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RESEARCH TRENDS AND ISSUES INCLUDING COMPUTATIONAL THINKING IN SCIENCE EDUCATION AND MATHEMATICS EDUCATION IN THE REPUBLIC OF KOREA

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Abstract. *Software (SW) is one of the key technologies in modern society, and its importance is receiving the attention of the educational community. In addition, Computational Thinking (CT) has been studied in fields of various education such as computer science, science, mathematics, and technology. The prominence of computer science education has increased in K-12 South Korean schools with the effect of the 2015 Revised National Curriculum and the National Plan for Activating Software Education. In addition, there are active efforts to include CT in science, technology, and mathematics classrooms. Therefore, this study aims to review prior studies on CT in science and mathematics education. The results of this study are as follows: 1) CT in science and mathematics education has a different conceptual approach than CT in computer education. Science education is mostly about problem-solving activities using computers, and mathematics education mostly utilizes the 'abstraction' related approach. 2) The key to improving CT in both subjects is to implement practical experience in science and mathematics education. Variables of interest in prior studies were scientific and mathematical problem-solving skills, the attitude of subjects, and creativity. 3) CT education in science and mathematics education has used a convergence education approach (STEAM education).*

Keywords: *computational thinking, mathematics education, research trend analysis, science education*

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Introduction

Computational Thinking (CT) is an essential competency in the 21st century's intelligent information-oriented society. There is rapidly increasing interest in software-based industries such as the Internet of Things, big data, 5G, and artificial intelligence, which are core technologies for the 4th Industrial Revolution. Accordingly, new attempts have been made around the world in education to nurture people in related competencies (Shahroom & Hussin, 2018). In particular, software (SW) has been highlighted. While previously education systems implemented information and communication technology (ICT) education that promotes computerization or information technology literacy, most of them are currently shifting to emphasize software, programming, coding, etc. (Korea Education and Research Information Service, 2013).

In line with this trend in South Korea, the Ministry of Education (2016) announced the "Basic Plan for Activating Software Education." In addition, the Ministry of Education of South Korea organized the curriculum for "the 2015 revised curriculum (technology/home economics)/information subject," and made SW education required in elementary and middle schools since 2018. The 2015 revised curriculum recommends that six core competencies for information be promoted in school education. Among these, "knowledge information processing ability for rational problem solving" further supports the necessity of information subject education (Ministry of Education, 2015).

South Korea is making efforts to nurture creative convergence talents by selecting a competency-based curriculum model rather than a subject-centered curriculum (Ministry of Education, 2015). However, in recent SW-related school policies (such as AI education leading schools), other subjects were excluded and only information teachers were allowed to take charge (Ministry of Science and Technology Information and Communication, 2021). This view is contrary to the direction from the Ministry of Education, which aims for convergence education, and reflects an immature policy management method.

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Recently, the educational field is making efforts to improve Information Technology (IT) and SW-related competencies (like computational thinking). The UK greatly increased the number of required computer-related courses, and in some places, such as France, software-related contents were incorporated into mathematics and technology subjects (Lee, 2020). As such, most developed countries (USA, Canada, UK, Finland, etc.) are promoting these IT and SW-related competencies by including them in national-level convergence education (like science, technology, engineering, mathematics: STEM) (Kwon et al., 2020).

Convergence education in South Korea is called STEAM (Science, Technology, Engineering, Arts, Mathematics) education. In line with this global trend, Korea is also promoting convergence education and SW education. There is research literature that analyzes the trends in information subject research and studies that analyze the current status of convergence education by subject, but there is insufficient research dealing with how IT or SW-related competencies are being studied in convergence education (Kwon et al., 2020; Min & Shim, 2021))

In the above context, the purpose of this study was to understand how computational thinking was integrated into convergence education. For this, considering South Korea's competency-based curriculum model, this study limited the research variable to CT, and the subjects to science education and mathematics education, which are classified as the primary subjects. After that, research trends related to CT were classified into the two subjects, and how CT is applied in each subject was investigated and analyzed. The research questions are as follows:

- • How is computational thinking defined in science and mathematics education?
- • How is computational thinking applied in science and mathematics education?
- • What is the difference between the approaches to computational thinking in science education and mathematics education?

