ANALYZING EXECUTIVE FUNCTIONING, COMPUTATIONAL THINKING AND ACADEMIC ACHIEVEMENT AMONG PRE-ADOLESCENT STUDENTS

By

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https://doi.org/10.26634/jpsy.19.1.21699

Date Received: 27/02/2025 *Date Revised: 15/03/2025* *Date Accepted: 25/04/2025*

ABSTRACT

Executive functioning skills are very essential components of effective learning, innovative thinking, and decision-making that are necessary for the growing minds of the twenty-first century. Executive functioning refers to the collection of mental processes that guide and control psychological behavior and activities. Working memory, attentional control, and cognitive flexibility are considered the important executive functioning skills. A large number of studies has revealed that executive functioning skills are substantially connected with self-regulated classroom behaviors that promote students' academic development, school readiness, and learning. Computational thinking skills are being increasingly regarded as a necessary skill for thriving in our highly advanced technological environment. It is classified by skills like decomposition, pattern identification, abstraction, and algorithmic thinking. Previous research findings revealed that incorporating computational thinking into education improves problem-solving, creativity, and innovation. This study investigates the relationship between youngsters' executive functioning skills and computational thinking capabilities, with a focus on how these two talents improve academic accomplishment in pre-adolescent children. The purposive random sampling technique was adopted to select 68 pre-adolescent students for this study. Percentage analysis, t-tests, and correlational studies were used for this quantitative analysis. The findings of this research emphasize the value of an interdisciplinary educational framework that develops both skill sets and gets students ready for the challenges of the twenty-first century. The results of this study suggest that targeted interventions and teaching strategies may greatly enhance preadolescents' cognitive and academic performance, ultimately resulting in the development of an era of capable and flexible thinkers.

Keywords: Executive Functioning Skills, Computational Thinking, Working Memory, Cognitive Flexibility, Algorithmic Thinking.

INTRODUCTION

The pre-adolescent phase, which normally lasts from ages 10 to 12, is a critical period in a child's growth in education. During this time, students undergo major physical, cognitive, emotional, and social changes, which impact their learning experiences and lay the groundwork for future academic achievement (Halpern et al., 2007; Hyde, 2014; Zelazo et al., 2016). According to Piaget (1970), during the pre-adolescent phase, young children transition from concrete to formal operational thinking. This implies they begin to deal with abstract notions, logical thinking, and complicated problem solving. These cognitive transformations make it an excellent time to introduce more complicated courses such as mathematics, science, and computational thinking, which need pupils to analyze information, see patterns, and get involved in systematic reasoning. Computational thinking is regarded as the most significant rising 21st century talent in our technologically advanced environment. Executive functioning skills, including attentional control, working memory, and cognitive flexibility, develop rapidly during pre-adolescence and serve as essential for academic achievement (Diamond, 2013; Sulik & Obradović, 2017). Cognitive flexibility is a crucial feature of executive function that allows students to switch between tasks and ideas more successfully (Best et al., 2011). Working memory enables pupils to store and manipulate information, and attentional control enables them to focus on pertinent tasks while ignoring distractions. This set of skills aids not just academic activities but also emotional management and social behavior (Blair & Raver, 2015).

Executive Functioning Skills

Executive function is a general term that refers to a number of interconnected components and is frequently defined as having three domains: Working memory is the capacity to hold onto and manipulate pertinent knowledge for small periods of time without the use of cues or other cues, as well as to plan and execute goal-directed actions. Attentional control is a capability to select appropriate information for a task while controlling distractions (Drigas & Karyotaki, 2017). Cognitive flexibility or shifting: The capacity to alter plans and activities in response to circumstances and the environment; the capacity to adjust spatial or interpersonal views. The frontal lobe controls an enormous number of executive functions. Engle et al. (1999) defined executive attention as the human capacity to focus attention on ongoing cognitive processes. Executive function (EF) is a set of cognitive skills that help or regulate a person's conduct in a number of cognitive (including academic), social, and other domains (Marschark et al., 2018). Executive function (EF) skills are linked with a number of educational outcomes, including specialist academic skills, school involvement, and self-controlled classroom conduct (Diamond, 2013; Obradović et al., 2018). The executive functioning skills examined in both settings have an impact on students' ability to manage their attention, behaviors, and emotions in the classroom and their performance on standardized academic assessments (Obradovic et al., 2018). When assessing students' EF skills in a classroom, a novel, group-based evaluation method provides a reliable and viable alternative to a traditional, individual assessment method. According to Best et al. (2011) and Diamond (2013), it involves the capacity to stay focused, adapt to changing attention, inhibit distracting impulses, and modify and retrieve information from working memory. There is a strong correlation between working memory and fluid intelligence (Salthouse & Pink, 2008). Working memory training in schools led by teachers enhances academic performance (Holmes & Gathercole, 2014; Musso et al., 2012). A group-based assessment method provides a suitable and consistent alternative for traditional individual tests when evaluating students' English proficiency in the classroom, claim Obradovic et al. (2018). Particularly when assessed after the task, individual variations in EF predicted differences in student teaching (Begolli et al., 2018). The role of executive functioning skills in relational reasoning, as well as environmentally sound knowledge of EF's significance in classroom mathematics education (Nyroos et al., 2018). Reading and math proficiency at various points in time were predicted by executive function. EF is seen as a comprehensive set of capabilities that encourages learning and inhibitions.

