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Online scratch activities during the COVID-19 pandemic: Computational and creative thinking

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ABSTRACT

This paper investigated the effect of online Scratch activities on college students' computational and creative thinking. The study adopted a mixed research design including one group pretest-posttest. The sample consisted of 24 child development undergraduates (23 female and 1 male) in the 2019-2020 academic year. The research was carried out in "Teaching science and mathematics in preschool education" course and lasted 12 weeks. The participants developed Scratch projects based on eight learning outcomes (four math and four science). Data were collected using the Computational Thinking Scale, the Marmara Creative Thinking Dispositions Scale, and reflective journals. The quantitative data were analyzed using a paired sample t-test. The qualitative data were analyzed using content analysis. The results showed that Scratch activities helped students develop computational and creative thinking. The results of this study provide evidence that Scratch activities develop the students' higher order skills. Ultimately, this research study recommends that Scratch activities ought to be integrated to science and mathematics education curriculums.

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1. INTRODUCTION

Rapid developments in information and communication technologies (ICT) and today's conditions reveal the necessity of raising individuals in accordance with 21st century skills. Researchers have postulated that computational and creative thinking which are the ones of the 21st-century skills are important for the needs of our age and are interrelated [1], [2]. Creative thinking is defined as one's ability to solve problems innovatively and create original and valuable products [3]. Although creativity has been taught mainly from the perspective of art and design for many years, it is now accepted that it contributes to various areas of life [4], [5]. Many studies revealed that in classroom activities, creative experience not only supports students' academic success, but also can increase students' innovative thinking, motivation and participation in the learning process [6], [7]. Computational thinking, the term which Wing brought to educational research literature [8], is a fundamental skill (reading, writing, arithmetic thinking) that has been a focal point of attention in recent years [9]–[11] and is a recent concept associated with the ability to "think like a computer scientist" at each level of education [8]. Computational thinking is one of the eight practices in Science and Engineering Applications within the framework of the Next Generation of Science Standards (NGSS) [12] and National Research Council (NRC) [13].

Researchers suggest that everybody should develop computational and creative thinking at an early age. Therefore, the teachers should first develop their computational and creative thinking so that they can incorporate them into their teaching [14], [15], because teachers are responsible for helping students develop their learning and skills. However, they are inadequate on computational and creative thinking and how to integrate them into their teaching. In this regard, to both develop the teachers' computational and creative thinking and promote their integration abilities of these skills into their teaching/learning, many countries have recognized the importance of computational and creative thinking and tried to incorporate them into their curricula. They have also developed numerous online platforms, especially game-based learning environments [16]. It has been stated that online platforms and programming activities support these skills in the creation of works in different fields [17]–[19]. Of these online platforms, block-based platforms (Scratch) provide students with the opportunity to "extend their creative expression to solve problems, create computational artifacts," and develop new knowledge [20].

The growth of creative expression and the development of creative thinking are supported by digital learning environments that encourage programming or computational thinking. Scratch, which is developed by Massachusetts Institute of Technology (MIT), is a free and visual programming language that enables K-12 students develop and create interactive learning objects such as animations, simulations, and games. It is a user-friendly program that provides instant feedback allowing students to program. It provides even inexperienced students with the opportunity to control the actions of different objects and create programs by bringing blocks together through "drag-and-drop" [21]–[23]. Scratch could be utilized to enhance both students' mathematical concepts and computational thinking skills. In this respect, to improve the participants' computational and creative thinking, they developed animations/similations related to four science and four math learning outcomes using Scratch during COVİD-19 pandemic in this study.

There is no consensus on the definition of computational thinking [21] although it is a popular topic that has been intensely studied over the last years [24]. However, we need to identify the similarities and differences among those definitions instead of trying to come up with a definite one [25]. For example, Papert, who was the first to use the term "computational thinking", argues that computational ideas can change the way children think in different areas [26]. The International Society for Technology in Education (ISTE) defines computational thinking as a logical organization, data analysis, and problem-solving process that involves generating solutions through algorithmic thinking and identifying, analyzing, and applying effective, and adequate possible solutions [27].

Computational thinking is related to the following concepts: i) Abstraction: Making a phenomenon more understandable by eliminating unnecessary details; ii) Algorithmic thinking: Finding a solution by clearly describing process steps [28]; iii) Decomposition: Making it easier to solve complex problems, better understanding new situations, and making large systems easier to design [28]; iv) Simultaneity: Completing different tasks at the same time for the same purpose; v) Debugging: Systematically analyzing and evaluating through different skills (testing, monitoring, logical thinking) to predict and verify outcomes; and vi) Generalization: Identifying and using patterns, similarities, and connections.

In recent years, there has been a consensus that creativity is a 21st-century skill that should be incorporated into curricula [29], [30]. Researchers define creativity in different ways. Creativity is a complex and multifaceted concept that is difficult to define [31]. Torrance defines it as "the process of sensing difficulties, problems, gaps in information, missing elements, something askew; making guesses and formulating hypotheses about these deficiencies; evaluating and testing these guesses and hypotheses; possibly revising and retesting them; and, last, communicating the results" [32]. Amabile defines creativity as one's ability to produce anything novel and useful [33].