Theoretical Background

Computational Thinking

The term computational thinking was first used by Papert (1980) in his book *Mindstorms*, and quickly spread through a study entitled "Computational Thinking" by Wing (2006). In South Korea, it is used in various forms such as computational thinking, computer scientific thinking, and computational thinking. Since the term computing thinking was used in the 2015 revised curriculum, it has been referred to as computational thinking in South Korea (MOE, 2015).

Computational thinking has received a lot of attention and research over the past few years, Currently, there is still no consensus on the components and definitions (Brenna & Resnick, 2012). A wide variety of scholars have defined the operational definition of computational thinking, and the definitions differ as shown in Table 1. However, Wing's (2006) study is frequently cited for its definition of CT and its components. Wing (2006) gave the operational definition of computational thinking as "integrative problem-solving thinking following the fundamental concept of computer science."

Table 1
Definition of CT

Researcher	**Computational Thinking Definition**
Wing (2006)	Convergent problem-solving thinking following the fundamental concept of computer science
ISTE & CSTA (2011)	A problem-solving process that includes logical organization and analysis of data, representation of data through abstraction, automating solutions through algorithmic thinking, defining and implementing possible solutions, and generalizing solutions to other problems
Barr & Stephenson (2011)	An approach to solving a problem in a computer-implementable way and a problem-solving methodology
Ministry of Education (2015b)	The ability to understand real life and various academic problems using the basic concepts and principles of computer science and computing systems, and to creatively implement and apply solutions

Studies on the components of CT have also been conducted. Table 2 summarizes representative existing studies on CT components. The CT components presented by the International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA) are defined by educators (Barr et al., 2011). Furthermore,

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there is a CT component created for evaluation by Brennan and Resnick (2012) at the MIT Media Lab. Brennan and Resnick's study evaluates CT based on Scratch, an educational programming language (EPL), because Scratch was developed at the MIT Media Lab. In addition, there is also the definition of the Google Computer Science (CS) education program and the definition of the Ministry of Education, which are frequently cited in Korea.

Computational Thinking in Curriculum

Wing (2006) said that computational thinking is not a computer's thinking, but a person's way of thinking that follows the computer's method, and emphasized that it is a necessary ability for everyone. Therefore, computational thinking education should pursue a convergence approach, but the current computational thinking education in South Korea is being promoted centered on information subjects. Moreover, computational thinking in Korean is translated as computing thinking. This leads to a misunderstanding of "computational" (regardless of using a computer) to mean "computing" (using a computer) (Chang, 2017).

Nevertheless, studies to apply computational thinking to the curriculum are being actively conducted in science education and mathematics education. In science education, research is being carried out to link to the curriculum by focusing on problem solving and inquiry, while using words as they are (Park & Green, 2019; Kang & Kim, 2020). Mathematics researchers argue that computational thinking is different from computing thinking. Therefore, they said that the Korean expression of computing thinking that emphasizes the use of computers is not correct. For this reason, they prefer the term computational thinking (Ahn, 2014; Chang, 2107; Kim, 2019).

Table 2
CT Components of Previous Studies

Researcher (Year)	Wing (2006)	ISTE & CSTA (2011)	Brennan & Resnick (2012) in MIT Media Lab	Google (2016) by Stephenson	Ministry of Education (2015)
CT Components	·Abstraction ·Algorithms ·Automation ·Problem Decomposition ·Generalization	·Formulating ·Organizing ·Analyzing ·Modelling ·Abstractions ·Algorithmic Thinking ·Automating ·Efficiency ·Generalizing ·Transferring	·Concept: Sequences, Loops, Events, Parallelism, Conditionals, Operators, Data ·Practice: Being Incremental and Iterative, Testing and Debugging, Reusing and Remixing, Abstracting and Modularizing ·Perspective: Expressing, Connecting, Questioning	·Abstraction, ·Algorithms & Procedures, Automation ·Data Collection & Analysis ·Data Representation ·Modeling & Simulation, ·Parallelization & Problem Decomposition	·Collecting data ·Data analysis ·Structured ·Abstraction: Decomposition, Modeling, Algorithms ·Automation: Coding, Simulation ·Generalization