Computational Thinking Skills

Computational thinking is a kind of analytical thinking process (Wing, 2006). Computational thinking improves students' problem-solving skills, allowing them to be more creative in discovering solutions (Figueiredo, 2017). Wing (2017) defines computational thinking (CT) as "*... the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent*" (p. 8).

It is classified by the skills like decomposition, pattern identification, abstraction, and algorithmic thinking. According to Miller (1956), the human memory has a capacity of only 7 $\pm$ 2 things. This suggests that a lot of issues are too complex for the human mind to process in their whole without being divided into smaller, easier-to-manage activities. "Breaking down into manageable steps" is a technique is called as decomposition. Finding patterns in problems and other people's experiences is known as pattern recognition; the capacity to concentrate on the most crucial details and identify distinct differences in order to adapt a single solution to a variety of situations is called abstraction. Algorithms are developed in a step-by-step manner in problem solving. Anyone can use this strategy, regardless of task or area of expertise. The first thing to determine about a pupil is whether they possess computational thinking. CT is an important skill for their future personal and professional lives. According to Wing (2006), children can learn to think analytically while solving issues by using computational thinking skills in the training of reading, writing, and math. We need to learn more about the cognitive and psychological skills that underpin the many aspects of computational thinking, as well as how these skills change as young children progress. CT promotes skills, attitudes, and concepts for optimized technology usage (Bilbao et al., 2021). Mathematics achievement is related to students' computational thinking skills (Chongo et al., 2020). Computational thinking (CT) is a cognitive process; therefore, it can exist independently of technology. According to Subrahmanyam et al. (2000) and Sysło (2015), computational thinking is a group of essential mental strategies and abilities that have a basis in computers but are applicable to all fields well beyond computer science.

1. Literature Review

Bacconi et al. (2016) conducted a qualitative study that provided a complete summary of computational thinking skills. This study focused on CT skills among European schoolchildren. At the fundamental levels, emphasis is placed on computational thinking, coding, programming, and transversal abilities. Roman-Gonalez et al. (2017) gave a CT exam to a group of 1251 Spanish pupils. The study findings show that computational thinking is correlated with spatial reasoning and problem-solving abilities. Lapawi and Husnin (2020) revealed that involving computational thinking abilities in scientific instruction improves students' creativity and innovation. Robertson et al. (2020) investigated the link between executive functioning and computational thinking. It examined the connection between learners' executive functions and programming debugging. The results of the study showed a moderate relationship between executive functioning, debugging, and programming. Spieler et al. (2020) investigated cognitive aspects in programming performance and game design activities, with a particular emphasis on CT abilities and cognitive processes in programming. They discovered that design aspects connected with arithmetic ability and working memory, whereas game elements correlated with creativity and age. Arithmetic skills have a significant impact on computational thinking skills. Zakaria and Iksan (2020) conducted a study on 343 secondary school students in Malaysia to assess their computational thinking skills according to their educational attainment and gender. High school pupils' CT skills are evaluated based on their gender. Compared to male pupils, female students exhibit higher degrees of computational thinking. Gerosa et al. (2021) conducted a study on cognitive capacities and computational thinking at the age of five, finding evidence for connections with sequencing and symbolic number comparison. The study investigated how computational thinking is associated with cognitive ability in kindergarten students. The study findings revealed that there are beneficial connections between robot programming and computational thinking abilities. Assessed the cognitive stimulation of executive function using computational thinking. Computational thinking skills are a collection of subskills (Zhang & Nouri, 2020). The study evaluated the efficacy of CT training using programming for kids between the ages of 10 and 11. Working memory, inhibition, and planning are among the executive functions covered in the program. The findings showed that elementary students' working memory, inhibition, and planning improved significantly and that there were significant differences in executive functioning abilities between the experimental and control groups.

