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A REVIEW OF COMPUTATIONAL THINKING: FOCUS ON SCIENCE EDUCATION[1]

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ABSTRACT

With the onset of the digital age, computational thinking skills have been included in our lives. Computational thinking skills are not limited to computers, but are integrated into every interdisciplinary field to maximize learning. Integration of computational thinking in science education facilitates the understanding of complex subjects that are difficult to understand. Computational thinking skills can be used in developing scientific solutions to problems encountered in daily life. In our research, in order to examine how the computational thinking skills included in science education are handled, a systematic review was conducted by analyzing a total of 31 studies that meet the inclusion and exclusion criteria in the "Springer", "Web of Science", "Ebscohost", "Eric", "Science Direct", "Science Direct", "Google scholar" databases, including the concept of computational thinking related to science education. According to the research findings, it is observed that the study group in the analyzed studies generally consists of teachers and K12 (secondary school) level students. In many studies conducted in this field, programming training is given to students with computer support. At the end of the training, students develop videos, simulations and models. Teachers, on the other hand, have been trained on how to integrate computational thinking into science education and application examples have been made. When the researches are examined, it is observed that science education, STEM, programming, coding, simulation, modelling, computational thinking are intertwined. One of the important findings of the research is that while there are science education studies in which computational thinking is added with pre-school teachers, there are no studies with pre-school students.

Keywords: Science education, science classrooms, computational thinking, systematic review

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INTRODUCTION

The digital age has begun with the introduction of the computer, which is a gateway to the world of our future. With this era, it is important to include computational thinking skills in our daily lives as a skill that we can use not only in the professions dealing with computers, but also in solving the problems we face in daily life. However, we should not think of computational thinking only as a programming skill. Because this thinking skill includes skills such as creative thinking and critical thinking. However, the fact that ISTE (International Society for Technology in Education, 2016) has added computational thinking to the standards that students should acquire makes us realize that "computational thinking" is a skill that everyone should have in the 21st century. One of the main reasons for this is that computational thinking is seen as a universal skill like reading, writing and basic mathematics (J. M. Wing & Stanzione, 2016). The "computational thinker" standard simply means that students develop and use strategies to solve and understand problems by harnessing the power of technological methods to test and improve solutions. Computational thinking also emphasizes skills such as creative thinking, algorithmic thinking, critical thinking and collaboration, which are known to be important in developing problem-solving skills (ISTE, 2016).

Computational thinking was first defined as a general term that refers to people's high-level thinking skills through software and calculations using computer systems (Papert, 1980). In the content of the defined statements, it is stated as the handling of possibilities in the evaluation process by using problem solving and data analysis skills (Papert, 1996). However, (J. Wing, 2008; J. M. Wing, 2006) added new concepts to the definition as the use of computational methods such as problem solving and understanding human behavior. In addition, (J. M. Wing, 2006) states that the arithmetic of formulating problems used in computer science should be used as a basic skill in understanding reading, writing, mathematics and natural sciences. According to the researchers, there is no common definition of computational thinking. The definitions in which the dimensions of computational thinking are handled differently are given in Table 1 below.

Table 1. Different Definitions of Computational Thinking

References	***Definitions of Computational Thinking***
(Costa et al., 2015; Grover & Pea, 2013)	There is no agreed definition.
(J. Wing, 2008; J. M. Wing, 2006)	Computational thinking includes different processes such as problem solving, critical thinking, abstraction, analytical and algorithmic thinking.
(Kazimoglu et al., 2012),	The five basic skills of computational thinking are "problem solving, algorithm building, error detection, simulation and socialization".
(CSTA & ISTE, 2011)	Computational thinking is a combination of creativity, algorithmic thinking, critical thinking, problem solving and collaboration.
(Kranov et al., 2010)	Critical thinking and problem solving are the two most widely accepted skills in the computational thinking literature.
(Kalelioğlu, 2018)	Abstraction, algorithmic thinking and problem solving are the 3 most recognized components.
(Weintrop et al., 2016)	• Collection, grouping, manipulation, analysis and presentation of information • Computer modeling and simulation • Computational problem solving practices: preparation of the problem via computer, effective solution. Determining the path, generating different solutions, summarizing, debugging the errors encountered in reaching the solution

Based on the different views of the scientists in Table 1, there are two different distinctions in the definitions. For example, (Weintrop et al., 2016) think that computational thinking will be developed depending on the computer, while (CSTA & ISTE, 2011), in its addition to higher level learning skills, considers computational thinking as a 21st century skill that should be used in daily life by adding algorithm, critical thinking, problem solving, collaboration to students' curricula.

According to (Yadav et al., 2018) computational thinking includes the following topics.

- Decomposition: Involves breaking down a complex task or problem into small solvable or feasible parts by looking at it from the big picture.
- Pattern matching: After large problems are broken down into smaller parts, similarities are matched. This is called pattern matching in computer language.
- Abstraction: The information that remains after separating the similar from the different in a problem or task.
- Algorithm: All the steps to be used in solving the problem or task are algorithms. There are detailed solution paths in the algorithm. Expressions such as "if/ else" used in computer programming language can be used in algorithm design.
- Evaluation: It is the evaluation of the result reached as a result of the steps used in the algorithm.
- Debugging: As a result of the evaluation, the wrong step in the algorithm can be corrected by going to the wrong step in the algorithm.

Based on the definitions of computational thinking, it can be said that it is a thinking process that can be used in solving problems. Adding computational thinking to different disciplinary fields such as biology, chemistry, physics, science education and STEM makes it easier to explore innovations in these fields(Lee et al., 2020).

Developing Computational Thinking in Science Education

While computer technology requires an understanding of the capabilities of computers, computational thinking is not the same as learning to program or write code. Computational thinking is a systematic thought process rather than a specific body of knowledge. Computational thinking is considered to be of great importance in science, technology, engineering and mathematics (STEM) subjects (Martin & Jacobsen, 2018), as it is seen as the process of solving problems by using algorithms through computers (Shute et al., 2017). The combination of STEM and computational thinking renames the sub-branches of science such as computational biology, computational chemistry, computational physics (Lee et al., 2020). Science and computational thinking should not be limited to STEM. Computational thinking is of great importance in teaching and enriching the content of the science curriculum (Aksit & Wiebe, 2020; Dickes et al., 2016; Hutchins et al., 2020; Malone et al., 2018; Peel et al., 2019). Helps students understand the application of scientific methods in science courses (Malyn-Smith et al., 2018; Weintrop et al., 2016; Wiese & Linn, 2021). As computational thinking becomes increasingly descriptive of modern scientific practice in general, it can be concluded that computational thinking is of critical importance for science educators, curriculum designers and assessment and evaluation experts. In order to transfer computational thinking to all areas of education, information about its importance and how it should be incorporated should be provided to stakeholders at all levels of education. In this way, it can facilitate the understanding and transfer of computational thinking.