2. LITERATURE REVIEW

In the literature, there have been many research on computational thinking creative thinking. In particular, Turkish researchers have focused on computational thinking since 2018 [34]–[40]. Of these studies, the researchers addressed computational thinking skills [34], [35], [37], [39]–[42], computational thinking self-efficacy [43], problem-solving [42], computational thinking skills with Dr. Scratch [44], academic performance [39], [40], and computational thinking perceived self-efficacy [36]. In these studies, the sample often consisted of middle school students [40]–[62]. Looking on the creative thinking, the researchers intensely carried out many research on creativity. In general, there are many research on computational and creative thinking from different perspectives, including looking at how these two constructs interact [19], [63] and looking at creativity within the context of computational thinking [64], [65].

Additionally, despite the fact that many computer-based learning platforms such as Scratch support the development of computational thinking abilities, research has so far focused mainly on qualitative approaches [9], [66]. However, there is only limited research that both quantitatively and qualitatively investigating the effect of using Scratch on computational and creative thinking. Since coding education has become popular all over the world, especially in Turkey, in recent years, we believe that this subject should attract more attention. Therefore, this study aimed to investigate the effect of online Scratch activities on computational and creative thinking of the college students studying in the Department Child Development during the COVID-19 pandemic.

This study investigated the effect of online Scratch activities on college students' computational and creative thinking. Thus, there were several research questions of the study: i) Is there a significant difference between pre-test and post-test mean scores of college students' computational thinking?; ii) Is there a significant difference between pre-test and post-test mean scores of college students' creative thinking?; and iii) How did the online Scratch activities affect the college students' computational and creative thinking during the process?

3. RESEARCH METHOD

This study used a mixed research design (quantitative and qualitative) including one group pretest-posttest design to evaluate the effect of online Scratch activities on the college students' computational and creative thinking [45]. A mixed research design helps researchers reduce biases inherent in either quantitative or qualitative methods and increase validity and reliability [46]. In line with this design, quantitative data were collected using the Computational Thinking Scale (CTS) and the Marmara Creative Thinking Dispositions Scale (MCTDS). The instruments were administered to the participants before (pre-test) and after the intervention (post-test). Qualitative data were obtained from participants' reflective journals.

3.1. Sample

The sample consisted of 24 undergraduate students (23 female and 1 male) in the Department of Child Development in the 2019-2020 academic year. All of them participated in the study on a voluntary basis. The participants had no experience in Scratch and the level of their technological knowledge was low. Their age varied from 17 to 20.

3.2. Procedure

The study was carried out in "Teaching Science and Mathematics in Preschool Education" course and lasted for 12 weeks in the first semester. The students participated in weekly both synchronous and asynchronous discussion forums during semester on Moodle Learning Management System. In the first week, the pre-tests were administered to all PSTs prior to the implementation. The participants were asked to develop Scratch projects related to science and math learning outcomes. Therefore, in the following weeks, to help the participants become familiar with the implementation and the functions of the Scratch and show how to use it, they received practical training about Scratch. For example, they learned how to drag and drop code blocks, save their Scratch projects, and create activities through algorithmic thinking and logic constructs. Specific demo for Scratch projects showing how to use code blocks in their projects was also provided to them. After the fourth week, the participants were asked to individually prepare separate Scratch projects for each week. As a result, each participant developed a total of 8 original Scratch projects related to four science and four math learning outcomes. The researchers evaluated their projects and provided instant feedback to them. Throughout the study, the participants also kept reflective journals based on the protocol questions related to Scratch projects on their personal blogs on Moodle.

3.3. Data collection tools

To investigate the students' computational thinking levels, Computational Thinking Scale (CTS) developed by Ertuğrul-Akyol was used [47]. The instrument consists of 30 items and three subscales (computational thinking, robotics-coding and software, and professional development and career planning). The items are rated on a five-point Likert-type scale (1=Strongly disagree, 2=Disagree, 3=Undecided, 4=Agree, 5=Strongly agree). The total score of the scale ranges from 30 to 150.

The other quantitative data collection tool is The Marmara Creative Thinking Dispositions Scale (MCTDS). This scale developed by Özgenel and Çetin [48] was used to determine the students' creative thinking levels. There are six subscales (self-discipline, innovation search, courage, inquisitive, doubt, and flexibility) and 25 items on the scale. The items are rated on a five-point Likert-type scale (1=Never, 2=Rarely, 3=Sometimes, 4=Generally, 5=Always). The total score of this scale ranges from 25 to 125. Cronbach's alpha reliability coefficient of the tests are 0.860 and 0.897, respectively. The qualitative data were collected from the participants' reflective journals. For the reflective journal, a protocol including 10 questions were developed based on the literature. They were asked to keep a journal every week and respond to questions related to their Scratch projects in order to reflect on their experiences, thoughts, and challenges.