2. Need and Significance of the Study

In a technologically evolved environment, the capability to think computationally is becoming more and more important for survival. According to Wing (2006), children can learn to think analytically while solving issues by using CT skills in the training of reading, writing, and math. It is essential to gain a better knowledge of the psychological and cognitive abilities that enable the many aspects of computational thinking and how these talents develop throughout the lives of young children. Executive function refers to a set of talents that govern an individual's overall cognitive control. Developing executive functioning (EF) skills is critical for academic and personal success (Begum et al., 2021). EF skills help students improve their computational thinking skills by allowing them to plan, execute, and selectively focus on essential information while avoiding distractions and adjusting to new innovations in complicated activities. The investigator, being a teacher educator and a research scholar, wants to investigate the link between computational thinking skills, executive functioning skills, and academic achievement.

3. Objectives of the Study

- To find the difference between boys and girls in executive functioning skills, computational thinking skills, and academic achievement
- To find the difference between urban and rural students in executive functioning skills, computational thinking skills, and academic achievement.
- To find the difference between Age-11 and Age-12 pre-adolescent in executive functioning skills, computational thinking skills, and academic achievement.
- To find the relationship among executive functioning skills, computational thinking skills, and academic achievement.

4. Research Questions

- What is the level of computational thinking skills of pre-adolescent students?
- What is the level of executive functioning skills of pre-adolescent students?
- What is the difference between pre-adolescent boys and girls in computational thinking skills?
- What is the difference between pre-adolescent boys and girls in executive functioning skills?
- What is the relationship among computational thinking skills, attentional control, and achievement in mathematics?

5. Methodology

5.1 Population and Sampless

68 pre-adolescent students were selected as a sample from a government-aided school (35 students (11 years old) and 33 students (12 years old)). Purposive random sampling technique was adopted for this study.

5.2 Data Collection Procedure

The data for this study were collected from pre-adolescent students from a government-aided school. This study was conducted in accordance with the ethical standards set forth by Gandhigram Rural Institute (DTBU), and formal permission was secured from school authorities. Since the participants of this study were minors, special ethical considerations were taken into account to ensure their protection and well-being throughout the research process. Consent forms were distributed to the guardians, and only students with signed consent forms were included in the study. Participants were provided with detailed information about the purpose of the study, procedures, risks, and the voluntary nature of participation. Confidentiality of the participants' data was strictly maintained, and all identifying information was anonymized to protect their privacy.

The sample consisted of 68 students aged between 11 and 12, all of whom voluntarily agreed to participate in the study. The data collection was carried out over a one-week period during regular school hours to minimize the disruption to the student's learning schedules.

The data collection process involved the assessment of executive functioning skills, computational thinking skills, and academic achievement. The following steps were undertaken:

5.2.1 Demographic and Academic Data

The investigator collected pre-adolescent students' demographic information for the analysis and students' midterm test marks taken for the consideration of academic achievement.

5.2.2 Computational Thinking Skills Questionnaire

The computational thinking skills questionnaire was constructed by the investigator, and it contains 10 problem-solving questions related to basic arithmetic operations usage in algebraic expressions.

5.2.3 Executive Functioning Skills

Executive functioning skills were assessed through the following tasks:

- *Working Memory-Digit Span Task:* The digit span task assesses verbal short-term memory (ahead) and verbal working memory (backwards) (Wechsler, 1991). During the digit span task, the investigator reads out a series of numbers. Children must repeat this process in either the same (forward) or reversed order. Trial difficulty was based on the length of the sequence, which increased by one digit after two trials at the same difficulty level. The exercise ends when a youngster mistakenly repeats two subsequent trials of the same difficulty level. The WISC (Wechsler Intelligence Scale for Children) digit span subtest is a reliable and valuable measure of children's working memory, with a test-retest reliability of $\alpha = .82$ (Kaufman, 2006; Wechsler, 1991).
- *Attentional Control-Stroop Color and Word Test (SCWT):* Attentional control ability assessed by Stroop task. The Stroop Color and Word Test (SCWT) is a neuropsychological test that is widely used in both experimental and clinical settings. It evaluates the ability to prevent cognitive interference, which happens when processing one input characteristic impacts the simultaneous processing of another (Stroop, 1992). Respondents must read three distinct tables as fast as they can in the most widely used version of the SCWT, which was first presented by Stroop in 1992. The "congruous condition" is illustrated in two of them, where participants are required to name different color patches (C) and read color words printed in black ink (W). Color words are printed in an uneven color ink (for instance, "red" is printed in green ink) in the third table, which is called the color-word (CW) condition. Instead of reading the word in this incongruent condition, participants are required to identify the ink's color. The quantity of correctly named items in 45 seconds under the CW condition, the quantity of correctly named items in 45 seconds under the W condition, and the quantity of correctly named items in 45 seconds under the C condition. The Stroop effect is the name given to this difficulty in suppressing the more automatic process. Although the SCWT is widely used to evaluate cognitive distraction mitigation skills.
- *Cognitive Flexibility-Digit Symbol Substitution Task (DSST):* The DSST is a paper-and-pencil cognitive test administered on a single sheet of paper in which a subject must match symbols to numbers using a key located at the top of the page. The subject enters the symbol into the spaces beneath a row of numbers. The score is determined by the number of accurate symbols obtained within the 60-second time limit. This task is used to assess cognitive flexibility.

6. Data Analysis and Findings

All the data was collected and analyzed by using SPSS and MS-Excel software. Percentage analysis, t-tests, and correlation studies were made.

Table 1 shows the average scores for each task performed by the pre-adolescent participants. It is inferred that there is no gender difference between boys and girls in the computational thinking skills of pre-adolescent students. All the students' working memory average score is 5.2. In the Stroop test, congruent boys score better than girls, but in incongruent scores, it is reported that girls are better in attentional control. In the DSST task, boys scored a higher value than the girls.

Figures 1 to 4 show the comparative performance of boys and girls across various cognitive tasks. Figure 1 compares working memory abilities, showing results from forward digit span, backward digit span, and total digit

Name of the Task	Variables	Group	Boys	Girls
Forward Digit Span Test	Working Memory	5.72	5.88	5.53
Backward Digit Span Test	Working Memory	4.69	4.55	4.84
Total Digit Span Score	Working Memory	5.2	5.22	5.18
Digit Symbol Substitution Task	Cognitive Flexibility	256.26	287.63	220.9
Stroop Test-congruence	Attentional Control	52.75	53.16	52.28
Stroop Test-Incongruence	Attentional Control	34.04	33.38	34.78
Stroop Interference	Attentional Control	18.7	19.77	17.5
Computational Thinking Test	CT Skill Percentage	40.58	40	41.25
Mid-Term Test-percentage	Academic Achievement	61.39	58.15	65.04

Table 1. Average Score of Each Task Performed by the Pre-adolescent

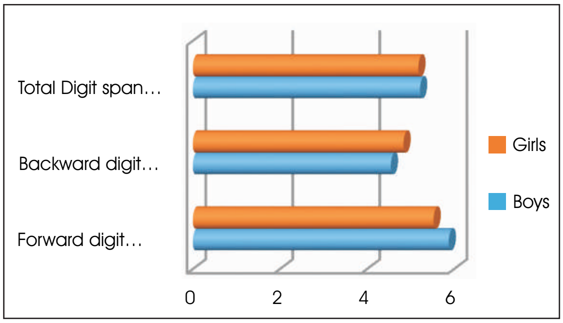

Figure 1. Scores of Boys and Girls in Working Memory Tasks

span tasks, with minimal differences observed between genders. Figure 2 shows the percentage distribution in the Digit Symbol Substitution Task, where boys scored 57% and girls 43%. Figure 3 highlights attentional control scores under Stroop test conditions, indicating performance differences in both congruent and incongruent settings. Figure 4 shows the percentage scores in the computational thinking test, with girls slightly outperforming boys. Together, these figures provide insights into gender-based variations in cognitive abilities among pre-adolescent students.