Conceptualizing computational thinking beyond computer science enriches the learning environments of primary and secondary school students. The dimensions of computational thinking can be added to different dimensions of science fields. For example, (Weintrop et al., 2016) and (Lee et al., 2020) developed solutions for how to integrate computational thinking practices into middle school mathematics, science, and STEM subjects. In mathematics and science education, computational thinking is used to design and make creative proposals for solving scientific and innovative problems (Council, 2013). Since computational thinking includes the steps of scientific process skills in science, it provides the opportunity to go deeper into the content of science lessons by using computational thinking in science teaching (Yadav et al., 2018). Programming languages can be used to simulate the modeling of abstract subjects in the science course. Algorithm creation, which is the basis of programming languages, is one of the topics that constitute computational thinking (Basu et al., 2016). When the studies in which computational thinking is included in the field of science are examined, it is seen that computational thinking is added to STEM education, computer programming is used in solving complex problems in physics subjects, and coding education is used in explaining science education by making it a (Cutumisu et al., 2019; Kalelioğlu, 2018; Lee et al., 2020; Tang et al., 2020). However, these studies do not provide a detailed analysis of how CT (Computational Thinking) is used in science teaching and learning. Therefore, this paper reviews studies on the use of CT in science teaching and learning by stakeholders at all levels of education.

Research Questions

Although it is thought that embedding computational thinking as a teaching method strategy in the classroom can have positive effects on learning, many science educators seem to be confused about how applications involving computational thinking should be carried out and whether they will contribute to students' understanding of scientific concepts and their active participation in experimental studies (Ersozlu et al., 2023; Waterman et al., 2020). For example, science teachers teach as a body of content and often adopt rote learning to validate theory (Li & Schoenfeld, 2019). This tends to limit the conceptual process by which a student needs to use computational thinking to explain the issues and scientific problems they encounter in their environment, to be curious and then to develop and test ideas. With recent developments in the recognition of the importance of CT in science education, computational thinking constitutes a new domain to support conceptual understanding in science teaching and scientific practices. The purpose of this study is to review and synthesize published empirical studies that focus on the inclusion of CT in science education. This review provides an examination of how educators can utilize CT in the teaching and learning process in science education. This study addresses the following research questions:

Which research model was used in the studies?

Which data collection methods were used to reveal the effectiveness of computational thinking in science education?
Which subject areas in science education are included in computational thinking?
Which study groups were used to measure the effectiveness of computational thinking in science education?
In which years are the studies conducted more?

METHOD

Review Criteria and Analysis of Relevance of Studies

In our study, we conducted a systematic review to investigate how computational thinking is used in science education. Ebscohost, Eric, Springer, Web of Science and Google Scholar databases were searched. The search was designed using the keywords "Computational Thinking" "Science Education". A total of 31 studies that matched the inclusion and exclusion criteria in the databases were selected to be analyzed. Three of these studies were found in Google Scholar using the Turkish words "Computational Thinking" "Science Education". One study was found by searching the words "Computational Thinking" "Science Education" in Google Scholar. The remaining studies were found by searching the words "Computational Thinking" "Science Education". Selection criteria were made within the limits specified in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)(Moher et al., 2009). Figure 1 shows the selection criteria determined by the PRISMA structure. The priority as a research criterion in the research is to add studies with keywords.

- Studies with teachers, teacher candidates, students in primary and secondary high school groups,
- Studies involving computational thinking in science education,
- Studies with activities prepared on the basis of computational thinking in science education,
- Studies in which science curricula are created by combining teaching method techniques and integrating knowledge and operational thinking,
- Work submitted or published in peer-reviewed articles and documented in English only,
- Publications between 2013 and July 2023.

The exclusion criteria are as follows;

- This includes book chapters, conference proceedings, literature reviews, theses, dissertations, letters to the editor, scientific writing about computational thinking (think pieces, technical reports, blogs, presentations, etc.);
- Not focused on science education and science topics;
- Not published in peer-reviewed sources;
- Publications that were not written in English and Turkish languages and studies that were only STEM were not included because the keyword "STEM" was not completely covered by "Science Education".
- Articles that only addressed "computational thinking" or only included technological applications used in "science education" were not included in our study.

- Studies that did not include the words "Computational Thinking" "Science Education" "Science Classroom" "Computational Thinking" "Science Education" in their article titles were eliminated.