3.4. Data analysis

The quantitative data were analyzed using the SPSS at a significance level of 0.05. First, the normality was tested using the Shapiro-Wilk test because the sample size is less than 50. The results indicated that the data were normally distributed ($p>0.05$). Therefore, for investigating the effect of online Scratch activities on computational and creative thinking, paired sample t-test was used. The qualitative data were analyzed using content analysis. Content analysis involves three stages: i) Conceptualizing data; ii) Organizing the data logically according to resulting concepts; and iii) Identifying themes that describe the data [49]. The first and second authors coded the qualitative data independently and compared them. Inter-rater reliability was found to be high (.86).

4. RESULTS

4.1. Is there a significant difference between pre-test and post-test mean scores of college students' computational thinking?

The results from the analysis of the quantitative and qualitative data of computational thinking are presented in Table 1. The paired sample t-test was used to determine the impact of the intervention on participants' computational thinking. The results showed that participants had a significantly higher mean posttest score than the pre-test score [$t_{(23)}=-7.68$; $p=0.000$], indicating that the intervention helped participants develop their computational thinking.

Table 1. Paired sample t-test scores on the participants' computational thinking

Variable	N	Test	X	S	$t_{(23)}$	P
Computational		Pre-test	2.31	.58		
thinking	24	Post-test	3.21	.43	-7.68	.000

4.2. Is there a significant difference between pre-test and post-test mean scores of college students' creative thinking?

The findings of the paired sample t-test used for determining the impact of the intervention on participants' creative thinking showed that participants had a significantly higher mean post-test MCTDS score than the pre-test score [$t_{(23)}=-11.41$; $p=0.000$]. This finding indicates that the intervention improved participants' creative thinking as shown in Table 2.

Table 2. Paired sample t-test scores on the participants' creative thinking

Variable	N	Test	X	S	$t_{(23)}$	P
Creative		Pre-test	3.43	.35		
thinking	24	Post-test	4.37	.32	-11.41	.000

4.3. How did the online Scratch activities affect the college students' computational and creative thinking?

Table 3 shows the qualitative results regarding the participants' computational thinking from their reflective journals. The qualitative results showed that the intervention helped participants develop their computational thinking over the weeks. Under the category of "repetitive actions," participants did not address anything in their blogs in the first week. However, almost all participants mentioned about repetitive actions in their blogs in the last week (N=20). Under the category of "algorithmic thinking," very few participants expressed their views about planning and steps in the first weeks. However, most participants mentioned those concepts in the last weeks. None of the participants expressed their opinions about using the code blocks in the first week. However, 20 participants addressed it in the eighth week.

Under the category of "decomposition," participants did not say anything about defining and subdividing a problem in the first week. However, they started to mention as the weeks progressed. Under the category of "simultaneity," participants were able to create projects flawlessly and fluidly, create activities that fit the purpose, and complete more than one task at the same time. Several quotes from the students' reflective journals and some screenshots from their Scratch projects are presented in Figures 1 and 2.

Table 3. Qualitative results regarding computational thinking

Category	Code	Frequency							
		W1	W2	W3	W4	W5	W6	W7	W8
Repetitive actions	Typing codes easily for repetitive actions	-	3	8	11	15	17	20	20
	Continuous rotation	-	2	5	6	10	12	15	17
	Continuous motion	-	3	5	7	11	13	15	19
	Continuous speech	-	2	5	8	10	14	16	18
	Continuous sound	-	2	5	5	7	9	9	12
Algorithmic thinking	Planning	-	5	8	10	13	15	17	21
	Following the steps	-	2	5	7	10	12	14	17
	Planning what code blocks to use	-	3	4	8	10	12	15	20
Decomposition	Defining and subdividing a problem	-	3	5	8	10	13	17	19
Simultaneity	Making it flawless and fluid	-	2	5	7	10	12	15	19
	Helped me develop the ability to complete two tasks at the same time	-	5	7	10	11	13	15	16
	Creating an activity that fits the purpose	-	2	3	6	8	12	15	20

Some quotes about repetitive actions (P15) and algorithmic thinking (P13):

> "*I know how to use codes for repetitive actions, so I can type the codes and get the repetitive actions going, like dropping music, for example*." (P15-week 3)
> "*I got the hang of the codes, so I was able to get all planets rotating for a certain period of time.*" (P15-week 4)
> "*For example, I was able to get the mother pigeon to clap her wings in a very short time because I learned what code was where, so I had no trouble finding them.*" (P15-week 6)
> "*I made a list of the necessary steps. You should first design and then actualize it so that you wouldn't confuse things. Everything goes wrong the same way if you misplace a code. So, I was very careful with it.*" (P13-week 6)

Figure 1. Scratch projects screenshots of (a) P15-week2, (b) P15-week4, (c) P15-week7, (d) P13-week1, (e) P13-week3, (f) P13-week6

Some quotes about decomposition (P2) and simultaneity (P17):

> "*For example, the problem is how to design a math activity on Scratch. The subproblem is "Is the level of knowledge about geometric shapes sufficient?" First, defining the problem and then moving on to action helped me realize the significance of defining a problem before going about a task.*" (P2-week 2)
> "*First, I chose a backdrop and a sprite and then events and motions, which helped me create my project of taking a walk-in nature.*" (P2-week 4)

