11 | 37 | 12 | 63 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 20 | 1 | 6 | 30 | 19 | 7 | 63 |
| 21 | 2 | 28 | 21 | 11 | 1 | 63 |
| 22 | 2 | 16 | 20 | 21 | 4 | 63 |
| 23 | 2 | 6 | 11 | 39 | 5 | 63 |
| 24 | 0 | 3 | 13 | 35 | 12 | 63 |
| 25 | 1 | 6 | 22 | 17 | 17 | 63 |
| 26 | 0 | 4 | 29 | 22 | 8 | 63 |

Appendix 2.6 Result of Indonesian students` career interests

| Boy | | | | | |
|---|---|---|---|---|---|
| No | Question | Not at all interested | Not so interested | Interested | Very interested |
| 1 | Physics: is the studyof basic laws governing he motion, energy, structure, and interactions of matter. This can include studying the nature of the universe. *(aviation engineer, alternative energy technician, lab technician, physicist, astronomer)* | 2 | 16 | 26 | 4 |
| 2 | Environmental work: involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling. *(pollution control analyst, environmental engineer or scientist, erosion control specialist, energy systems engineer and maintenance technicican)* | 2 | 13 | 28 | 5 |
| 3 | Biology and Zoology: involves the study of living organism (such as plants and animals) and the processes of life. This includes working with farm animals and in areas like nutrition and breeding. *(biologycal technician, biological scientist, plant breeder, crop lab technician, animal scientist, geneticist, zoologist)* | 3 | 16 | 24 | 5 |
| 4 | Veterinary work: involves the science of preventing or treating disease of animals *(veterinary assistant, veterinarian, livestock producer, animal caretaker)* | 1 | 22 | 22 | 3 |
| 5 | Mathematics is the science of number and their operations. It involves computation, algorithms and theory used to solve problems and summarize data. *(accountant, applied mathematician, economist, financial analyst, mathematician, statistician, market researcher, stock market analyst)* | 4 | 21 | 17 | 6 |
| 6 | Medicine: involves maintaining health and preventing and treating disease. *(physician`s assistant, nurse, doctor, nutritionist, emergency medical technician, physical therapist, dentist)* | 2 | 18 | 18 | 10 |

| | | | | | |
|---|---|---|---|---|---|
| 7 | Earth Science: is study of earth, including the air, land and ocean. *(geologist, weather forecaster, archaeologist, geoscientist)* | 1 | 18 | 20 | 9 |
| 8 | Computer Science: consist of the development and testing of computer systems, designing new programs and helping others to use computers. *(computer support specialist, computer programmer, computer and network technician, gaming designer, computer software engineer, information technology specialist)* | 1 | 13 | 17 | 17 |
| 9 | Medical Science: involves researching human disease and working to find new solution to human health problems. *(clinical laboratory technologist, medical scientist, biomedical engineer, epidemologist, pharmacologist)* | 3 | 24 | 18 | 3 |
| 10 | Chemistry: use amth and experiments to search for new chemicals, and to study the structure of matter and how it behaves. *(chemical technician, chemist, chemical engineer)* | 1 | 27 | 18 | 2 |
| 11 | Energy: involves the study and generation of power, such as heat or electricity. *(electrician, electrical engineer, heating, ventilation, nuclear enginer, systems engineer, alternative energy systems installer or technician)* | 1 | 11 | 31 | 5 |
| 12 | Engineeering: involves designing, testing, and manufacturing new products (like machines, bridges, building, and electronics) through the use mathematics, science, and computers. *(civil, industrial, agricultural, or mechanical engineers, welder, auto-mechanic, engineering technician, construction manager)* | 1 | 10 | 29 | 8 |

| Girl | | | | | |
|---|---|---|---|---|---|
| No | Question | Not at all interested | Not so interested | Interested | Very interested |
| 1 | Physics: is the studyof basic laws governing he motion, energy, structure, and interactions of matter. This can include studying the nature of the universe. *(aviation engineer, alternative energy technician, lab technician, physicist, astronomer)* | 1 | 25 | 31 | 6 |

