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学位論文の要旨（論文の内容の要旨）
Summary of the Dissertation (Summary of Dissertation Contents)

論　文　題　目
Dissertation title

STEM Education for the Crucial Thinking Skills in Indonesian Science Education

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Chapter 1 described the issues in this study through the background and problem statement. In this chapter, the national as well as international issues such as “the mean performance of Indonesian science education still that got lower than the Organization for Economic Co-operation and Development (OECD) average and more than half of Indonesian students do not possess adequate skills to compete in the labor market” got attention from researcher and become the basic problem of this study.

Chapter 2 dealt with the literature reviews in this study, theoretical framework, research objectives, research questions, the significance of this study, and composition of the dissertation. There were four literature review starting from skills gained through STEM education, STEM education, and STEM education among the countries. The second part was the theoretical framework of this study. This study adapted the STEM education framework from The Global STEM Alliance that aims to identify the best practices in science, technology, engineering, and mathematics. This framework has three essential areas: *Essential skills* (Crucial thinking skills)*, Instructional design of STEM education (*STEM content integration, real-world application, Scaffolding*),* and *Evidence of effectiveness* (Implementation of STEM education). All these three essential areas were utilized to figure out the important information/conditions that should be known before STEM education is fully implemented in Indonesia. The main focus of this study was to investigate the current condition of STEM education and how far STEM implementation can solve the current issues in case of skills’ development in Indonesia, especially in physics education for upper secondary level. This study has confirmed three essential areas based the theoretical framework divided into three stages with three sub-objectives: RO1: To specify the crucial thinking skills in science education through systematic literature review; RO2: To identify the instructional design of STEM education (STEM content integration, real-world application, and scaffolding) in Indonesia for secondary level; RO3: To determine the effect of STEM education on the crucial thinking skills for secondary level.

Chapter 3 explained overall methodology from three sub-objectives based on the theoretical framework and the relationships among three stages. The first stage aimed to find out the current crucial skills in science education that can be solved through the implementation of STEM education in Indonesia. In this stage, researcher has conducted a systematic literature review. 288 articles were eligible for full-text screening and at the end, only 78 articles that were ready to be reviewed. The second stage purposed to understand the current condition of instructional design in Indonesia. In total, 14 teachers were interviewed using six questions about the processes of teachers on knowing,

understanding, and implementing STEM education in their classes. The qualitative data analysis was used inductive approach and conducting traditionally with five processes: organizing data, identifying framework, sorting data, descriptive analysis arrangement, and finishing with the second order analysis. The third stage aimed to reveal the effectiveness of STEM education in solving the current crucial thinking skills in Indonesia. The total participants were 63 secondary level students in the grade X that were divided into two groups; STEM and traditional group. These two groups were taught by the same teacher and learned the same within the four times of teaching session. 24 items of two-tier multiple-choice from LCTSR are utilized to measure students' reasoning skills. For further analysis, researcher analyzed with SPSS program using Analysis Covariance and t-test analysis. The relationship among three stages can be considered through how these stages were supporting each other's to reveal three essential areas of STEM implementation Indonesia with considering teachers and students condition as the significant element in education. The findings from the first stage was utilized to identify the implementation of STEM education in Indonesia, the second stage's findings were utilized to reveal the instructional design of STEM education in Indonesia from teachers' perspective, and the last findings were revealed the effect of STEM education in Indonesia through applying the first and the second stage finding and participant.

Chapter 4 explained the details of the first stage "essential skills (The crucial thinking skills)" of the study through methodology and the result a systematic literature review. This data collection aimed to find out the most crucial thinking skills that should be developed in the students' cognition domain, particularly among science process skills, critical thinking skills and reasoning skills that were included to the list of essential skills in STEM education. Further, the relationships of these three skills were divided into five groups based on Piaget's theory: (1) SPS group, (2) combination between SPS and RS, (3) combination among SPS, RS, and CTS, (4) combination between RS and CTS, (5) CTS group. Then, this systematic review identified, selected, synthesized, and appraised previous studies in skills development that meet prespecified inclusion criteria. Based on the data analysis, the first crucial skills came from SPS group including defining operational variables skill and measuring. The second is crucial skills between SPS and RS including Identification & controlling variable, Formulating hypothesis, Experimental design, Conducting Experiment. The third is crucial skills among SPS, RS, and CTS that consisted of Interpreting data, Inference, and Analysis skills. The fourth crucial skill exists in the group combination between RS and CTS consisted of Simple explanation (conservation reasoning/EI), Explanation, Evaluation. In conclusion, most of the crucial thinking skills in science education were covered in the first, second, the third, and the fourth group and narrowed down to the reasoning skills domain only.

Chapter 5 employed phenomenological research in order to understand teacher's perceptions related to their understanding and experiences of STEM education in Indonesia through preconditions "STEM professional development program". This was related to *Instructional Design:* the second essential area in the STEM education framework that consisted of three points (STEM content integration, real-world application, and scaffolding). This stage was conducted purposive sampling from 38 sub-districts in Pangkep to explore the diversity and discover comprehensive data. Researcher has conducted semi-structured interview for five new teachers and nine experienced teachers with six questions. All teachers revealed that STEM education does not exist in the university level in Indonesia for the last 30 years based on their teaching experience. Currently, STEM education was adapted by the government and delivered by supervisors through MGMP meeting. Teachers realized that STEM education is interesting; provides hands-on activities; the most updated learning process. Teachers also confirmed a huge advantages of STEM Education. Otherwise, government and all facilitators in education, including teachers, must give more awareness in supporting the capabilities to prepare STEM implementation in the schools. Some challenges and limitations of STEM education in Indonesia were revealed by the teachers. In conclusion, all these findings revealed teachers' confirmation about STEM content that should be presented as interdisciplinary approach and embedded in or related to real-world scenarios. However, the education materials in Indonesia did not include enough guidance for teachers and/or embedded student support to implement STEM education in the school and other challenges might be appear during the implementation.

Chapter 6 figured out how the implementation of STEM education was affected to the crucial

thinking skill in Indonesian's science education. This was the last essential area of STEM education framework. In this stage, the total participants were 63 secondary level students in the grade X that are divided into two groups; STEM and traditional group. Researcher used 24 items of two-tier multiple-choice from LCTSR. This test can be utilized to assess students' scientific reasoning skills in six domains: conservation laws, proportional reasoning, control variables probabilistic reasoning, correlation reasoning, and Hypothetical-deductive reasoning. These skills were found also as the most crucial skills in science education in chapter 4. When comparing the subskills' mean score between traditional and STEM group, most of the subskills do not have differences even the result of ANCOVA shows the significant value in the effect of STEM education on crucial thinking skills. STEM education can support the crucial thinking skills only for hypothetical-deductive thinking skill. It showed through the improvement of mean score and a statistically significant difference between pre- and post-test value of this skill in the STEM group. A lot of factors revealed as the cause the findings such as teachers' understanding on STEM education and also the STEM educational design in this study that mostly focused on the experiment part.

Chapter 7 elaborated the overall conclusions, the implications, the limitations and the recommendations of this study based on the findings in chapter 4, 5, and 6. Stage 1 and stage 2 resulted in the current conditions of STEM education in Indonesia. They were confirmed through specific crucial thinking skills and teachers' perception on the instructional design of STEM education. Although stage 3 failed to support the effectiveness of STEM education to solve all crucial thinking skills in Indonesia. However, the mean score in STEM group showed improvement on hypothetical-deductive thinking skills with the significant difference on the score between pre- and post-test. Preparations need to be made and the challenges need to be addressed before the official curriculum from the government is fully implemented.