> "*It helped me with the thing, first I thought about which sprite and backdrop to choose and which code blocks to use, and then I created my project of matching with numbers.*" (P2-week 5)
> "*First, I asked myself what kind of activity I could create with numbers, how to use the addition, what codes to use, which helped me create an activity that fit the project, identifying a problem and dividing it into subproblems helped me create my project by doing and living.*" (P2-week 6)
> "*It helped me perform more than one thing at the same time because first, I think about how to adapt the events to my sprites and then what codes to use. I mean, it helped me think about more than one thing at the same time. The events unfold consecutively at the same time.*" (P17-week 4)
> "*To create a Scratch project, you have to think about more than one thing. You have to think about what codes to use and what sprites to choose. For example, I used codes for fruits and then vegetables. My math topic was the sets; that's how I managed the whole process.*" (P17-week 6)

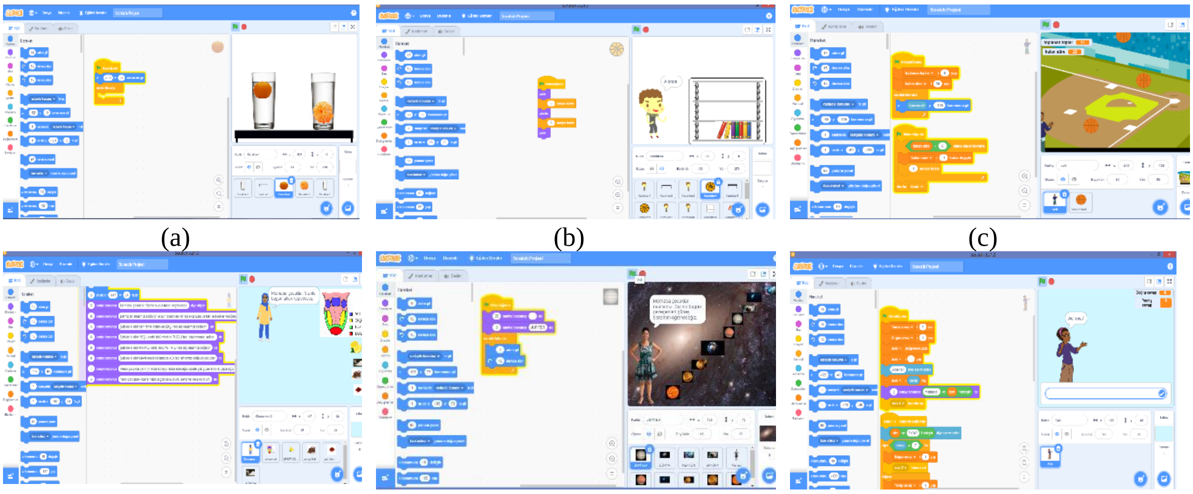

Figure 2. Scratch projects screenshots of (a) P2-week1, (b) P2-week4, (c) P2-week7, (d) P17-week1, (e) P17-week3, (f) P17-week8

Table 4 shows the qualitative results regarding the participants' computational thinking from their reflective journals. The qualitative results showed that the participants' creative thinking improved throughout the process. In the category of "fluency," only a few participants stated that the intervention improved their comprehensibility in the first weeks, whereas most participants noted it in the last weeks. More than half the participants remarked that the intervention helped them envision things and design things mentally in the last weeks. In the category of "originality," the students expressed that the intervention helped them create new things, use different blocks, and put new knowledge into practice in a different way. The quotes from the students' reflective journals and some screenshots from their Scratch projects as displayed in Figure 3.

Table 4. Qualitative results regarding creative thinking

Category	Code	Frequency							
		W1	W2	W3	W4	W5	W6	W7	W8
Fluency	Envisioning	2	6	9	12	15	15	18	21
	Increasing comprehensibility	1	2	7	11	15	16	18	20
	Designing mentally	1	3	6	10	12	15	17	18
Originality	Creating new things	1	3	7	10	12	15	15	20
	Using different blocks	-	1	3	7	10	12	14	16
	Putting new knowledge into practice in a different way	1	1	5	6	8	12	15	16

Some quotes about fluency (P3) and originality (P9):

> "*I think I made some progress on using the Scratch.*" (P3-week 2)

"*Of course, the course helped me think more deeply and from a broader perspective. The process was quite hard, but it made me feel more alert because it encouraged me to think in three dimensions.*" (P3-week 3)

"*The design process is mentally quite challenging. But as I focused on Scratch, I realized that Scratch projects are not as difficult as they used to be. I make sure that the material and objects are as close to reality as possible because kids remember what they see.*" (P3-week 5)

"*I've realized that I can create new and different visual things.*" (P9-week 4)

"*Now I can design and develop my own games.*" (P9-week 5)