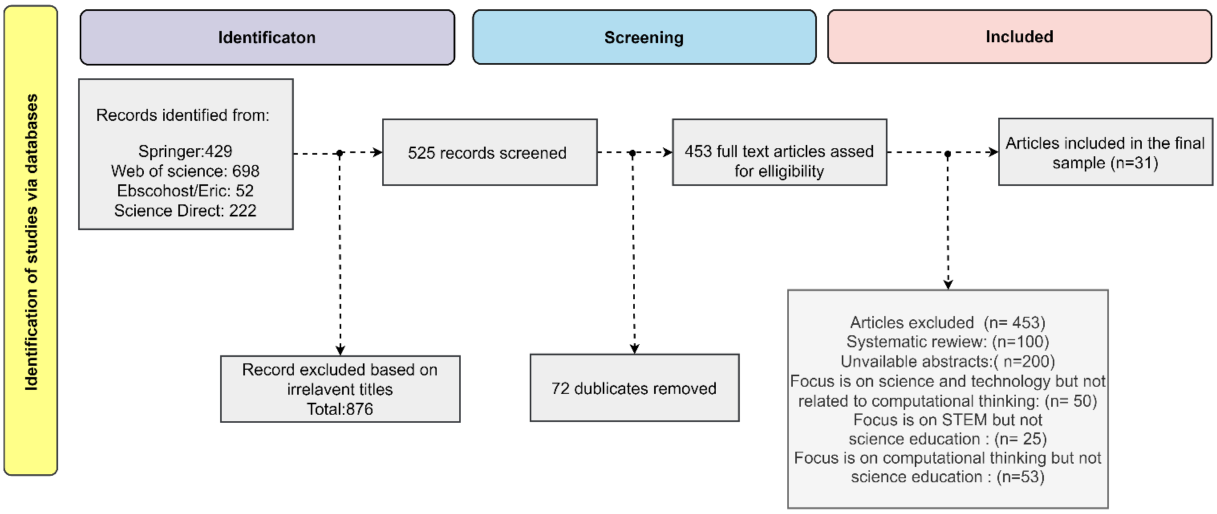

Figure 1. Selection Criteria of Studies (Moher et al., 2009) PRISMA adapted.

In line with the selection criteria, the studies were analyzed under the headings of author-year, title of the study, working group, subject learning areas, and methodology used in the study in line with a general framework determined by the researchers to increase validity. In order to increase the reliability of our study, two researchers searched the web databases with independent keywords. In case of disagreement, a consensus was reached and the articles to be discussed within the scope of the study were determined by consensus.

Limitations of the Research

One of the limitations of our research is to examine the studies in which computational thinking is included in science education. The years between 2013 and 2023 were selected to examine the studies in which science education and computational thinking were included. The studies in formats such as conference proceedings, letters to the editor, books, book chapters, theses were not included and were limited to published scientific articles. Studies that do not include science education in their keywords and are limited to STEM are not included. The reviewed studies examined brief intervention programs at the classroom level focusing on activities, games, and new approaches designed to teach concepts that constitute computational thinking.

FINDINGS

The identified articles were separated and then the studies that were common in the databases were eliminated and the final version is given in Table 2-7. These strategies provided information on evaluating the effectiveness of some of the approaches used in the integration of computational thinking in science courses based on quantitative studies and new approaches in terms of both theory and practice.

Table 2. Research on computational thinking and science education included in the study Part-1

Author and Year	Title	Implementation Group	Subject Learning Area	Method
(Kite & Park, 2023b)	What's Computational Thinking? Secondary Science Teachers Conceptualizations of Computational Thinking (CT) And Perceived Barriers to CT Integration	Science teachers teaching in secondary education	Teachers' views on computational thinking, the problems they experience in integrating it into the lesson and what are the obstacles in front of it	Qualitative study evaluation of teachers' opinions as a result of open-ended questions
(Christensen & Lombardi, 2023)	Biological Evolution Learning and Computational Thinking: Enhancing Understanding Through Integration of Disciplinary Core Knowledge and Scientific Practice	High school students	In learning the subject of "Evolution", which is one of the biology subjects integrated with computational thinking, both the development of computational thinking and the subject of "Evolution"	A quasi experimental study
(Çiftçi & Topçu, 2023)	Improving Early Childhood teacher candidates Computational Thinking Skills Through The Unplugged Computational Thinking İntegrated Stem Approach	Pre-school Teacher Candidates	The effects of STEM approach integrating computational thinking without computers on early childhood preservice teachers' IT skills (creativity, algorithmic thinking, critical thinking, problem solving)	A pre-test post-test quasi-experimental quantitative study
(Kite & Park, 2023a)	Context Matters: Secondary Science Teachers' Integration of Process-based, Unplugged Computational Thinking into Science Curriculum	High school science teachers	The aim was to identify the shortcomings and obstacles in incorporating computational thinking into science courses.	A qualitative study A semi-structured interview was conducted
(Kite & Park, 2022)	Preparing Inservice Science Teachers to Bring Unplugged Computational Thinking to Their Students	Science teachers	A study was conducted on how to integrate computational thinking into the science curriculum in in-service training for science teachers.	Mixed method While interviews were conducted for qualitative data, for the quantitative step, the findings of computational thinking self-efficacy were evaluated
(Arık & Topçu, 2022)	Computational Thinking Integration into Science Classrooms: Example of Digestive System	6th grade middle school students	The effectiveness of the digestive system unit in which computational thinking was integrated without computers was compared with the lesson taught with the traditional method.	A quantitative study pretest posttest experimental study

Table 3. Research on computational thinking and science education included in the study Part-2

Author and Year	Title	Implementation Group	Subject Learning Area	Method
(Peters-Burton et al., 2022)	High School Science Teacher Use of Planning Tools to Integrate Computational Thinking	Science teachers	The focus was on teachers' use of two unique tools, task analysis and decision tree, to integrate CT into data applications in science lesson plans and the effectiveness of the prepared lesson plans was tested.	A qualitative study was evaluated using phenomenology
(Arslanhan & Artun, 2021)	Teacher Opinions on Integration of Information Processing Skills into Science Education	Science teachers	The opinions of the teachers who participated in the code and implement week activities teaching the science course were taken.	Qualitative research Semi-structured interview questions
(Sari & Karaşahin, 2020)	Computational Thinking in Science Education: Evaluating a Teaching Activity	Science teacher candidates	To examine the usability of computational thinking in science teaching by evaluating their views on a teaching activity based on computational thinking.	Qualitative research Semi-structured interview
(Mensan et al., 2020)	Development and Validation of Unplugged Activity of Computational Thinking in Science Module to Integrate Computational Thinking in Primary Science Education	Primary school students	The effect of procedural thinking on knowledge added in modules and stages in science education is examined	Quantitative study
(Silva et al., 2020)	Science Education and Computational Thinking – Adapting Two Projects From Classroom Learning to Emergency Distance Learning	Primary school 1st and 5th grade students	In the Covid 19 process, a two-stage project was developed and in the first stage, a course in which computational thinking was added to increase the environmental awareness of 1st grade students and in the second stage of the project, the effect of computational thinking in teaching plants and animals for 5th grade students was examined.	In the first phase of the mixed method project, quantitative and in the second phase, qualitative studies were conducted.