Research Methodology

Data Collection and Pre-processing

In order to understand the current status of research related to CT in mathematics and science education domestic academic journals and theses were surveyed from 2013 to 2021 (2nd quarter). In Research Information Sharing Service (RISS) and Korean Studies Information Service System (KISS), science education was searched for computational thinking, science, science education, and mathematics education was searched for computational

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thinking, mathematics, and mathematics education. Researchers developed an analytical framework for the literature review to identify and select research papers related to CT in science and mathematics education. After that, researchers systematically analyzed related publications in a wide range of journals to obtain a comprehensive overview of the current status and trends of research in science and mathematics education related to CT.

Statistical Analysis

As a result of the search, 1338 journals and degree-related papers were found in science education, and 703 journals and degree-related papers in mathematics education were searched for a total of 2041 studies. Among 2041 studies, a total of 59 studies were selected as research subjects as a result of screening duplicates, conferences, and irrelevant studies. Among 59 studies, 24 were science education and 35 were mathematics education. As shown in Figure 1, 59 studies selected through literature search were categorized by year of publication, publisher, publication status, academic classification (science, mathematics), research method 1 (conceptual, development, implementation), and research method 2 (quantitative, qualitative, mixed), implementation type (regular subject, creative experience activity, free semester, gifted education, etc.), and target class (elementary, middle, high school, university, pre-service teacher, teacher).

Figure 1
Framework for Analysis

Analysis Categories	Detail Categories
Publication Type	☐ Peer Review Journal Papers (KCI Indexed) ☐ Degree related Papers (Thesis or Dissertation)
Academic Classification	☐ Math Education ☐ Science Education
Research Methods	☐ Conceptual (theoretical) ☐ Survey ☐ Development (Program, Curriculum) ☐ Implementation (Quasi-experiment, Case Study)
Research Design	☐ Qualitative ☐ Quantitative ☐ Mixed-Methods
Implementation Types (For Implementation Study Only)	☐ Regular Subject ☐ Creative Experience Activity ☐ Free Semester/Year ☐ Gifted Education ☐ Others
Target Class	☐ Elementary ☐ Middle ☐ High ☐ Others

Research Results

Research Trends of Computational Thinking in Science and Mathematics Education

Year of Publication

In the analysis, the number of publications each year increased rapidly after 2018, when SW education became required as shown in Table 3.

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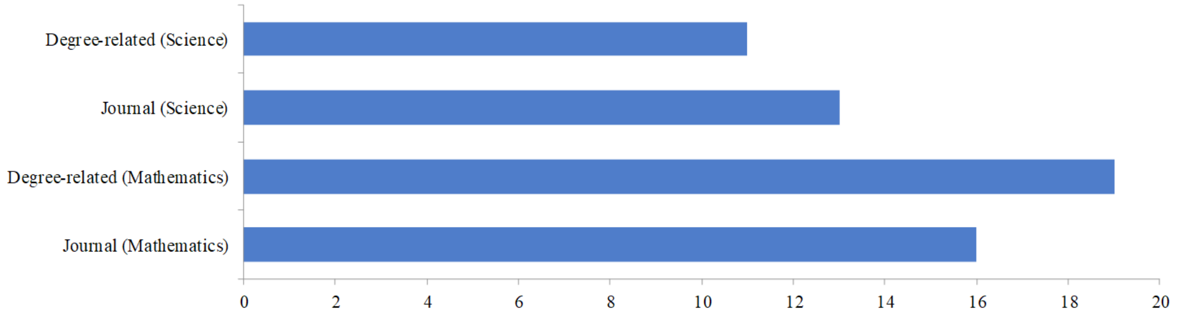
Table 3
Definition on CT

Year	Raw	Percentage (%)
2011	1	1.7
2013	1	1.7
2014	3	5.1
2015	4	6.8
2016	3	5.1
2017	3	5.1
2018	13	22.0
2019	15	25.4
2020	14	23.7
2021 (until 2nd quarter)	2	3.4

Publication Types

As shown in Figure 2, among 59 studies, 29 journals and 30 degree-related papers were published. Of the 30 theses, 28 were master's level, and there were no doctoral theses in mathematics education, only in science education. There were 35 papers related to mathematics education, and 24 papers related to science education, and mathematics education was relatively high.