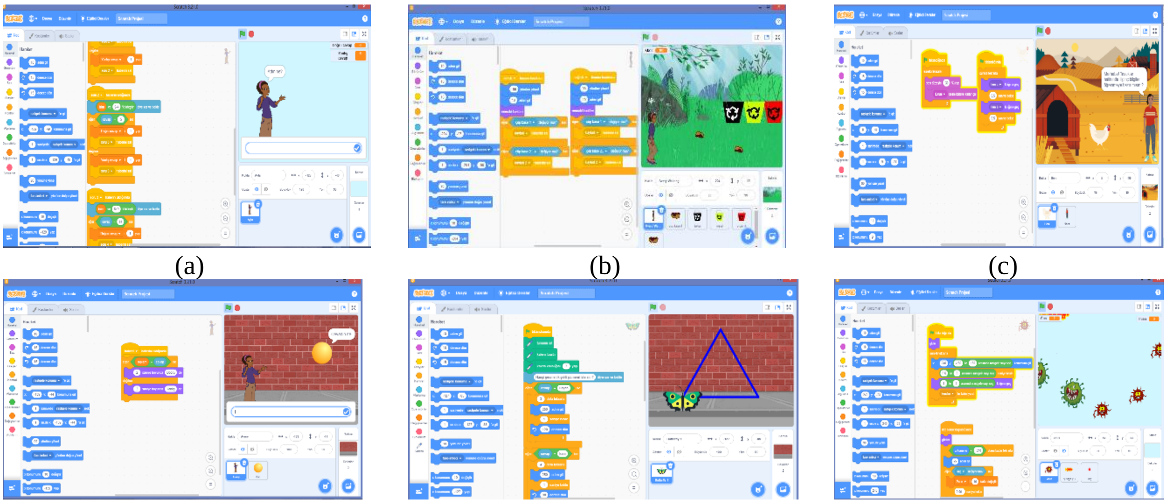

Figure 3. Scratch projects screenshots of (a) P3-week2, (b) P3-week5, (c) P3-week8, (d) P9-week3, (e) P9-week4, (f) P9-week7

5. DISCUSSION

This study investigated the effect of online Scratch activities on college students' computational and creative thinking. The quantitative findings of the first research question of the study showed that the intervention enhanced the participants' their computational thinking. Our results are consistent with those of many research in the literature [52]–[56], [60], [61]. Many research indicated that using Scratch helped the learners to develop their computational thinking [52], [60], [61], [67], [68]. For example, Rodríguez-Martínez, González-Calero, and Sáez-López [52] found that Scratch helped six graders learn math concepts and develop computational thinking. In another study, the researchers determined that Scratch activities enhanced fifth graders' computational thinking skills [67].

The quantitative findings regarding the second research question of the study showed that Scratch activities improved the students' creative thinking. Previous studies found similar findings [57]–[59]. For example, Park *et al.* [59] conducted a study with 27 Korean primary school students using Scratch and educational robots. The curriculum in the study was divided into three stages: fundamental, advanced, and application. In the fundamental stage, the students learned and practiced basic programming language. In the advanced stage, they learned and practiced advanced programming language. In the application stage, they applied programming to Korean, music, and math. The results showed that the activities helped the students develop fluency and originality, which are two subfactors of creativity. The results of this study support that block-based platforms such as Scratch provide students with the opportunity to "extend their creative expression to solve problems, create computational artifacts," and develop new knowledge [20].

The findings on third research question of the study showed that qualitative findings obtained from reflective journals supported those of the quantitative analysis. The results indicated that the participants did not mention almost anything about computational and creative thinking in their reflective journals in the first weeks. One of the reasons of this may be that the college students at first had difficulty in understanding about what and how to do because they received online education during the COVID-19 pandemic. The other is that computational and creative thinking are complex skills that take some time to develop. However, in the following weeks, they began to highlight about these skills, suggesting that the Scratch activities helped themselves develop their computational and creative thinking. Previous studies provide these findings. For example, Ozyol [41] at first found that students had difficulty learning the sub concepts of computational thinking and had inadequate knowledge of the process. However, in the last weeks, he noted that they developed coding and algorithmic thinking skills, learned many concepts (e.g., rotation, variable), and made decisions more quickly and easily. Çatlak, Tekdal, and Baz [51] conducted a literature review and concluded that students considered Scratch an easy, engaging, and fun program that helped them develop algorithmic thinking and programming skills and made them more creative and motivated. In addition, reflective journals often subjectively focus on personal experiences, reactions, and reflections. Therefore, this might improve students' critical thinking abilities, motivate them to reflect on their own thinking (meta-cognition), and help for their assignments [69].

6. CONCLUSION

This study investigating the impact of online Scratch activities on the computational and creative thinking of college students concluded that the intervention enhanced these skills that are 21st century skills. In addition, this study indicated that both qualitative and quantitative findings support each other. The results imply that the outcomes of this study are applicable in education practice. Therefore, to educate qualified individuals with 21st century skills, the scratch activities ought to be integrated into both science and mathematics education curriculums and teacher education programs.

The results in general show that Scratch helps college students develop computational and creative thinking. However, this study has two limitations. First, there was no control group in this study. Although our results indicate that Scratch is effective in developing the students' computational and creative thinking, a research design with a control group would have been ideal for making valuable comparisons and drawing more definitive conclusions. Second, we did not investigate whether some personal characteristics affect their computational and creative thinking, although it has been found to be associated with computational and creative thinking. However, this was because almost all students in the classroom were female. Researchers should integrate Scratch into other disciplines and determine its effect on different dependent variables. We offer that they should also conduct longitudinal studies to better understand the long-term effects of Scratch activities on students' computational and creative thinking.