Table 4. Research on computational thinking and science education included in the study Part-3

Author and Year	Title	Implementation Group	Subject Learning Area	Method
(Ntourou et al., 2021)	A Study of the Impact of Arduino and Visual Programming In Self-Efficacy, Motivation, Computational Thinking and 5th Grade Students' Perceptions on Electricity	5th grade students	5th grade students' science achievement of Arduino and Scratch programs in which electricity subject was added	Quantitative study
(Lapawi & Husnin, 2020)	The Effect of Computational Thinking Module on Achievement in Scienceonal Thinking Modules on Achievement in Science	Secondary school students	The effect of a science module based on computational thinking on academic achievement is examined.	A quantitative study uses a quasi-experimental model
(Mensan et al., 2020)	Development and Validation of Unplugged Activity of Computational Thinking in Science Module to Integrate Computational Thinking in Primary Science Education	Secondary school students	The effect of modular non-computerized computational thinking activities on middle school students is examined	A quantitative study An experimental study including pre-test post-test
(Ketelhut et al., 2020)	Teacher Change Following A Professional Development Experience in Integrating Computational Thinking into Elementary Science	Primary school teachers	It includes two different modules. The first group participated in the professional development workshop and the other group participated in the science inquiry group. Studies were conducted on how to integrate computational thinking into lessons.	In a qualitative study, the opinions of the teachers participating in the module were taken
(Arastoopour Irgens et al., 2020)	Modeling and Measuring High School Students' Computational Thinking Practices in Science	High school students	Examines how to make biology lessons effective by adding computational thinking and STEM developed for high school students	Pre-test and post-test were conducted for mixed method quantitative studies. Opinions are sought for qualitative studies
(Waterman et al., 2020)	Integrating Computational Thinking into Elementary Science Curriculum: an Examination of Activities that Support Students' Computational Thinking in the Service of Disciplinary Learning	3rd grade students	In the 3rd grade science course, computational thinking was integrated in 3 steps. The effectiveness of the lessons taught by adding computational thinking through the ecosystem model was tested.	Assessments such as creating tables and drawing graphs are made by students during the lesson

Table 5. Research on computational thinking and science education included in the study Part-4

Author and Year	Title	Implementation Group	Subject Learning Area	Method
(Hutchins et al., 2020)	C2STEM: a System for Synergistic Learning of Physics and Computational Thinking	High school students	The effectiveness of the course prepared by combining stem and computational thinking on the basis of physics course was examined.	Mixed method
(Aksit & Wiebe, 2020)	Grades Exploring Force and Motion Concepts in Middle Using Computational Modeling: a Classroom Intervention Study	Secondary school 8th grade students	It tests the effectiveness of a one-week lesson taught by adding computational thinking and simulation program to the force-motion unit in the science course.	A mixed work Pre-test post-test for quantitative dimension, in-class activity evaluation and interview results for qualitative dimension
(Luo et al., 2020)	Exploring The Evolution of Two Girls' Conceptions and Practices in Computational Thinking in Science	2 Primary school girls	The development of CT concepts and practices in science in two primary school girls who participated in a four-week CT-integrated science unit in a summer camp.	Qualitative study
(Kaya, Yesilyurt, et al., 2019)	Examining the Impact of a Computational Thinking Intervention on Pre-Service Elementary Science Teachers' Computational Thinking Teaching Efficacy Beliefs, Interest and Confidence	Science teacher candidates	Pre-service science teachers' self-efficacy, interest and confidence in a curriculum in which STEM and computational thinking were added	Quantitative study
(Breslyn & McGinnis, 2019)	Investigating Preservice Elementary Science Teachers' Understanding of Climate Change from A Computational Thinking Systems Perspective	Primary teacher candidates	Examines how computational thinking (CT), especially systems thinking (ST), can prepare educators to teach about climate change.	A qualitative study used rating rubric
(YAMAN & Cakir, 2018)	The Effect of Flipped Classroom Model on Students' Science Success and Computational Thinking Skills	Middle school 7th grade students	The effect of the flipped classroom (F2C) model on students' science achievement (SAS) and computer thinking (CT) skills in science course was investigated.	Pre-test post-test quasi-experimental design It was collected using the FB test and the BD scale.

Table 6. Research on computational thinking and science education included in the study Part-5

Author and Year	Title	Implementation Group	Subject Learning Area	Method
(Bati et al., 2018)	Teaching The Concept of Time: A Steam-Based Program on Computational Thinking in Science Education	Secondary school 8th grade students	Developing STEM-based computational thinking skills for teaching space-time concepts to middle school students (Physics mathematics based)	Mixed method quantitative and qualitative study
(Garneli & Chorianopoulos, 2018)	Programming Video Games and Simulations in Science Education: Exploring Computational Thinking Through Code Analysis	Middle School 3rd grade students	The contribution of physics topics supported by simulation or video games on the development of computational thinking	A longitudinal study with a mixed design pretest posttest
(Hestness et al., 2018)	Professional Knowledge Building within an Elementary Teacher Professional Development Experience on Computational Thinking in Science Education	Teacher candidates	The impact of computational thinking on professional development was examined.	Qualitative studies used more than one data collection method (field notes, artifacts, drawings, etc.)
(Yadav et al., 2018)	Computational Thinking in Elementary Classrooms: Measuring Teacher Understanding of Computational Ideas for Teaching Science	Teachers	It includes teachers' views on how computational thinking should be integrated into the process and assessment phases of science teaching.	A qualitative study includes case studies with open-ended questions
(Boulden et al., 2018)	Computational Thinking Integration into Middle Grades Science Classrooms: Strategies for Meeting the Challenges	Secondary school students	The aim of the study was to evaluate the results of students' experiences in the course of computational thinking added to the middle school science course.	Qualitative study

Table 7. Research on computational thinking and science education included in the study Part-6

Author and Year	Title	Implementation Group	Subject Learning Area	Method
(Jaipal-Jamani & Angeli, 2017)	Effect of Robotics on Elementary Preservice Teachers' Self-Efficacy, Science Learning, and Computational Thinking.	Primary education teacher candidates	The effect of teacher candidates self-efficacy towards the inclusion of STEM and robotics in the course content on science education knowledge operational thinking	Quantitative study
(Basu et al., 2016)	Identifying Middle School Students' Challenges İn Computational Thinking-based Science Learning	Secondary school students	A research study with CTSiM (Computational Thinking in Simulation and Modeling), a computational thinking-based learning environment for K-12 science where students create and simulate computational models to study and understand scientific processes	A quantitative study applied a multiple-choice test with a pre- and post-test
(Sengupta et al., 2013)	Integrating Computational Thinking with K-12 Science Education Using Agent-Based Computing: A Theoretical Framework	Secondary school 6th grade students	The effectiveness of the course contents prepared by combining certain topics from physics and biology units with information processing thinking for middle school students is tested.	An experimental pre-test post-test quantitative study

RESULTS

In this study, it is examined how computational thinking is handled in the studies of the subjects in science education, which study group is used in the studies examined and which of the steps of computational thinking applied according to the study groups is selected.

