Meta-Analysis of Researches of STEAM with Coding Education – in Korea

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Abstract. We thought that programs applied with programming (coding) and creative/convergence education (STEAM) which are representative educational trends in the 4th industrial revolution era, are very useful strategy for improving the problem solving capabilities and creativeness. We need well-defined process for developing the IT-based STEAM program and well-defined evaluation criteria to verify the program. In this paper, we tried to analyze the previous related researches to identify the process and evaluation tools for IT-based STEAM program design.

1 Introduction

In the case of STEM that began in the US, it was aimed at enhancing students' academic achievement related to STEM subjects, inducing interest in related subjects, and encouraging female and ethnic minority students to enter science and engineering. In Korea, despite high academic achievement compared to other countries, STEM education was started to improve efficacy, confidence, and interest in relatively low science learning and to solve the phenomenon of students avoiding science and engineering [1]. The IT-centered STEAM education program has been proven to help students understand the principles of science and mathematics concepts through solving math and engineering problems through their own real-life experiences and knowledge utilization [2]. From 2015, coding education was enforced into the curriculum of elementary school. Then, form the 2018, coding education was involved as individual subject into middle school. Therefore, we thought that it was necessary what topics have been studied and what kinds of research areas were interested in IT-based STEAM education.

We select 16 thesis of master and ph.D degree from the riss.net which is the knowledge repository in Korea. We searched the paper with the keywords such as STEAM, coding, programming, and computational thinking. 19 papers were retrieved but 3 papers are not related with programming education so that we excludes them. In this paper, we surveyed 16 papers and analyzed them with 6 perspectives: (1) degree of school, (2) Subject of STEAM and tools of coding education, (3) Goals of the research, (4) strategies of research and course design, (5) Type of contents designed in each researches, (6) Evaluation methods. In Sect. 2, we described the background knowledge of STEAM and coding education. In Sect. 3, we summaries the research results of

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17 papers. We explains our results of meta-analysis in Sect. 4 and discuss the future research directions in Sect. 5.

2 Background Domain

2.1 STEAM Education

STEAM education has its roots in STEM education, which is at the heart of US education reform. STEM was used as an acronym for Science, Technology, Engineering, and Mathematics at the National Science Foundation (NSF). As it continuously appeared in education policies or education related issues, it has gained attention in science education all over the world. STEM education emphasizes the convergence and practice of STEM-related subjects in order to secure competitiveness in the age of globalization suitable for the changes and challenges of the 21st century [3]. In 2011, Korea's Ministry of Education, Science and Technology announced its plans to implement STEAM education which increases understanding, interest, and the potential of science and technology in elementary and secondary schools with the objective of realizing talent power by cultivating creative talents in science and technology in its work report (Ministry of Education, Science and Technology, 2011; Ministry of Education, Science and Technology, 2010). STEAM, which added arts (including the humanities in a broad sense) activities to the STEM education in the United States and the United Kingdom has become a term for convergence talent education in Korea. The Ministry of Education, Science and Technology (2011) defined STEAM an educational program that enhances students' interest and understanding of science and technology and fosters STEAM literacy and problem-solving skills based on science and technology. The Korea Foundation for the Advancement of Science and Creativity (a) defines STEAM as "education to develop students' interest and understanding of science and technology and to develop STEAM Literacy based on science and technology and real-life problem-solving skills."

2.2 Software Education

Computational thinking is the process of thinking about how to solve the various complex problems that humans face in real life, and it is a comprehensive thinking process to solve the problem-solving process effectively and efficiently through the powerful capabilities provided by computing devices. Computational thinking is emphasized as a core competency that a learner should have in the 21st century, where computing technology is the backbone of society and people need the ability to use it to solve complex problems. It is recognized as a fundamental skill such as reading, writing, and counting that everybody must know [4]. Computational thinking is the ability to correctly analyze a given problem into a logical, critical, or creative thinking problem and solve it. Based on the definition of computational thinking, it is composed of 5 computational components including algorithm, decomposition, generalization, abstraction, and evaluation [5].