REFERENCES

[1] M. D. DeSchryver and A. Yadav, "Creative and computational thinking in the context of new literacies: Working with teachers to scaffold complex technology-mediated approaches to teaching and learning," *Journal of Technology and Teacher Education*, vol.23, no.3, pp. 411–431, 2015.

[2] F. Kalelioğlu, Y. Gülbahar, and V. Kukul, "A Framework for Computational Thinking Based on a Systematic Research Review," *Baltic Journal of Modern Computing*, vol. 4, no. 3, pp. 583–596, 2016.

[3] E. P. Torrance, *Torrance test of creative thinking: Norms–technical manual*. Princeton, NJ: Personnel Press Ginn, 1974.

[4] L. Donovan, T. D. Green, and C. Mason, "Examining the 21st century classroom: Developing an innovation configuration map," *Journal of Educational Computing Research*, vol. 50, no. 2, pp.161–178, 2014, doi: https://doi.org/10.2190/EC.50.2.a.

[5] C. C. Navarrete, "Creative thinking in digital game design and development: A case study," *Computers & Education*, vol. 69, pp. 320–331, 2013, doi: https://doi.org/10.1016/j.compedu.2013.07.025.

[6] K. J. Anthony, and W. M. Frazier, "Teaching Students to Create Undiscovered Ideas," *Science Scope*, vol. 33, no. 1, pp. 20–27, 2009. https://www.jstor.org/stable/43183898

[7] D. Davies, D. Jindal-Snape, C. Collier, R. Digby, P. Hay, and A. Howe, "Creative learning environments in education- A systematic literature review," *Thinking Skills and Creativity*, vol. 8, pp. 80–91, 2013, doi: 10.1016/j.tsc.2012.07.004.

[8] J. M. Wing, "Computational thinking," *Communications of the ACM*, vol. 49, no. 3, pp. 33–35, 2006, doi: 10.1145/1118178.1118215.

[9] K. Brennan, and M. Resnick, "New frameworks for studying and assessing the development of computational thinking," *Paper presented at the American Education Researcher Association*, Vancouver, Canada, 2012.

[10] M. Berry, *Computing in the national curriculum: A guide for primary teachers.* Bedford: Computing at School, 2013.

[11] National Research Council. *Report of a workshop on the scope and nature of computational thinking*. Washington, DC: National Academies Press, 2010.

[12] NGSS Lead States. *Next generation science standards: For states, by states*. Washington, DC: The National Academy Press, 2013.

[13] National Research Council, *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press, 2012.

[14] A. Yadav, S. Gretter, J. Good, and T. McLean, "Computational thinking in teacher education," in *Emerging research, practice, and policy on computational thinking*, Springer, Cham, 2017, pp. 205–220, doi: https://doi.org/10.1007/978-3-319-52691-1_13.

[15] A. Yadav, C. Mayfield, N. Zhou, S. Hambrusch, and J. T. Korb, "Computational thinking in elementary and secondary teacher education," *ACM Transactions on Computing Education (TOCE)*, vol. 14, no. 1, 2014, doi: https://doi.org/10.1145/2576872.

[16] A. Eguiluz, M. Guenaga, P. Garaizar, and C. Olivares-Rodrıguez, "Exploring the progression of early programmers in a set of computational thinking challenges via clickstream analysis," *IEEE Transactions on Emerging Topics in Computing*, vol. 8, no. 1, pp. 256–261, 2017, doi: https://doi.org/10.1109/TETC.2017.2768550.

[17] K. W. Lau and P. Y. Lee, "The use of virtual reality for creating unusual environmental stimulation to motivate students to explore creative ideas," *Interactive Learning Environments*, vol. 23, no. 1, pp. 3–18, 2015, doi: 10.1080/10494820.2012.745426.

[18] P. Mishra and A. Yadav, "Of art and algorithm: Rethinking technology & creativity in the 21st century," *TechTrends*, vol. 57, no. 3, p. 10–14, 2013, doi: https://doi.org/10.1007/s11528-013-0655-z.