| | | | | | |
|---|---|---|---|---|---|
| 2 | Environmental work: involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling. *(pollution control analyst, environmental engineer or scientist, erosion control specialist, energy systems engineer and maintenance technicican)* | 1 | 17 | 38 | 7 |
| 3 | Biology and Zoology: involves the study of living organism (such as plants and animals) and the processes of life. This includes working with farm animals and in areas like nutrition and breeding. *(biologycal technician, biological scientist, plant breeder, crop lab technician, animal scientist, geneticist, zoologist)* | 2 | 15 | 35 | 11 |
| 4 | Veterinary work: involves the science of preventing or treating disease of animals *(veterinary assistant, veterinarian, livestock producer, animal caretaker)* | 5 | 29 | 18 | 11 |
| 5 | Mathematics is the science of number and their operations. It involves computation, algorithms and theory used to solve problems and summarize data. *(accountant, applied mathematician, economist, financial analyst, mathematician, statistician, market researcher, stock market analyst)* | 5 | 26 | 21 | 11 |
| 6 | Medicine: involves maintaining health and preventing and treating disease. *(physician`s assistant, nurse, doctor, nutritionist, emergency medical technician, physical therapist, dentist)* | 0 | 6 | 35 | 22 |
| 7 | Earth Science: is study of earth, including the air, land and ocean. *(geologist, weather forecaster, archaeologist, geoscientist)* | 4 | 27 | 23 | 9 |
| 8 | Computer Science: consist of the development and testing of computer systems, designing new programs and helping others to use computers. *(computer support specialist, computer programmer, computer and network technician, gaming designer, computer software engineer, information technology specialist)* | 0 | 18 | 37 | 8 |

| | | | | | |
|---|---|---|---|---|---|
| 9 | Medical Science: involves researching human disease and working to find new solution to human health problems. *(clinical laboratory technologist, medical scientist, biomedical engineer, epidemologist, pharmacologist)* | 2 | 18 | 27 | 16 |
| 10 | Chemistry: use amth and experiments to search for new chemicals, and to study the structure of matter and how it behaves. *(chemical technician, chemist, chemical engineer)* | 2 | 20 | 34 | 7 |
| 11 | Energy: involves the study and generation of power, such as heat or electricity. *(electrician, electrical engineer, heating, ventilation, nuclear enginer, systems engineer, alternative energy systems installer or technician)* | 2 | 29 | 29 | 3 |
| 12 | Engineeering: involves designing, testing, and manufacturing new products (like machines, bridges, building, and electronics) through the use mathematics, science, and computers. *(civil, industrial, agricultural, or mechanical engineers, welder, auto-mechanic, engineering technician, construction manager)* | 5 | 24 | 31 | 3 |

Appendix 2.9 Result of critical thinking skills Japanese students

| Class | Group | Score of Dimension | | | | Total Score | Score |
|---|---|---|---|---|---|---|---|
| | | Purpose and question | Information | Assumptions and point of view | Implications and consequences | | |
| 1A | 1 | 4 | 4 | 3 | 3 | **14** | 3.5 |
| | 2 | 2 | 2 | 2 | 2 | **8** | 2 |
| | 3 | 3 | 2 | 2 | 1 | **8** | 2 |
| | 4 | 4 | 3 | 4 | 3 | **14** | 3.5 |
| | 5 | 4 | 3 | 2 | 2 | **11** | 2.75 |
| | 6 | 3 | 2 | 2 | 1 | **8** | 2 |
| | 7 | 4 | 4 | 3 | 3 | **14** | 3.5 |
| | 8 | 4 | 3 | 4 | 3 | **14** | 3.5 |
| | 9 | 4 | 4 | 3 | 3 | **14** | 3.5 |
| 1B | 1 | 3 | 3 | 3 | 3 | **12** | 3 |
| | 2 | 3 | 3 | 2 | 2 | **10** | 2.5 |
| | 3 | 4 | 3 | 3 | 3 | **13** | 3.25 |
| | 4 | 4 | 4 | 3 | 3 | **14** | 3.5 |
| | 5 | 3 | 2 | 2 | 2 | **9** | 2.25 |
| | 6 | 4 | 4 | 3 | 3 | **14** | 3.5 |
| | 7 | 3 | 1 | 1 | 1 | **6** | 1.5 |
| | 8 | 4 | 3 | 2 | 2 | **11** | 2.75 |
| | 9 | 3 | 3 | 2 | 2 | **10** | 2.5 |
| 1C | 1 | 4 | 4 | 3 | 3 | **14** | 3.5 |
| | 2 | 4 | 4 | 3 | 3 | **14** | 3.5 |
| | 3 | 3 | 3 | 2 | 2 | **10** | 2.5 |
| | 4 | 3 | 3 | 2 | 1 | **9** | 2.25 |
| | 5 | 4 | 3 | 3 | 3 | **13** | 3.25 |
| | 6 | 3 | 2 | 2 | 2 | **9** | 2.25 |
| | 7 | 3 | 3 | 2 | 2 | **10** | 2.5 |
| | 8 | 3 | 2 | 1 | 1 | **7** | 1.75 |
| | 9 | 3 | 3 | 2 | 1 | **9** | 2.25 |
| 1D | 1 | 4 | 3 | 3 | 3 | **13** | 3.25 |
| | 2 | 4 | 3 | 4 | 3 | **14** | 3.5 |
| | 3 | 3 | 3 | 3 | 3 | **12** | 3 |
| | 4 | 4 | 4 | 3 | 3 | **14** | 3.5 |
| | 5 | 3 | 3 | 2 | 3 | **11** | 2.75 |
| | 6 | 3 | 2 | 2 | 2 | **9** | 2.25 |
| | 7 | 2 | 2 | 2 | 1 | **7** | 1.75 |
| | 8 | 4 | 3 | 3 | 3 | **13** | 3.25 |
| | 9 | 4 | 4 | 3 | 3 | **14** | 3.5 |