Research Models Preferred in Studies

The results of the analysis related to the research question about which methods are preferred in the research on computational thinking in science are given in Figure 2.

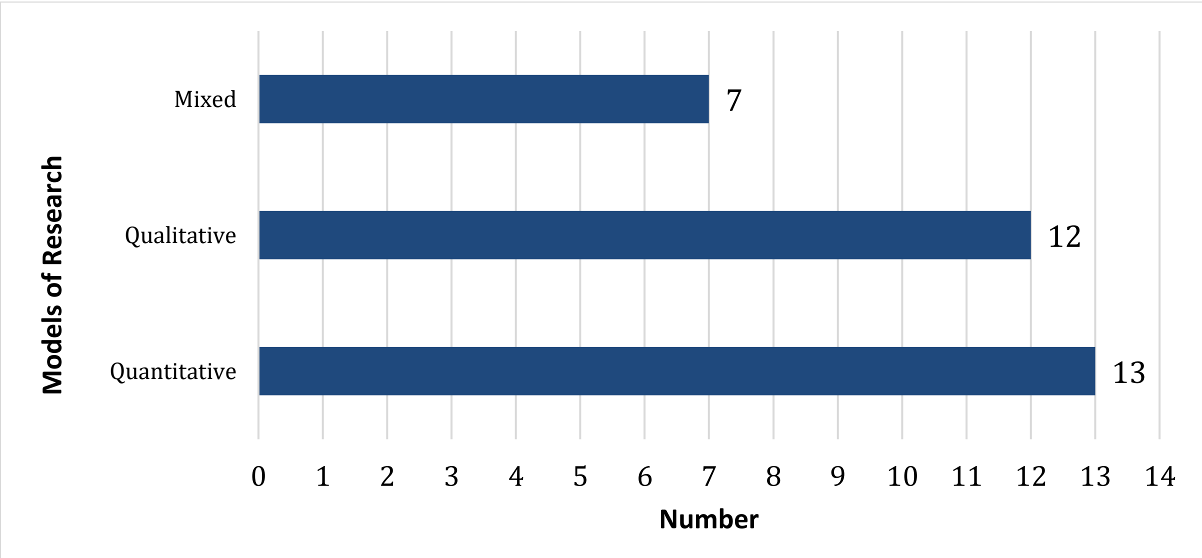

Figure 2. Distribution of articles according to research methods

When 31 studies were examined, it was seen that the most frequently used research method was quantitative research design, but it was also determined that the studies conducted in line with qualitative research design were close to this. It is seen that mixed methods are the least preferred research design. The distribution of articles according to research methods is shown in Figure 2. While 40.6% of the analyzed studies are quantitative studies, 37.5% are qualitative and the remaining studies are mixed method (21.9%)

Data Collection Tools Preferred in The Studies

The results of the analysis related to the research question about which data collection tools are preferred in the research on computational thinking in science are given in Figure 3.

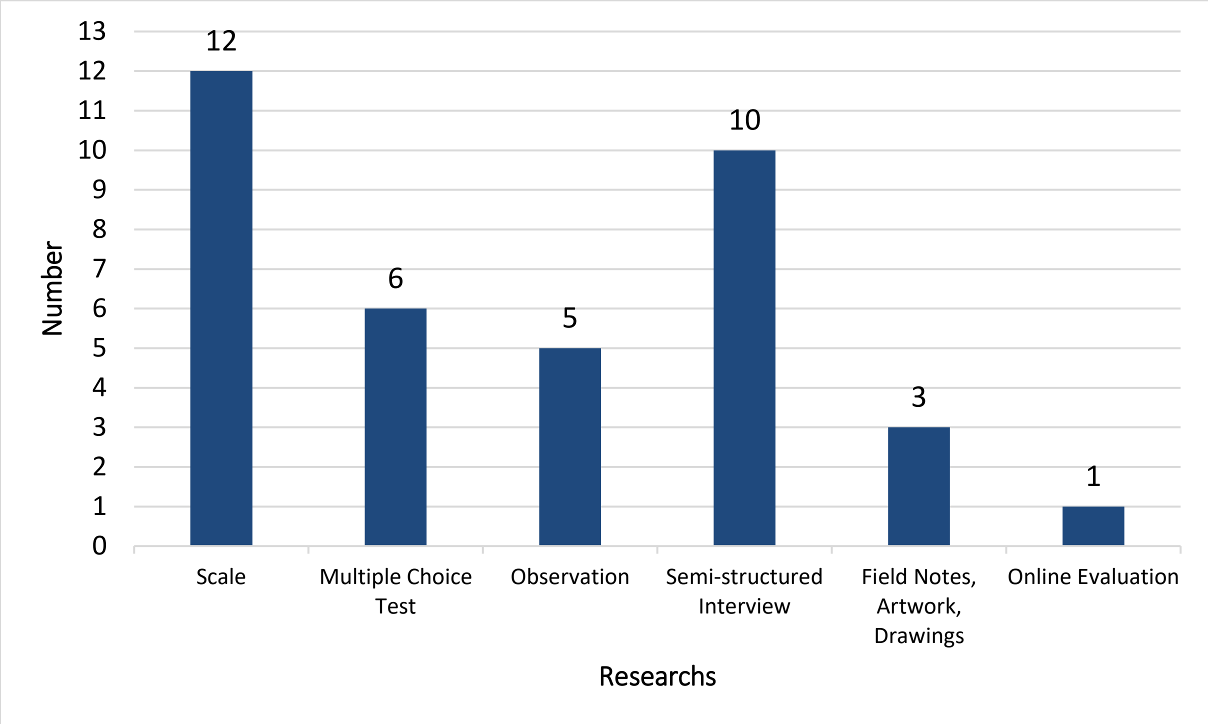

Figure 3. Data Collection Tools

When Figure 3 is examined, it is seen that the most preferred data collection tool is the scale, while online assessment is the least preferred. When we look at the other data collection tools, it is seen that semi-structured interview form, multiple-choice test, observation form and field notes-artwork-drawing are the most preferred, respectively. Below are some examples of how data collection tools were used in the studies.