[19] Y.-H. Seo and J.-H. Kim, “Analyzing the effects of coding education through pair programming for the computational thinking and creativity of elementary school students,” *Indian Journal of Science and Technology*, vol. 9, no. 46, pp. 1–5, 2016, doi: https://doi.org/10.17485/ijst/2016/v9i46/107837.
[20] A. Yadav, and S. Cooper, “Fostering creativity through computing,” *Communications of the ACM*, vol. 60, no. 2, pp. 31–33, 2017, doi: https://doi.org/10.1145/3029595.
[21] S. Grover and R. Pea, “Computational Thinking in K–12: A Review of the State of the Field,” *Educational Researcher*, vol. 42, no. 1, pp. 38–43, 2013, doi: https://doi.org/10.3102/0013189X12463051.
[22] M. Resnick *et al.* “Scratch: programming for all,” *Communications of the ACM,* vol. 52, no. 11, pp. 60–67, 2009, doi: https://doi.org/10.1145/1592761.1592779.
[23] P. Sengupta, J. S. Kinnebrew, S. Basu, G. Biswas, and D. Clark, “Integrating computational thinking with K-12 science education using agent-based computation: A theoretical framework,” *Education and Information Technologies*, vol. 18, no. 2, pp. 351–380, 2013, doi: https://doi.org/10.1007/s10639-012-9240-x.
[24] A. Şahiner and S. B. Kert, “Komputasyonel düşünme kavramı ile ilgili 2006-2015 yılları arasındaki çalışmaların incelenmesi,” *Avrupa Bilim ve Teknoloji Dergisi*, vol. 5, no. 9, pp. 38–43, 2016.
[25] J. Voogt, P. Fisser, J. Good, P. Mishra, and A. Yadav, “Computational thinking in compulsory education: towards an agenda for research and practice,” *Education and Information Technologies*, vol. 20, no. 4, pp. 715–728, 2015. doi: 10.1007/s10639-015-9412-6
[26] S. Papert, *Mindstorms: Children, computers, and powerful ideas*. NY: Basic Books, 1980.
[27] International Society for Technology in Education (ISTE) and The Computer Science Teachers Association (CSTA), “Operational definition of computational thinking for K-12 Education,” 2011.
[28] A. Csizmadia *et al.*, “Computational thinking: A guide for teachers,” 2015. [Online]. Available: https://eprints.soton.ac.uk/424545/1/150818_Computational_Thinking_1_.pdf.
[29] R. A. Beghetto, “Creativity in the classroom,” in *The Cambridge handbook of creativity*, Cambridge: Cambridge University Press, 2010, pp. 447–463.
[30] L. S. Vygotsky, “Imagination and creativity in childhood,” *Journal of Russian and East European Psychology,* vol. 42, no. 1, pp. 7–97, 2004, doi: https://doi.org/10.1080/10610405.2004.11059210.
[31] D. J. Treffinger, S. G. Isaksen, and K. B. Stead-Dorval, *Creative problem solving: An introduction*. Singapore: Prufrock Press Inc., 2006.
[32] E. P. Torrance, “Understanding creativity: where to start?” *Psychological Inquiry*, vol. 4, no. 3, pp. 232–234, 1993.
[33] T. M. Amabile, *Growing up creative: Nurturing a lifetime of creativity*. Crown House Publishing Limited, 1989.
[34] A. Akkaya, “The effects of serious games on students’ conceptual knowledge of object-oriented programming and computational thinking skills,” M.S. Thesis, Boğaziçi University, 2018.
[35] B. Berikan, “Bilgi işlemsel düşünme becerisine yönelik tasarlanan 'veri setleriyle problem çözme' öğrenme deneyiminin biçimlendirici değerlendirmesi,” Ph.D. dissertation, Gazi University, 2018.
[36] E. Erdem, “Blok tabanlı ortamlarda programlama öğretimi sürecinde farklı öğretim stratejilerinin çeşitli değişkenler açısından incelenmesi,” M.S. Thesis, Başkent University, 2018.
[37] U. Ilic, H. İ. Haseski, U. Tugtekin, “Publication trends over 10 years of computational thinking research,” *Contemporary Educational Technology*, vol. 9, no. 2, pp.131–153, 2018, doi: https://doi.org/10.30935/cet.414798.
[38] V. Kukul, “Programlama öğretiminde farklı yapılandırılan süreçlerin öğrencilerin bilgi işlemsel düşünme becerilerine, özyeterliliklerine ve programlama başarılarına etkisi,” M.S. Thesis, Gazi University, 2018.
[39] E. Şimşek, “Programlama öğretiminde robotik ve scratch uygulamalarının öğrencilerin bilgi işlemsel düşünme becerileri ve akademik başarılarına etkisi,” M.S. Thesis, Ondokuz Mayıs University, 2018.
[40] V. Yolcu, “Programlama eğitiminde robotik kullanımının akademik başarı, bilgi işlemsel düşünme becerisi ve öğrenme transferine etkisi,” M.S. Thesis, Süleyman Demirel University, 2018.
[41] B. Özyol, “Bilgi-işlemsel düşünme becerisinin kazandırılmasına yönelik bir ortam tasarımı ve geliştirilmesi,” M.S. Thesis, Afyon Kocatepe University, 2019.
[42] B. Turan, “Ortaokul öğrencilerinin geliştirdiği oyun ve robot projelerinde probleme dayalı öğrenmenin problem çözme ve bilgi işlemsel düşünme becerilerine etkisi,” M.S. Thesis, Van Yüzüncü Yıl University, 2019.
[43] N. Taş, “Farklılaştırılmış bilgisayar destekli matematik etkinliklerinin üstün yeteneklilerin bilgi işlemsel düşünme özyeterlikleri ve matematiğe yönelik tutumlarına etkisi,” Ph.D. Dissertation, Atatürk University, 2018.
[44] A. Oluk, and Ö. Korkmaz, “Comparing students' scratch skills with their computational thinking skills in terms of different variables,” *International Journal of Modern Education and Computer Science*, vol. 8, no. 11, pp. 1–7, 2016, doi: 10.5815/ijmecs.2016.11.01.
[45] J. W. Creswell, “Mapping the field of mixed methods research,” *Journal of Mixed Methods Research*, vol. 3, no. 2, pp. 95–108, 2008, doi: https://doi.org/10.1177/1558689808330883.
[46] J. W. Creswell and V. L. Plano Clark, *Designing and conducting mixed methods research*. Thousand Oaks, CA: Sage, 2011.
[47] B. Ertuğrul Akyol, “STEM etkinliklerinin fen bilgisi öğretmen adaylarının bilgi işlemsel, eleştirel, yaratıcı düşünme ve problem çözme becerilerine etkisi,” Ph.D. Dissertation, Erciyes University, 2020.
[48] M. Özgenel and M. Çetin, “Marmara yaratıcı düşünme eğilimleri ölçeğinin geliştirilmesi: Geçerlik ve güvenirlik çalışması,” *Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi*, vol. 46, no. 46, pp. 113–132, 2017, doi: https://doi.org/10.15285/maruaebd.335087.
[49] A. Yıldırım and H. Şimşek, *Sosyal bilimlerde nitel araştırma yöntemleri*. Ankara: Seçkin Yayınları, 2017.
[50] M. B. Miles and A. M. Huberman, *Qualitative data analysis: An expanded sourcebook*. Sage Publication, 1994.
[51] Ş. Çatlak, M. Tekdal, and F. Ç. Baz, “Scratch Yazılımı ile Programlama Öğretiminin Durumu: Bir Doküman İnceleme Çalışması,” *Journal of Instructional Technologies & Teacher Education*, vol. 4, no. 3, pp. 13–25, 2015, [Online]. Available: https://dergipark.org.tr/en/download/article-file/231335.
[52] J. A. Rodríguez-Martínez, J. A. González-Calero, and J. M. Sáez-López, “Computational thinking and mathematics using Scratch: an experiment with sixth-grade students,” *Interactive Learning Environments*, vol. 28, no. 3, pp. 316–327, 2020, doi: https://doi.org/10.1080/10494820.2019.1612448.
[53] L. A. Calao, J. Moreno-León, H. E. Correa, and G. Robles, “Developing Mathematical Thinking with Scratch an Experiment with 6th Grade Students,” in *European Conference on Technology Enhanced Learning,* Springer, Cham, 2015, pp. 17–27, doi: https://doi.org/10.1007/978-3-319-24258-3_2.
[54] L. Gabriele, F. Bertacchini, A. Tavernise, L. Vaca-Cárdenas, P. Pantano, and E. Bilotta, “Lesson planning by computational thinking skills in Italian pre-service teachers,” *Informatics in Education*, vol. 18, no. 1, pp. 69–104, 2019, doi: https://doi.org/10.15388/infedu.2019.04