3 Survey of Related Research

Kim [1] developed a STEAM education program that integrates science subjects and programming for elementary school students to develop a programming-oriented STEAM education program for enhancing computational thinking. We proposed and suggested digital storytelling, physical computing, and scientific writing as ideas to appropriately converge programming and STEAM's curriculum learning in a programming-oriented STEAM education program. Four STEAM educational programs were proposed and developed for elementary school students according to the objectives of various curriculum management, and their effects were verified by using test tools such as creativity, logical thinking ability, and interest in science.

In order to understand mathematics curriculum, Kim [6] developed a SW Convergence Mathematics Instruction Program based on computing thinking. SW Convergence Mathematics Instruction was defined as a program that allows students to think creatively and learn on their own to solve problems efficiently through computational principles and learned computing technologies when mathematical problems are given. We analyzed how SW Convergence Mathematics Instruction affects attitude, mathematical creativity, mathematical problem-solving ability of elementary and middle school students.

Kim [7] developed STEAM teaching and learning materials for mathematically gifted students using random numbers and physical computing, analyzed the effects of the developed data on students' STEAM core competency improvement, and confirmed the suitability of the developed teaching and learning materials. Based on the development criteria of STEAM teaching and learning materials, development direction and learning goals were set up and 20-period teaching and learning materials for middle school mathematic gifted students were developed. In order to verify the validity of the developed gifted teaching and learning materials for mathematics, we observed participation in the class situation and measured the change using the STEAM core competency evaluation framework. In addition, we examined the changes of learners through pre and post tests by using convergence problem solving ability tests and future talent competency tests.

Yu [8] implemented programming based experiential activities in consideration of developmental stage and characteristics of elementary students. Lego WEDO robots were selected as an educational tool that not only motivates and attract students' interests but that is also easily manipulated. A STEAM program using Lego WEDO was developed and applied to two 6th grade classes. The effect of participant learners on computing thinking ability was analyzed. After applying 13 periods of STEAM programs, the pre and post computational thinking scores were compared and levels of satisfaction were surveyed. The computational thinking ability evaluation was carried out with self-developed items that were reviewed by experts in terms of performance and analysis, algorithms and codes, generalization, structuring, and data analysis.

Although the most effective education is algorithm and programming education for the improvement of creative problem solving, Lee [9] suggests that the development of teaching and learning methods for programming education is very scarce and relies on traditional methods. STEAM-based education approaches from the integrated

viewpoint of how it relates to various subjects in one problem centering on real life problems. STEAM-based education can be a teaching and learning strategy to improve creative problem-solving ability. A STEAM based robot programming educational process was developed and applied to secondary students gifted in informatics. STEAM learning was compared with disciplinary robot programming lessons focused on acquiring concepts and the effects on creative problem-solving abilities were inspected.

Yoo [10] developed the STEAM-based learning materials for robot use for creativity enhancement for elementary gifted students. Through studies that verify the effects of applying this, we selected the robot-based learning subject suitable for elementary school gifted students and designed the lesson to achieve the learning goal. The effects of creativity were inspected.

Han [11] argued that SW Convergence Education for increasing creativity, communication ability, consideration, conversion ability in students must be implemented, and suggested a SW coding-based convergence program for elementary students gifted in science. After applying this to elementary students gifted in mathematics/sciences, the validity was verified through the effectiveness test.

Lee [12] developed and applied middle school mathematics statistics unit and Python Programming Convergence Instructions (STEAM) according to the contents system and achievement standard of the information department and mathematics department The problem-solving ability, the programming interest, and the pre-test and post-test of mathematical interest were examined to verify the effects of the statistical-python fusion class on problem solving ability, programming interest, and interest in mathematics.

Lee [13] developed a STEAM-based education program that can be applied in the field by combining the content of science subjects with scratch that can be easily accessed by learners. The effects of STEAM-based education programs using scratch on the creativity and the positive characteristics related to science of elementary school students were verified.

Hong [14] developed SW convergence education program using scratch that can be applied for a long time and verified how ICT literacy and SW awareness of elementary school students are affected.

Sung [15] practiced intelligent robot-driven programming directly and claimed that creative robots can be trained to adapt to the student's competence, understand and apply algorithms, and naturally acquire logical thinking and creativity. It is proved that the students become more interested in learning with their sense of accomplishment and self-confidence that they can feel when they operate correctly according to the control program they designed with the robot they made. For this purpose, a program was designed to improve storytelling ability by designing and creating various structures using frames and rivets with Tami, an intelligent educational robot consisting of convergence contents of science, technology, engineering, art and mathematics.