Table 2 shows the calculation of the sample t-test to determine the difference between pre-adolescent boys and girls. It is revealed that there is no gender difference in

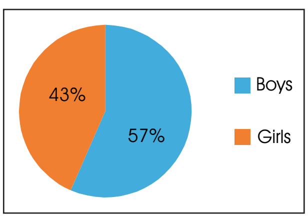

Figure 2. Gender-wise Distribution in Digit Symbol Task

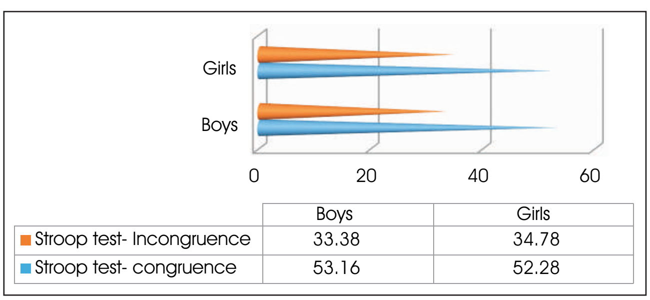

Figure 3. Attentional Control Scores in the Stroop Test by Gender and Condition

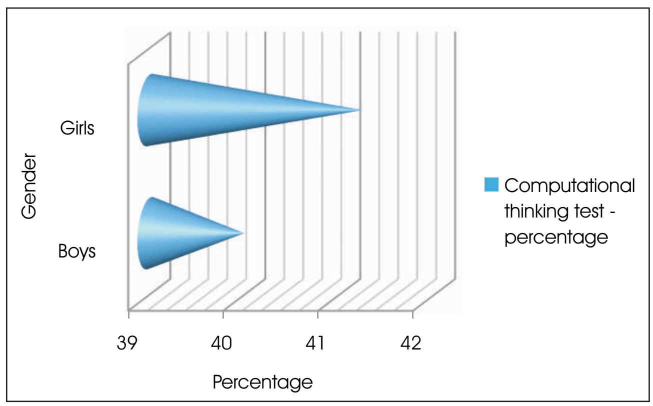

Figure 4. Computational Thinking Test Scores by Gender

Variables	Gender	N	Mean	Std. Deviation	p-value	L.S
Working memory	Boys	36	5.22	1.27	0.919	N.S
	Girls	32	5.18	1.55		
cognitive Flexibility	Boys	36	287.64	65.40	.000	Sig.
	Girls	32	220.97	67.59		
Attentional control	Boys	36	33.39	7.16	.512	N.S
	Girls	32	34.78	10.14		
Computational thinking skills	Boys	36	40.00	22.39	.787	N.S
	Girls	32	41.25	14.14		
Academic achievement	Boys	36	58.15	16.90	.069	N.S
	Girls	32	64.83	12.17		

Table 2. Samples t-test Comparing Boys and Girls Pre-adolescent Students

working memory, attentional control, computational thinking skills, and academic achievement. There is a significant difference between boys and girls in cognitive flexibility (p-value is less than 0.05).

Table 3 shows the calculation of the sample's t-test examining the difference between urban and rural pre-adolescent students. It is inferred that there is no significant difference between urban and rural students in executive functioning skills, including working memory, cognitive flexibility, and attentional controls, computational thinking skills, and academic achievement.

Table 4 shows the correlations among all the variables. There is a positive relationship among computational thinking skills, working memory, attentional control, and academic achievement. Cognitive flexibility has a very low negative relationship with computational thinking skills and attentional control.

7. Results and Discussions

The study found no gender difference in computational thinking skills. This study supports the previous study's conclusions that there are no gender differences in CT capabilities (Chongo et al., 2020; Sirakaya, 2020). The average score of all pre-adolescent kids in computational thinking is only 40%. However, kids earned 61% on academic achievement tests. Since computational thinking is in its early stages in the country, the majority of teachers and students are unaware of it. The majority of problems are solved using solely the traditional approach. However, computational thinking is a novel way to problem-solve, according to the constructivist model of instruction. The NEP-2020 (National Education Policy) emphasizes the significance of creative thinking rather than rote learning. The NEP-2020 emphasizes the significance of creative thinking rather than rote learning. The National Education Policy emphasized the need for computational thinking for problem-solving. Computational thinking skills and executive functioning skills do not change amongst pre-adolescents based on their home status, whether rural or urban.