Figure 2
Publication Types



Research Methods

As for the research type, 11 were technical (conceptual) studies, 3 were in science education, and 8 were in mathematics education, suggesting mathematics education is widely studied. Program development studies included 4 in science education and 8 in mathematics education. There were a total of 32 implementation studies, 15 in science education and 17 in mathematics education. There were 4 research studies. Among the types of research, implementation research was the most common, and the program was developed, and the effect on students was analyzed.

Additionally, among the total of 32 implementation studies, 7 were quantitative, 5 were qualitative, and 20 were mixed. Except for those that were not clearly defined in terms of implementation, there were 6 regular

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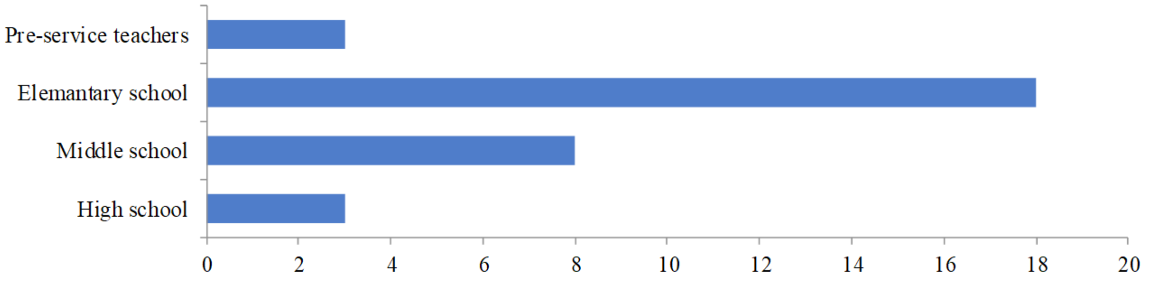
subjects, 6 gifted education, 4 free semesters, and 12 others. In the case of others, various creative experience activities and other special programs were implemented.

School Class

As shown in Figure 3, among the 32 experimental studies in total, 3 high school students, 8 junior high schools, 18 elementary schools, and 3 pre-service teachers were studied in experimental studies.

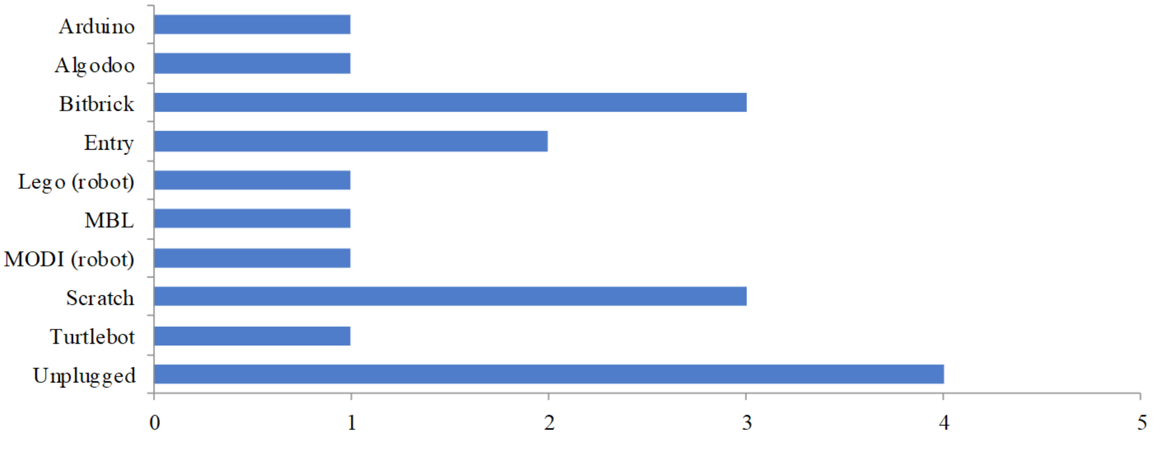
Figure 3
School Class for Participants



Teaching and Learning Tools

As shown in Figure 4, using unplugged activities was the most common teaching and learning tool in science education, but considering that Entry is a program similar to Scratch, it can be said that Education Programming Language (EPL) activities were the most common.