In order to increase the interest of mathematics, Kim [16] developed a STEAM-based mathematics learning program using scratch, focusing on mathematics. After

analyzing contents of mathematics learning contents and STEAM, we developed a mathematical learning program using scratch by applying a model of convergence learning. The developed program was applied to students in the first year of high school to verify the effect on high school students' interest in mathematics.

Shin [17] developed a creative STEAM education program using scratches for use in elementary schools and examined and verified the changes in creativity and learner response as applied to actual school sites. The state of elementary school students was classified into cognitive, affective, and behavioral domains. The most difficult units were identified through questionnaires and the selected magnetic field unit was classified into STEAM elements.

Na [18] developed the STEAM program using unplugged computing techniques on the subject of social studies subjects and applied it to elementary schools to verify the improvement of creative problem-solving ability.

Jung [19] developed and applied the STEAM education program in the arts field to enhance creativity. Since the arts subjects such as Korean language, music, and art are the subjects preferred by female students, the STEAM program proved that female students brought a change in their attitudes toward computers. It is significant that the existing STEAM education program was developed based on science and mathematics, while the STEAM education program centered on the arts area was developed and applied.

4 Meta-Analysis of Related Researches

In Korea, teachers for elementary school are graduated from National university of Education. To improve the problem solving capabilities and computational thinking, coding education was involved in elementary curriculum from 2015 in Korea. 65% papers (11 papers) were the results for elementary schools. Just 1 papers was written with the experimental results with high school students. The subject of STEAM with coding were science, mathematics, art, social studies, and Korean Language (Table 1).

Table 1. Subjects of STEAM and coding education

	Science	Math	Painting	Social studies	Music	Ethics	Korean language
# of researches	6	5	4	2	1	1	1
Ratio (%)	37.5	31.3	25.0	12.5	6.3	6.3	6.3

The tools of STEAM with coding were scratch, unplugged, Lego-wedo, Physical computing, Robot programming, and Python. The ratio of Scratch was highest but various tools were adopted for researches.

The goals of many researches were to improve the interests and creativity of each subject (Table 2). Some researches tried to improve the general creativity and problem solving capabilities. Not many researches considered of the computational thinking.

Table 2. Analysis of research goals

	Outcomes & creativity of subject	Creativity	Problem-solving	Computational thinking	Self-effectiveness
# of researches	6	7	4	2	1
Ratio (%)	37.5	43.8	25.0	12.5	6.3

Almost researches designed the course of 14 h and more. It means that many researches was designed for after-school activities and the some part of regular class. 2 researches suggested the course design for very long courses of 36 h. These 2 researches were designed for regular class in elementary school. Just 5 researches applied the instructional systems design (ISD) framework and the other researches applied just their own design strategy. Just 3 researches were evaluated their studies by own questionnaire or evaluation tools. The other researches were evaluated with well-defined evaluation tools. The most popular evaluation tools were Torrance's creativity evaluation tools (A type) and simplified version for creative problem-solving capability checklist introduced by Korean Educational Development Institute. The Aiken Attitude to Mathematics Scales was used to evaluate the improvement of interest and creativeness in Math and science subject. All researches provided syllabus for suggested program. Some researches provided detail syllabus and course materials.

5 Discussions

Convergent programs with programming (coding) and STEAM are very powerful and useful paradigm for creative/convergence education. In Korea, elementary and secondary schools have tries to implement STEAM education for increasing the understanding, interest, and the potential of science and technology. Also coding education was embedded for improving the problem-solving capability. Actually, coding education might be powerful tool for engineering in STEAM and also practical tool for STEAM education. In this paper, we tried to analyze the trends of IT-based (coding) STEAM education researches in Korea since we tried to develop the program for high school students. After coding education was involved as regular course in elementary schools, many researches related IT-based STEAM education was suggested. So far, not many researches are launched for high schools. Also, math and science were the major subjects for convergence with coding since these subjects are considered as critical subject for creativeness. There are not many researches about art including language education and problem-based learning. From the analysis of related research, we suggested further researches appropriate instructional systems design process and strategies and more verified evaluation framework for various objectives of program.

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