- In the mixed study conducted by (Kite & Park, 2022), the quantitative step was supported by the analysis made by applying a Likert-type scale, while the qualitative step was supported by group discussions, field notes and preparation of lesson plans.
- In qualitative research, semi-structured interviews were generally used (Hestness et al., 2018; Kite & Park, 2022; Peters-Burton et al., 2022).
- In order to determine the knowledge of the study group about the relevant subject, open-ended questions were asked through case studies (Yadav et al., 2018).
- The evaluation of the online games that students play about the topic researched in the course includes the evaluation of the graphs drawn online (Waterman et al., 2020).
- The rating rubric prepared by the researchers was used for the evaluation of the study (Breslyn & McGinnis, 2019).

The results showed that scale analysis or multiple-choice tests were most commonly used in quantitative studies. In qualitative studies, semi-structured interviews, field notes, portfolio presentations and group discussions were used. In mixed-method studies, pre-test post-test experimental studies, scales, observations and semi-structured interviews were used.

Subject Area

The results of the analysis of which subject area is addressed in the research on computational thinking in science are shown in Figure 4.

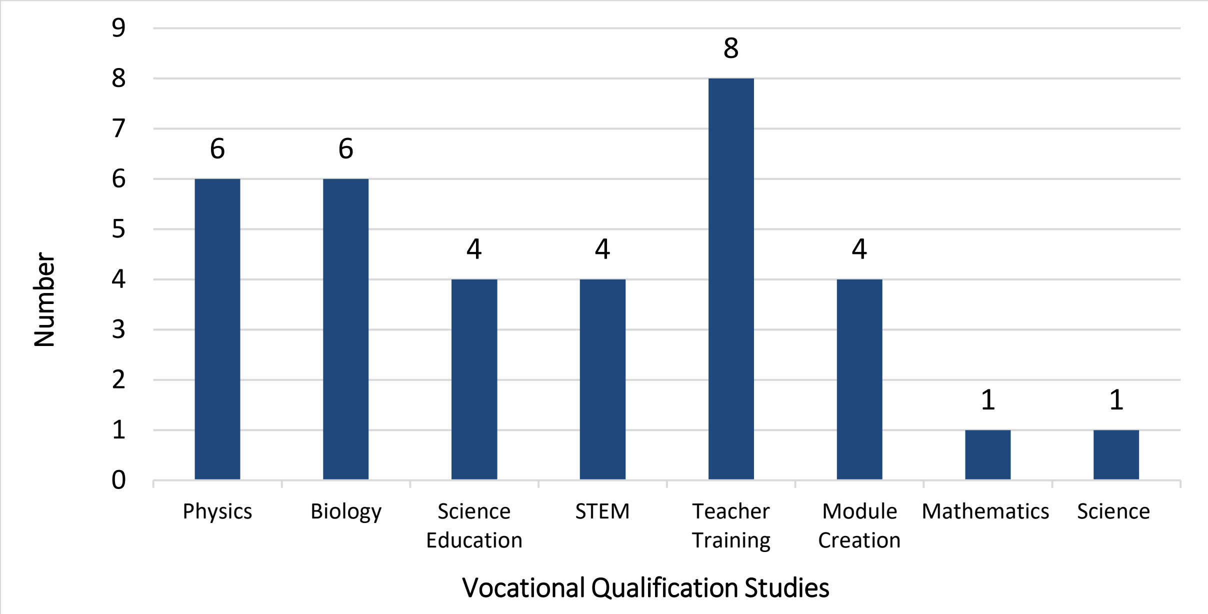

Figure 4. Subject Area

When Figure 4 is examined, it can be seen that the teacher education studies conducted with teachers or prospective teachers in physics, mathematics, biology, STEM, science lesson plan development, and teacher education studies with teachers or prospective teachers focused on the development of teachers' professional competencies for courses that include computational thinking. In some studies, there are lesson plan modules prepared on the basis of the subject area of "science" that are not applied to a single field.

Participant Groups Where the Work Is Carried Out

The results of the analysis of the participant groups in the studies conducted in science on computational thinking are shown in Figure 5.