The lack of difference may be attributed to increased access to educational resources in both rural and urban locations. It is feasible that both rural and urban schools deliver equally good education in areas that improve computational thinking and executive functioning skills. The findings show that all pupils, regardless of geography,

Variables	Residential Status	N	Mean	Std. Deviation	p- value	L.S
Working Memory (Digit span task)	URBAN	43	5.11	1.38	0.492	N.S
	RURAL	25	5.36	1.42		
Cognitive Flexibility (DSST)	URBAN	43	263.44	69.37	0.298	N.S
	RURAL	25	243.92	81.25		
Attentional Control Stroop Task	URBAN	43	33.70	8.16	0.669	N.S
	RURAL	25	34.64	9.60		
Computational Thinking Skills Test	URBAN	43	38.26	18.57	0.183	N.S
	RURAL	25	44.6	18.98		
Academic Achievement	URBAN	43	60.93	15.85	0.795	N.S
	RURAL	25	61.93	14.10		

Table 3. Samples t-tests Comparing Urban and Rural Pre-adolescent Students

Correlations						
		Computational ThinkingSkills	Working Memory	Cognitive Flexibility	Attentional Control	Academic Achievement
Computational Thinking Skills	Pearson Correlation	1	.093	-.016	.135	.198
Working Memory	Pearson Correlation	.093	1	.081	.144	.241*
Cognitive Flexibility	Pearson Correlation	-.016	.081	1	-.095	.095
Attentional Control	Pearson Correlation	.135	.144	-.095	1	.196
Academic Achievement	Pearson Correlation	.198	.241*	.095	.196	1

Table 4. Correlation Among all the Variables

have access to high-quality education and resources to help them develop cognitively and physically (Neitzel, 2018). In relationship studies, computational thinking skills have a strong positive link with working memory. Working memory is essential for the many levels of computational reasoning. For example, when deconstructing an issue, working memory assists in keeping track of the various elements of the problem and how they interact with one another. Computational thinking frequently includes remembering numerous bits of information at the same time, such as when abstracting crucial aspects from a difficult problem or constructing algorithms. For effective management and organized information, one must have a strong working memory. Developing computational thinking skills can lead to improved working memory. The study findings also demonstrated a beneficial association between computational thinking and another essential executive functioning skill, attentional control. Strong attentional control aids in cognitive load management, which is critical for performing challenging computational tasks. It enables people to prioritize work, manage resources effectively, and stay focused on the most important aspects of the problem. Poor attentional control can lead to errors in calculating tasks, such as missing vital information or improperly utilizing methods.

8. Limitations and Delimitations

This study does not look into other aspects like students' socioeconomic condition and type of schools. The sample size is very small. Studies conducted in only one government-aided school are the limitations of this study. Future research should look into other aspects, such as socioeconomic status or specialized school resources, to better understand the dynamics of skill development in varied settings.

Conclusion

With an emphasis on gender and residential status, the current study investigated the association between pre-adolescent pupils' academic accomplishment, executive functioning abilities, and computational thinking abilities. The results showed that working memory, attentional control, and computational thinking abilities do not significantly differ between males and girls. This is consistent with earlier studies showing that there are no significant gender differences in early adolescent cognitive abilities such as memory and problem-solving. Furthermore, the positive link revealed between working memory, attentional control, and academic accomplishment highlights the importance of executive function in academic success. Executive skills, such as working memory and attentional control, are required for higher-order thinking and problem-solving, both of which are essential for success in computational activities and overall academic achievement. These findings are consistent with previous research on the role of executive function as an indicator of academic achievement. These findings have important ramifications for classroom instruction as well as educational policy. Since enhancing working memory and attentional control can directly affect academic achievement and computational thinking skills, schools and educators should concentrate on helping students develop their executive functioning skills through focused interventions.

Understanding the relationship between computational thinking skills and executive functioning skills might help educators establish more effective instructional strategies. For example, breaking down problems into smaller, comprehensible chunks can assist students with limited working memory capacity in engaging in computational thinking. Providing external aids such as diagrams and step-by-step tutorials can lower the cognitive burden on working memory, allowing students to concentrate on strengthening their computational thinking skills without feeling overloaded. Because computational thinking is still in its early phases, the majority of teachers, particularly those in government schools, are unfamiliar with it. The majority of research on computational thinking concentrated entirely on computer science. As a result, more research and awareness are needed about computational thinking skills and their applications in mathematics. To summarize, executive functioning skills such as working memory and attentional control are crucial for enabling and sustaining computational reasoning. The interaction of various cognitive processes is critical for successful problem solving and learning, especially in subjects such as computer science and mathematics. So executive functioning skills are essential to successful computational thinking.

Acknowledgment

The authors appreciate the cooperation of the headmaster, teachers, and authorities of Al-Ameen Urdu-Tamil High School, Madurai, Tamil Nadu.

Disclosures and Funding

No funding was received for this study.

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https://doi.org/10.4018/978-1-7998-1479-5.ch008

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