Appendix 2.8 Result of Japanese students` attitudes toward STEM

**Male Students**

| | Strongly Disagree | Disagree | Neither disagree nor agree | Agree | Strongly agree | Total |
|---|---|---|---|---|---|---|
| **Math** | | | | | | |
| 1 | 34 | 14 | 18 | 7 | 8 | 81 |
| 2 | 3 | 8 | 27 | 23 | 20 | 81 |
| 3 | 16 | 15 | 19 | 19 | 12 | 81 |
| 4 | 4 | 8 | 23 | 26 | 20 | 81 |
| 5 | 10 | 16 | 30 | 18 | 7 | 81 |
| 6 | 2 | 8 | 27 | 29 | 15 | 81 |
| 7 | 5 | 9 | 18 | 27 | 22 | 81 |
| 8 | 4 | 7 | 20 | 32 | 17 | 80 |
| **Scienec** | | | | | | |
| 9 | 3 | 7 | 25 | 23 | 23 | 81 |
| 10 | 8 | 7 | 24 | 22 | 20 | 81 |
| 11 | 5 | 9 | 22 | 15 | 30 | 81 |
| 12 | 1 | 6 | 18 | 36 | 20 | 81 |
| 13 | 4 | 6 | 22 | 27 | 22 | 81 |
| 14 | 4 | 8 | 29 | 17 | 22 | 80 |
| 15 | 1 | 12 | 24 | 24 | 20 | 81 |
| 16 | 2 | 11 | 38 | 14 | 16 | 81 |
| 17 | 1 | 16 | 26 | 23 | 15 | 81 |
| Technology and Engineering | | | | | | |
| 18 | 4 | 5 | 14 | 25 | 33 | 81 |
| 19 | 2 | 6 | 17 | 34 | 22 | 81 |
| 20 | 4 | 8 | 14 | 34 | 21 | 81 |
| 21 | 5 | 6 | 15 | 26 | 29 | 81 |
| 22 | 2 | 8 | 20 | 29 | 22 | 81 |
| 23 | 6 | 5 | 15 | 29 | 26 | 81 |
| 24 | 2 | 7 | 15 | 33 | 24 | 81 |
| 25 | 2 | 5 | 25 | 27 | 22 | 81 |
| 26 | 3 | 7 | 23 | 30 | 18 | 81 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Male | | | | | | |
| Math | | | | | | |
| 1 | 170 | 56 | 54 | 14 | 8 | 3.728395062 |
| 2 | 3 | 16 | 81 | 92 | 100 | 3.604938272 |
| 3 | 80 | 60 | 57 | 38 | 10 | 3.024691358 |
| 4 | 4 | 16 | 69 | 104 | 100 | 3.617283951 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 35 | 56 | 90 | 24 | 8 | 2.62962963 |
| 6 | 2 | 16 | 81 | 116 | 75 | 3.580246914 |
| 7 | 5 | 18 | 54 | 108 | 110 | 3.641975309 |
| 8 | 4 | 14 | 60 | 128 | 85 | 3.592592593 |
| Science | | | | | | |
| 9 | 3 | 14 | 75 | 92 | 115 | 3.691358025 |
| 10 | 8 | 14 | 72 | 88 | 100 | 3.481481481 |
| 11 | 5 | 18 | 66 | 60 | 150 | 3.691358025 |
| 12 | 1 | 12 | 54 | 144 | 100 | 3.839506173 |
| 13 | 4 | 12 | 66 | 108 | 110 | 3.703703704 |
| 14 | 4 | 16 | 87 | 68 | 110 | 3.518518519 |
| 15 | 1 | 24 | 72 | 96 | 100 | 3.617283951 |
| 16 | 10 | 64 | 114 | 28 | 4 | 2.716049383 |
| 17 | 1 | 32 | 78 | 92 | 75 | 3.432098765 |
| Tech and Engineering | | | | | | |
| 18 | 4 | 10 | 42 | 100 | 165 | 3.962962963 |
| 19 | 2 | 12 | 51 | 136 | 110 | 3.839506173 |
| 20 | 4 | 16 | 42 | 136 | 105 | 3.740740741 |
| 21 | 5 | 12 | 45 | 104 | 145 | 3.839506173 |
| 22 | 2 | 16 | 60 | 116 | 110 | 3.75308642 |
| 23 | 6 | 10 | 45 | 116 | 130 | 3.790123457 |
| 24 | 2 | 14 | 45 | 132 | 120 | 3.864197531 |
| 25 | 2 | 10 | 75 | 108 | 110 | 3.765432099 |
| 26 | 3 | 14 | 69 | 120 | 90 | 3.654320988 |