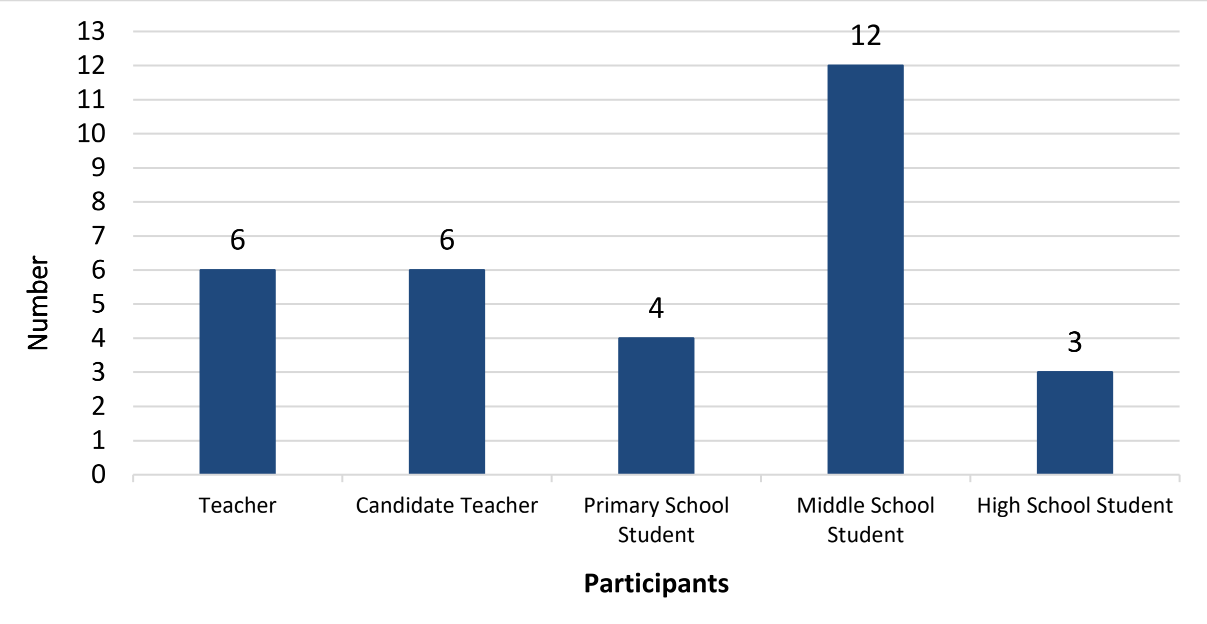

Figure 5. Participant group

When Figure 5 is analyzed, it is seen that the group with the highest number of studies was middle school students, while the lowest number of studies was conducted with high school students. However, the fact that no study was conducted with pre-school students stands out as a striking finding.

Years of Studies

The results of the analysis of research on computational thinking in the sciences according to years are shown in Figure 6.

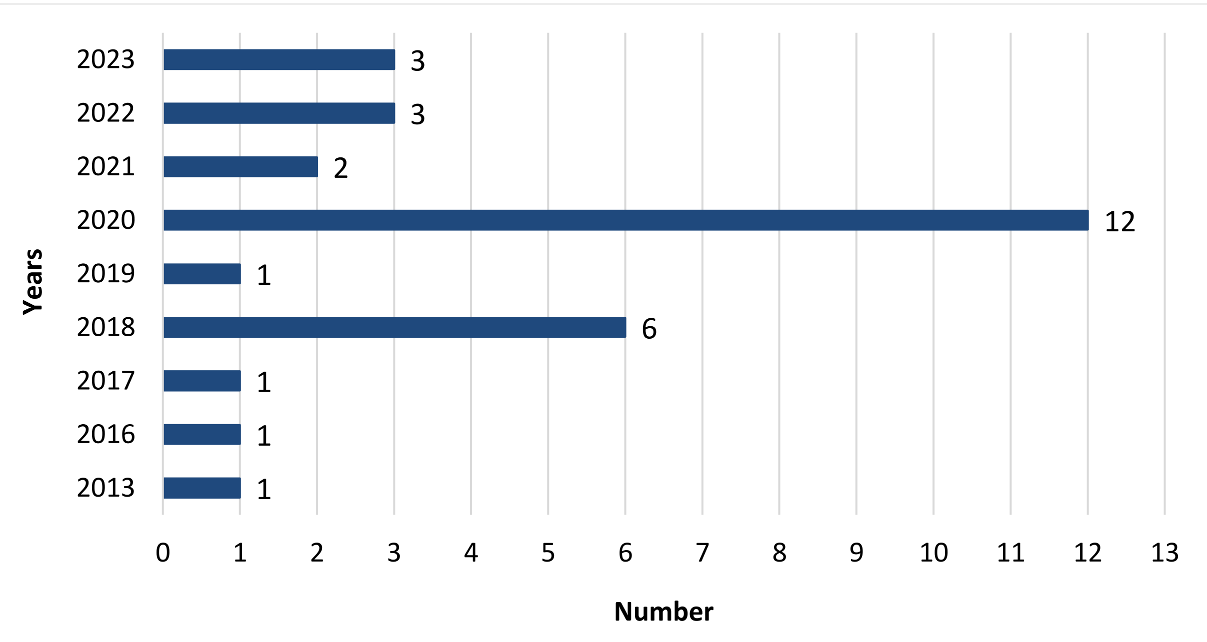

Figure 6. Distribution of studies by years

When the years in which the studies were conducted are examined, it is seen that the highest number of studies was conducted in 2020 and the number has decreased to the present day. (Kampylis et al., 2023), in their systematic review on the integration of computational thinking in primary and secondary schools, concluded that while there was an increase in the literature in 2020, a decrease was observed in 2021.

CONCLUSION and DISCUSSION

This study aimed to examine the literature on how computational thinking is incorporated into science education. When the research on computational thinking and preschool students is examined, computational thinking is an important skill for children to express their ideas to shape their learning (J. M. Wing, 2006).While STEM teaching with computational thinking focuses on coding education, robotics and programming, some studies focus on teaching terms that constitute computational thinking such as definition, patterning, collaboration, algorithm (Bers et al., 2014, 2019; Papadakis et al., 2016; Relkin et al., 2021; Weintrop et al., 2016). However, in our study, one of the most important findings that draws attention is that while studies were conducted with "primary, middle and high school students" in the selection of the study group, there are no studies on the science course in which computational thinking is integrated with "preschool students". Considering that high-level learning skills in science education should be acquired starting from preschool, researchers can design and implement science activities in which computational thinking is integrated with preschool students in future studies.

Conceptual definitions of computational thinking have been made and there is still no common definition. In the definitions made, the content of computational thinking consists of concepts such as abstraction, algorithmic thinking, debugging, data processing, coding, decomposition, pattern, definition, both with and without the support of technology (Ogegbo & Ramnarain, 2022). However, in various studies, it is observed that the concepts that constitute computational thinking are added to the studies. In their study, (Aksit & Wiebe, 2020) aimed to teach the "Force and Motion" unit through block-based programming within the framework of Scratch programming with the acquisition of concepts such as abstraction, algorithm creation, coding, and explained that students were successful both in the subject of "Force and Motion" and in the concepts that constitute computational thinking. Similarly, (Kaya, Newley, et al., 2019) conducted an after-school study in which computational thinking concepts and activities such as algorithms, abstraction, pattern recognition, debugging, decomposition and iterative design were taught to primary school students. According to the results of this study, it is seen that participation in the study provides students with opportunities to learn basic computational thinking skills while teaching them about animal habitats and engineering.