Figure 4
Teaching and Learning Tools – Science



Other than that, various physical computing tools such as Bitbrick, Arduino, Lego, MODI, and Turtlebot were used. In addition, Microcomputer Based Laboratory (MBL) and Algodoo (physical experiment program) linked to scientific experiments were also used once.

This study counted the frequency for each tool if two or more tools were used in one study. However, the case of requesting C language like Arduino was not counted in the number of C language.

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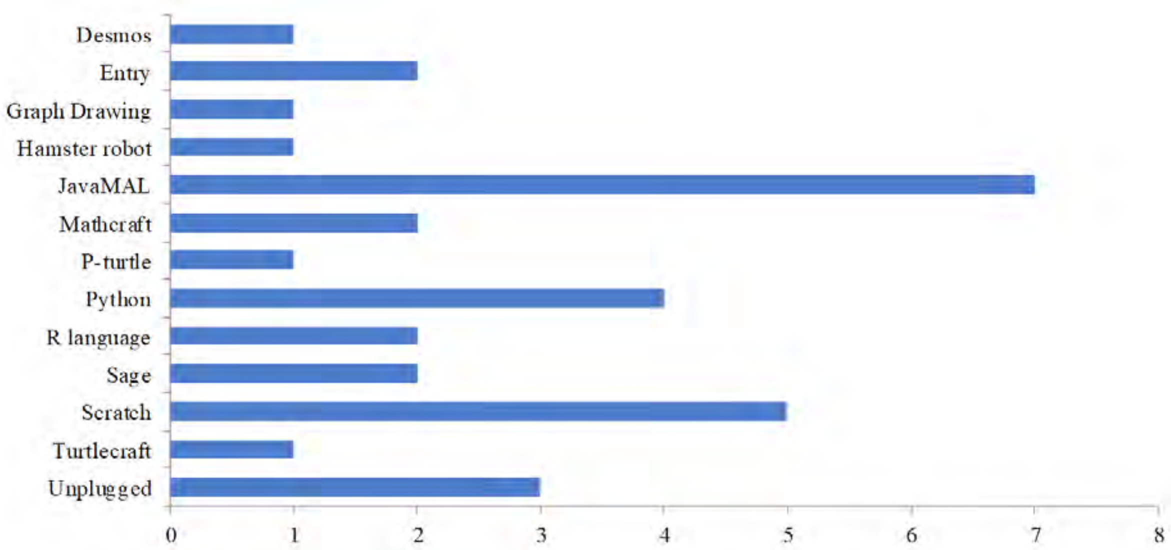
Figure 5 shows the use of teaching and learning tools in mathematics education. The javaMAL (block stacking) used at Seoul National University's Gifted Learning Center is the most used, followed by Scratch (developed by M.I.T Media Lab), Python, and Unplugged. Additionally, block stacking tools similar to javaMAL are used, such as Turtlecraft and Mathcraft. An entry similar to Scratch was also used as the EPL. The rest had graph drawing tools such as Sage, Graph Drawing and Desmos, and P-turtle (probability statistics program) and R language were used for probability statistics. As for the physical tool, the Hamster robot was used only once.

Figure 5
Teaching and Learning Tools – Mathematics



Although it is difficult to sort the variety of teaching and learning tools, EPL was the most used as a teaching and learning tool in science and mathematics education as a whole. Relatively, science education tried to use teaching and learning tools capable of physical computing (bitbrick, Arduino, etc.) rather than mathematics education. These lead to examples of science curricula that use physical computing tools to solve scientific problems. For mathematics education, the physical form of the hamster robot was used only once. On the other hand, mathematics education uses tools that can visualize mathematical concepts, such as block stacking (javaMAL, Turtlecraft, Mathcraft), P-turtle, sage, and Graph Drawing. In addition, various tools were applied to the curriculum such as algebra, geometry, probability, and statistics.