**Female Students**

| | **Strongly Disagree** | **Disagree** | **Neither disagree nor agree** | **Agree** | **Strongly agree** | **Total** |
|---|---|---|---|---|---|---|
| **Math** | | | | | | |
| 1 | 14 | 17 | 14 | 18 | 16 | 79 |
| 2 | 5 | 9 | 18 | 25 | 22 | 79 |
| 3 | 2 | 7 | 13 | 35 | 22 | 79 |
| 4 | 2 | 7 | 16 | 34 | 20 | 79 |
| 5 | 3 | 5 | 14 | 30 | 27 | 79 |
| 6 | 2 | 5 | 19 | 32 | 21 | 79 |
| 7 | 4 | 9 | 25 | 24 | 17 | 79 |
| 8 | 6 | 11 | 19 | 23 | 20 | 79 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Science** | | | | | | |
| 9 | 4 | 14 | 23 | 25 | 13 | 79 |
| 10 | 5 | 11 | 25 | 22 | 16 | 79 |
| 11 | 7 | 7 | 21 | 28 | 16 | 79 |
| 12 | 4 | 7 | 16 | 36 | 16 | 79 |
| 13 | 4 | 6 | 15 | 30 | 24 | 79 |
| 14 | 3 | 7 | 22 | 31 | 16 | 79 |
| 15 | 3 | 5 | 24 | 27 | 20 | 79 |
| 16 | 1 | 3 | 25 | 35 | 15 | 79 |
| 17 | 7 | 13 | 28 | 21 | 10 | 79 |
| **Tech and Engineering** | | | | | | |
| 18 | 3 | 5 | 23 | 26 | 22 | 79 |
| 19 | 3 | 5 | 21 | 32 | 18 | 79 |
| 20 | 5 | 8 | 18 | 30 | 18 | 79 |
| 21 | 4 | 6 | 19 | 30 | 20 | 79 |
| 22 | 3 | 6 | 19 | 26 | 25 | 79 |
| 23 | 7 | 12 | 21 | 23 | 16 | 79 |
| 24 | 3 | 6 | 21 | 27 | 22 | 79 |
| 25 | 2 | 10 | 22 | 26 | 19 | 79 |
| 26 | 4 | 14 | 28 | 21 | 12 | 79 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Female Students** | | | | | | |
| Math | | | | | | |
| 1 | 70 | 68 | 42 | 36 | 16 | 2.936708861 |
| 2 | 5 | 18 | 54 | 100 | 110 | 3.632911392 |
| 3 | 2 | 14 | 57 | 140 | 14 | 2.873417722 |
| 4 | 2 | 14 | 48 | 136 | 100 | 3.797468354 |
| 5 | 40 | 20 | 42 | 38 | 19 | 2.012658228 |
| 6 | 2 | 10 | 57 | 128 | 105 | 3.82278481 |
| 7 | 4 | 18 | 75 | 96 | 85 | 3.518987342 |
| 8 | 6 | 22 | 57 | 92 | 100 | 3.506329114 |
| Science | | | | | | |
| 9 | 4 | 28 | 69 | 100 | 65 | 3.367088608 |
| 10 | 5 | 22 | 75 | 88 | 80 | 3.417721519 |
| 11 | 7 | 14 | 63 | 112 | 80 | 3.493670886 |
| 12 | 4 | 14 | 48 | 144 | 80 | 3.670886076 |
| 13 | 4 | 12 | 45 | 120 | 120 | 3.810126582 |
| 14 | 3 | 14 | 66 | 124 | 80 | 3.632911392 |
| 15 | 3 | 10 | 72 | 108 | 100 | 3.708860759 |
| 16 | 20 | 40 | 75 | 26 | 15 | 2.227848101 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 17 | 7 | 26 | 84 | 84 | 50 | 3.17721519 |
| Tech and Engineering | | | | | | |
| 18 | 3 | 10 | 69 | 104 | 110 | 3.746835443 |
| 19 | 3 | 10 | 63 | 128 | 90 | 3.721518987 |
| 20 | 5 | 16 | 54 | 120 | 90 | 3.607594937 |
| 21 | 4 | 12 | 57 | 120 | 100 | 3.708860759 |
| 22 | 3 | 12 | 57 | 104 | 125 | 3.810126582 |
| 23 | 7 | 24 | 63 | 92 | 80 | 3.367088608 |
| 24 | 3 | 12 | 63 | 108 | 110 | 3.746835443 |
| 25 | 2 | 20 | 66 | 104 | 95 | 3.632911392 |
| 26 | 4 | 28 | 84 | 84 | 60 | 3.291139241 |