In general, studies have been conducted with both students and teachers and teacher candidates about what computational thinking is and how it should be incorporated into the science curriculum. Given that teachers' or teacher candidates understandings, attitudes, and beliefs influence their teaching of computational thinking in science curricula, an important step in the development of these programs is to identify teachers' conceptualization of computational thinking and its role in science education as well as their perceived barriers to computational thinking/science integration. In conceptualizing computational thinking as a specific type of thinking that can be used to build science students' problem-solving skills, it can be inferred that it is necessary to view a lack of understanding of computational thinking as a primary barrier to science integration; to believe that students are academically unprepared for science combined with computational thinking; and to support science teachers to focus on the what, why, and how of computational thinking/science integration (Kite & Park, 2022).

When the studies conducted with students were not examined, science courses in which STEM, simulation, coding, computational thinking activities without computers were integrated were taught and their effectiveness was investigated. It was concluded that students were more effective in learning the course content to which computational thinking was added than the traditional method (Arık & Topçu, 2022). It is also suggested that computational thinking can be effective in the development of problem solving skills, one of the higher order thinking skills (Yadav et al., 2014). (Christensen & Lombardi, 2023) conducted a quasi-experimental study in which computational thinking was and was not included in the subject of biological evolution. When we look at the results they shared, it was observed that in the subject of evolution in which computational thinking was included, students deepened more on the subject and were able to combine disciplinary ideas with scientific applications. It is argued that it can be more effective for students to deepen not only in biology subjects but also in the subject areas within the scope of science courses and to transfer their disciplinary knowledge. When used by combining programming and simulation to integrate computational thinking into the lessons, it makes a significant contribution to the acquisition of conceptual learning gains.

It can be inferred that after computational thinking is explained to teachers and teacher candidates and they gain competence about how it can be added to the course, they can develop positive attitudes towards the science course in their students.

In the articles we examined, in the integration of computational thinking, "teaching with modeling", "game-based teaching", "teaching focusing on problem solving skills", "lesson plans prepared by creating modules with computational thinking content", "several weeks of teaching with plans prepared within the scope of the project" were added to science education. (Luo et al., 2020) investigated the development of computational thinking concepts and practices in science education among female students attending two elementary schools who participated in a science course integrating computational thinking using the Dash robot and Blockly application in a summer camp. Cycles, sequences and algorithms were integrated into the topic "reproductive cycle of flowerless plants". Observations, participant drawings and analysis of the Blockly code revealed that children improved in their CT (Computational Thinking) practices. In addition, they shared the importance of science education integrated with computational thinking developed for this study, building the skeleton of coding concepts through non-computerized activities, promoting CT and integrating science education into the lessons of students at primary level. It can be said that in-class activities developed by adding different programming languages will help students develop a new project, model interdisciplinary issues, and contribute to creative problem solving.

In the studies, the methods used to evaluate the handling of computational thinking were semi-structured interviews, observation, field notes, portfolio evaluation, and evaluation of students' drawings during the lesson for the studies using qualitative research method, while in the studies using quantitative research method, computational thinking scale, self-efficacy scale in the lessons where teachers' lesson plans in which computational thinking was integrated, and multiple-choice achievement tests prepared within the scope of science course were used. In addition, course content applications prepared in the virtual environment, such as modeling, simulation, data modeling, abstraction, etc., were evaluated online by drawing graphics and coding the titles added to the lesson plan. When the evaluation part of the studies is analyzed, the most preferred evaluation method was to apply a scale. However, studies using only a few scales/questionnaires alone reflect limitations. This is because the use of questionnaires alone cannot provide in-depth information and evidence about students' thinking processes on computational thinking (Tang et al., 2020). In light of this, some of the reviewed studies found that using multiple assessment methods such as portfolios and interviews, questionnaires and achievement tests to examine students' higher-order thinking processes may be more effective for examining learning outcomes (Boulden et al., 2018; Hutchins et al., 2020).

RECOMMENDATIONS

When the studies are examined, abstraction forms the core set of concepts that constitute computational thinking, including algorithmic thinking, parsing, debugging, and generalization. These concepts are associated with various attitudes and skills (or practices), including the capacity to create, test and debug artifacts based on computational thinking, collaboration and creativity, and the capacity to solve open-ended problems. From this perspective, divergent thinking and creative problem-solving techniques need to be acquired from an early age in response to today's technology and changing conditions. Therefore, it has an important role in compulsory education. Coding/programming provides a suitable ground for making computational thinking concepts concrete. It can also be a learning tool for exploring other domains or for self-expression. However, it would not be correct to limit computational thinking to learning and practicing coding or programming. Computational thinking includes creativity, problem solving, critical thinking and collaborative learning. Computational thinking can be added to different disciplines in traditional ways such as pen and paper without being dependent on computers (Barendsen et al., 2016; Basu et al., 2020).

In studies that address computational thinking concepts in both primary and secondary education, programming and algorithm studies should be included in primary and secondary school basic curricula to develop Regarding curriculum integration, the results highlight different implications regarding the three main approaches adopted to integrate computational thinking:

- As a cross-curricular theme,
- Within other subjects (e.g. mathematics, technology, history, geography, etc.)
- As a separate subject (e.g. activities prepared with materials that are accessible to everyone, including both technological and non-computerized computational thinking where computational thinking skills are added)

The central role played by teachers, setting curriculum priorities and teacher self-efficacy are seen as key factors in teaching computational thinking. The positioning of computational thinking skills in the general curriculum may create various demands at both policy-making and educational management/organization levels. These demands include making space in the curriculum for the inclusion of core computer science concepts and programming languages to develop computational thinking skills; providing clear guidelines on the amount of time teachers should devote to teaching core computer science content; allocating sufficient resources to develop high-quality teaching materials; and sharing examples of activities that incorporate computational thinking skills. Positioning computational skills as a cross-curricular theme, it is crucial to clarify the respective responsibilities of each subject teacher in this process. For future research, the number of examples of activities that incorporate computational thinking could be increased. Teachers could be further informed about computational thinking. In the selection of the sample group, preschool students can be included in the studies in addition to middle and high school students.

ETHICAL TEXT

In this article, the journal writing rules, publication principles, research and publication ethics, and journal ethical rules were followed. The responsibility belongs to the author (s) for any violations that may arise regarding the article. This study does not require an ethics committee.

Contribution Rate Statement of Author(s): In this research, the contribution rate of the first author to the article is 50%, the contribution rate of the second author to the article is 50%.

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