Issues of Computational Thinking in Science and Mathematics Education

Definition of Computational Thinking

Concept, development, and implementation research areas occupied most of science and mathematics education research, and the key issue among them was the definition of CT and its components. Conceptual studies discussed the operational definitions of CT, definitions of components, their significance in education, and methods of evaluation application (Ahn, 2014; Chang, 2017; Park & Hwang, 2017; Park, 2018). Furthermore, there is a discussion on the definition of clear CT not only in conceptual research but also in development and implementation research (Seo, 2019; Park & Green, 2020). Researchers in science and mathematics education have studied and applied CT in various ways to achieve the purpose of each subject. As a result of the analysis, researchers in science and mathematics education were looking at CT from four perspectives. First, CT that emphasizes the use of computers in computer science (CS), second, CT in science education, third, CT in mathematics education, and fourth, CT for integrated education.

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The first point of view accepts the CT of CS as it is. This perspective, citing CS research, approaches CT as a "problem-solving strategy or computer-based problem-solving strategy" during learning rather than pursuing scientific and mathematical competency. Most of the time, the focus was on the use of the computer. Therefore, it emphasizes the use of CT as a teaching and learning strategy in each subject rather than defining CT or pursuing CT competency. Kim (2018) designed a science class to apply technology through graph drawing using Desmos, and Ahn (2014) presented a class to apply CT through the activity of drawing graphs with a computer in mathematics education. In the study of Han and Kim (2019), they tried to develop a computer-based science education program by simultaneously measuring changes in CT and scientific attitude in an earth science education program using EPL.

The second is the view of CT in science. Most research in science education emphasizes CT as a problem-solving strategy. Based on the relatively recent study of Barr et al. (2011), the approach as a scientific problem-solving activity was the most common (Hwang, Mun & Park, 2016; Mo, 2018, Kim, 2019; Kim, M. & Kim, S., 2020). In science education, there was no big difference in the approach to CT. Apart from the different emphasis, the rest of the science education studies also defined CT as a scientific problem-solving method and linked it with science education.

The third is to look at CT from the point of view of mathematics education. There has not yet been a unified view of CT in mathematics education (Hickmott, Prieto-Rodriguez, & Holmes, 2018). For this reason, many studies on mathematics education related to CT have been on definitions (Chang, 2017; Choi, 2020; Kim, 2019; Shim & Park, 2019). Most studies in mathematics education consider CT as problem-solving thinking and abstraction as the core. In addition, it was emphasized that computing tools are not essential (Chang, 2017; Kim, 2019; Shin & Koh, 2019). Therefore, many studies of mathematics education are currently approaching CT education as a teaching and learning method to improve students' abstract competency.

Lastly, some look CT as linked to integrated education. This is similar to the second and third views, but emphasizes a wider range of convergence education rather than the performance of each curriculum. There have been many different types of research. Park and Green (2020) conducted a study on how to analyze CT elements in integrated education that includes science subjects. Park and Green (2019) viewed CT as a catalyst for integrated education in science education, and said that the problem-solving ability of CT helps science education linking integrated education. Kim (2019) confirmed the effectiveness of mathematics education in integrated education including CT. Kim (2018) measured the change in students' attitudes toward integrated education in statistical education using R language based on CT. As such, there have been various studies related to integrated education in both science and mathematics education.

CT measurement tool in South Korea

There are three main types of evaluation tools for CT in Korea. The first was a tool to directly evaluate the coding ability of CT using block coding, and the second was an evaluation of the creativity type that emphasized the cognitive thinking aspect of CT and excluded block coding. Lastly, the third was the measurement of CT through questionnaire items.

Although there are some differences in measurement tools, about 50% of domestic CT evaluation tools use the Scratch-based evaluation of Brennan and Resnick (Choi, 2019). In addition, although there is not much research, the evaluation tool officially provided by the Ministry of Education for SW education leading schools also uses Scratch or Entry-based block coding evaluation (Yang et al., 2018). In conclusion, considering that Entry is almost the same as Scratch, the use of block coding-based evaluation in tools for evaluating CT in Korea is very high. However, the evaluation based on block coding is almost impossible to evaluate without prior knowledge of block coding, and it can be criticized for approaching CT only with coding that requires the use of a computer. This evaluation method conflicts with Wing's (2006) claim that CT is not related to the use of computers and cannot be the correct evaluation method.