Appendix 2.9 Result of Japanese students` career interests

Male Students

| No | Question | Not at all interested | Not so interested | Interested | Very interested |
|---|---|---|---|---|---|
| 1 | Physics: is the studyof basic laws governing he motion, energy, structure, and interactions of matter. This can include studying the nature of the universe. *(aviation engineer, alternative energy technician, lab technician, physicist, astronomer)* | 10 | 19 | 31 | 11 |
| 2 | Environmental work: involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling. *(pollution control analyst, environmental engineer or scientist, erosion control specialist, energy systems engineer and maintenance technicican)* | 17 | 37 | 21 | 6 |
| 3 | Biology and Zoology: involves the study of living organism (such as plants and animals) and the processes of life. This includes working with farm animals and in areas like nutrition and breeding. *(biologycal technician, biological scientist, plant breeder, crop lab technician, animal scientist, geneticist, zoologist)* | 17 | 33 | 22 | 9 |
| 4 | Veterinary work: involves the science of preventing or treating disease of animals *(veterinary assistant, veterinarian, livestock producer, animal caretaker)* | 25 | 34 | 19 | 3 |
| 5 | Mathematics is the science of number and their operations. It involves computation, algorithms and theory used to solve problems and summarize data. *(accountant, applied mathematician, economist, financial analyst, mathematician, statistician, market researcher, stock market analyst)* | 13 | 26 | 35 | 7 |
| 6 | Medicine: involves maintaining health and preventing and treating disease. *(physician`s assistant, nurse, doctor, nutritionist, emergency medical technician, physical therapist, dentist)* | 20 | 24 | 19 | 18 |