As a result of reviewing the literature on evaluation of CT, Kim's measuring tool (2014) was used the most among CT evaluation studies in Korea (Choi, 2019). Kim's tool also consists of Scratch-based CT evaluation items. The only feature of Kim's tool is that it discloses all test tools. Tools such as Moreno-Leon (Dr. Scratch), Beaver Challenge, and Choi's tool were frequently used after Kim's tool (Choi, 2019). The measurement of Moreno-Leon (2015) provides instant evaluation when the Scratch (block coding) file output is uploaded to the Dr. Scratch

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website. The website-based beaver challenge consists of items that even students without experience in block coding can solve, and is similar to general creativity problems. Choi (2014) is based on the evaluation of Brennan and Resnick (2012), and consists of questions to evaluate knowledge, performance, and attitude toward CT.

Major Variables in Science and Mathematics Education

There were a total of 25 studies that measured CT in 32 program implementation studies. Among them, few studies set only CT as a variable. Most of the studies set variables in a very diverse way to match the purpose of subject education. As described above, there have been few studies that have fully disclosed the CT measurement tool items. Therefore, it can be inferred that the tools used in computer education are difficult to apply to science and mathematics education as it is.

Most of the research related to science and mathematics education designated and analyzed various competencies as a variable pursued in each subject. In particular, attitudes toward science and mathematics learning, creativity, and problem-solving ability were outstanding. Researchers analyzed CT as well as scientific/mathematical attitudes, convergence educational learning attitudes, or academic achievement (Han & Kim 2019; Hwang, Mun & Park, 2016; Kim, 2018; Kim, D., 2019; Kim, Y., 2019; Sim & Park, 2019). Additionally, there were studies that measured problem-solving ability and creativity (Kim & Choi, 2019; Mo, 2018; So, 2016). In addition, there were a few studies that used programs related to CT but did not measure CT (Jeong, 2018; Sim & Park, 2019). Conversely, there have been studies that only measure CT (Hwang, Moon & Choi, 2020).

Discussion

Studies of information education show that CT can be learned in all subject areas regardless of the use of computers (Shin et al., 2016; Wing, 2006). Accordingly, studies on CT are active in other subjects as well. In particular, research studies were active in science and mathematics, which are STEM subjects. On the other hand, with the exception of information subjects, there were few studies in technology and engineering fields (Lee, 2019). Studies on science and mathematics education were not just computer-based, but involved systematic analysis, researching the cultivation of CT and its application in each subject.

By classifying and arranging a total of 59 research subjects, this study found that implementation research occupies the largest proportion with 32 subjects. In addition, most of the implementation studies included program development. If 12 program development studies were included, there were a total of 44 program development research topics. This study found that many research studies sought to develop programs or curricula related to CT.

In addition, it was possible to confirm that the selection of teaching and learning tools was different for each subject. As for the teaching and learning tools used in science education, the use of physical computing tools was the highest, except for block coding. The types vary greatly depending on the purpose of the study, but most used SBC or robot types. On the other hand, there was only one study using physical computing tools in mathematics education. There was a big difference in pursuing the purpose of each subject as described above. Science education actively used physical computing tools to develop scientific problem-solving ability. Mathematics education used a lot of tools to simulate or shape thinking. Accordingly, tools such as 3D block stacking and graph drawing were used. For this reason, compared to science education, the use of physical problem-solving tools was relatively small.

In addition, research on elementary education in the field of science and mathematics was the most active compared to other school levels. A possible explanation for this trend is that secondary education selects and requires different programs for each subject area in South Korea. On the other hand, it can be inferred that elementary education is an integrated degree, which is easily accessible in any subject. In elementary education research, most of the teaching and learning tools were EPL and unplugged. The high percentage of EPL and unplugged rates in the overall study was influenced by research on CT in primary education.

On the other hand, the key discussion among science and mathematics education studies related to CT was the understanding of CT focusing on subjects. As a result of the analysis, it was possible to broadly classify the four types of CT from the perspective of understanding. First, the view of accepting the definition of CS as it is; second, the view of science education that focuses on the subject; third, the view of mathematics education that focuses on the subject; and fourth, the view of integrated education.

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There are characteristics that should be recognized from these points of view. First, studies of CT in CS originally emphasized competency from a cognitive point of view, but there were many studies that simply emphasized the use of computers. Indeed, this view cites the definition, but does not apply it and just utilizes computers in science and mathematics classrooms. This maintained independence between variables when measuring other key variables besides CT. On the other hand, there were clear differences in the viewpoints of science and mathematics education. The point of approaching CT to realize the purpose of each subject was the same. In this process, science education studies approached CT as a tool to improve the efficiency of scientific problem solving, such as obtaining experimental data and solving problems using computers. Mathematics education studies compared the realm of CT with that of mathematics education, and redefined the elements of CT that should be pursued in mathematics education. The scholars who deal with mathematics education also emphasized the definition of the term "computational thinking" to center on thinking skills (like an abstraction) instead of the use of computers. This trend shows the same results as the systematic review conducted abroad (Nordby et al., 2022). Through these studies, science and mathematics education brought CT into each subject. Lastly, the perspective of integrated education took a more macroscopic approach than other viewpoints. Although there were various types of research, most emphasized convergence and integration rather than just the purpose of each subject. This perspective expected a synergistic effect of the subjects. The researchers conducted studies for various purposes, such as pioneering a new curriculum area and cultivating complex problem-solving skills.

On the other hand, research on science and mathematics education has also included a lot of studies on the evaluation of CT. Teaching and learning tools related to SW education in Korea are biased toward block coding and use Scratch and Entry in more than 70% of classes (Choi, 2019). The selection of teaching and learning tools affected the evaluation tools, and it was found that science and mathematics education also focused on Scratch-based evaluation. However, since the block coding method requires prior knowledge, it is impossible to evaluate it independently. Although Scratch can foster CT, it is important to remember that Scratch itself does not have to be evaluated when evaluating CT. Similarly, the absence of a CT evaluation tool was also pointed out as a problem in international studies (Waterman et al., 2020).

On the other hand, there were few studies in science and mathematics education that only used CT as a variable. Both subjects realized the purpose of the subject through methods such as evaluating the variables required in each subject with CT. In previous studies, each subject mainly set scientific and mathematical problem-solving skills, attitudes toward topics, and creativity as major variables of interest. As can be seen from the perspective of each subject or the analysis of teaching and learning tools, each subject mainly utilized the form of practical experience using CT, whether it was physical computing or visualization through software. Because of this, it was possible to observe practical characteristics as the main variables.

Conclusions and Implications

This study aimed to identify the trends of CT research conducted in science and mathematics education in Korea. Currently, there have been many studies on CT and convergence education in each field, but there have been few studies to analyze the trends of which and how much research is being conducted. Additionally, there were no studies comparing and analyzing CT studies in each field from the perspective of convergence education. This study would hold implications to other subjects (technology, engineering, etc.) as well as science and mathematics in the STEM field.

Research method analysis shows that mathematics is more active than science, and largely concentrated in program implementation research. Analysis by school level shows that elementary school students are more studied than middle school students. The analysis of teaching and learning tools showed that there are many block coding and physical computing tools. Through the analysis of these results, it was shown that the scientific approach relatively focused on problem-solving application, and the mathematics focused on the definition of CT in mathematics. In most studies, the same CT evaluation tools were used for the information subject.

Through this literature analysis, it was possible to know the differences between CT research conducted in science and mathematics. CT research was relatively active in mathematics education. CT has been mainly accepted as a means of problem-solving in science education. For this reason, CT studies in science education were relatively narrow compared to CT studies in mathematics education. On the other hand, CT research on

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science education found similarities with the research purpose of convergence education. Although the degree of emphasis was somewhat different, there was a common point of pursuing problem-solving skills through practical project learning. In this context, the approach of convergence education in each field is positive.

Unfortunately, in both fields, concrete studies on the effect of the curriculum applied with CT on students are lacking. In order to solve these problems, research from various perspectives is needed for the proper practice of CT education in science and mathematics education. In particular, in order to realize science and mathematics education, it is urgent to develop a CT evaluation tool for each field and to study the student effect.

Declaration of Interest

The authors declare no competing interest.

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