| | | | | | |
|---|---|---|---|---|---|
| 7 | Earth Science: is study of earth, including the air, land and ocean. *(geologist, weather forecaster, archaeologist, geoscientist)* | 21 | 29 | 23 | 8 |
| 8 | Computer Science: consist of the development and testing of computer systems, designing new programs and helping others to use computers. *(computer support specialist, computer programmer, computer and network technician, gaming designer, computer software engineer, information technology specialist)* | 2 | 20 | 38 | 21 |
| 9 | Medical Science: involves researching human disease and working to find new solution to human health problems. *(clinical laboratory technologist, medical scientist, biomedical engineer, epidemologist, pharmacologist)* | 22 | 23 | 21 | 15 |
| 10 | Chemistry: use amth and experiments to search for new chemicals, and to study the structure of matter and how it behaves. *(chemical technician, chemist, chemical engineer)* | 14 | 24 | 29 | 14 |
| 11 | Energy: involves the study and generation of power, such as heat or electricity. *(electrician, electrical engineer, heating, ventilation, nuclear enginer, systems engineer, alternative energy systems installer or technician)* | 10 | 23 | 32 | 16 |
| 12 | Engineeering: involves designing, testing, and manufacturing new products (like machines, bridges, building, and electronics) through the use mathematics, science, and computers. *(civil, industrial, agricultural, or mechanical engineers, welder, auto-mechanic, engineering technician, construction manager)* | 10 | 12 | 43 | 16 |

Female Students

| No | Question | Not at all interested | Not so interested | Interested | Very interested |
|---|---|---|---|---|---|
| 1 | Physics: is the studyof basic laws governing he motion, energy, structure, and interactions of matter. This can include studying the nature of the universe. *(aviation engineer, alternative energy technician, lab technician, physicist, astronomer)* | 14 | 30 | 24 | 15 |
| 2 | Environmental work: involves learning about physical and biological processes that govern nature and working to improve the environment. This includes finding and designing solutions to problems like pollution, reusing waste and recycling. *(pollution control analyst, environmental engineer or scientist, erosion control specialist, energy systems engineer and maintenance technicican)* | 20 | 29 | 15 | 13 |
| 3 | Biology and Zoology: involves the study of living organism (such as plants and animals) and the processes of life. This includes working with farm animals and in areas like nutrition and breeding. *(biologycal technician, biological scientist, plant breeder, crop lab technician, animal scientist, geneticist, zoologist)* | 14 | 16 | 28 | 19 |
| 4 | Veterinary work: involves the science of preventing or treating disease of animals *(veterinary assistant, veterinarian, livestock producer, animal caretaker)* | 14 | 16 | 25 | 19 |
| 5 | Mathematics is the science of number and their operations. It involves computation, algorithms and theory used to solve problems and summarize data. *(accountant, applied mathematician, economist, financial analyst, mathematician, statistician, market researcher, stock market analyst)* | 24 | 20 | 19 | 16 |
| 6 | Medicine: involves maintaining health and preventing and treating disease. *(physician`s assistant, nurse, doctor, nutritionist, emergency medical technician, physical therapist, dentist)* | 12 | 14 | 27 | 24 |

| | | | | | |
|---|---|---|---|---|---|
| 7 | Earth Science: is study of earth, including the air, land and ocean. *(geologist, weather forecaster, archaeologist, geoscientist)* | 18 | 22 | 24 | 13 |
| 8 | Computer Science: consist of the development and testing of computer systems, designing new programs and helping others to use computers. *(computer support specialist, computer programmer, computer and network technician, gaming designer, computer software engineer, information technology specialist)* | 18 | 27 | 15 | 17 |
| 9 | Medical Science: involves researching human disease and working to find new solution to human health problems. *(clinical laboratory technologist, medical scientist, biomedical engineer, epidemologist, pharmacologist)* | 13 | 18 | 25 | 18 |
| 10 | Chemistry: use amth and experiments to search for new chemicals, and to study the structure of matter and how it behaves. *(chemical technician, chemist, chemical engineer)* | 16 | 26 | 21 | 12 |
| 11 | Energy: involves the study and generation of power, such as heat or electricity. *(electrician, electrical engineer, heating, ventilation, nuclear enginer, systems engineer, alternative energy systems installer or technician)* | 21 | 28 | 17 | 9 |
| 12 | Engineeering: involves designing, testing, and manufacturing new products (like machines, bridges, building, and electronics) through the use mathematics, science, and computers. *(civil, industrial, agricultural, or mechanical engineers, welder, auto-mechanic, engineering technician, construction manager)* | 21 | 26 | 17 | 10 |