[55] H. Kim, H. Choi, J. Han, and H. So, "Enhancing teachers' ICT capacity for 21st century learning environment: Three cases of teacher education in Korea," *Australasian Journal of Educational Technology*, vol. 28, no. 6, pp. 965–982, 2012, doi: https://doi.org/10.14742/ajet.805.

[56] J.-M. Sáez-López, M. Román-González, and E. Vázquez-Cano, "Visual programming languages integrated across the curriculum in elementary school: A two year case study using "Scratch" in five schools," *Computers & Education*, vol. 97, pp. 129–141, 2016, doi: https://doi.org/10.1016/j.compedu.2016.03.003.

[57] K. Williams, I. Igel, R. Poveda, V. Kapila, and M. Iskander, "Enriching K-12 Science and Mathematics Education Using LEGOs," *Advances in Engineering Education*, vol. 3, no. 2, pp. 1–27, 2012.

[58] M. Barak and M. Assal, "Robotics and STEM learning: Students" achievements in assignments according to the P3 Task Taxonomy-practice, problem solving and projects," *International Journal of Technology and Design Education*, vol. 28, no. 1, pp. 121–144, 2016, doi: https://doi.org/10.1007/s10798-016-9385-9.

[59] I. Park, D. Kim, J. Oh, Y. Jang, and K. Lim, "Learning effects of pedagogical robots with programming in elementary school environments in Korea," *Indian Journal of Science and Technology*, vol. 8, no. 26, pp. 1–5, 2015, doi: 10.17485/ijst/2015/v8i26/80723.

[60] L. Benton, C. Hoyles, I. Kalas, and R. Noss, "Bridging primary programming and mathematics: Some findings of design research in England," *Digital Experiences in Mathematics Education*, vol. 3, no. 2, pp. 115–138, 2017, doi:10.1007/s40751-017-0028-x.

[61] N. Calder, "Using Scratch: An integrated problem-solving approach to mathematical thinking," *Australian Primary Mathematics Classroom*, vol. 15, no. 4, pp. 9–14, 2010.

[62] E. Polat, S. Hopcan, S. Kucuk, and B. Sisman, "A comprehensive assessment of secondary school students' computational thinking skills," *British Journal of Educational Technology*, vol. 52, no. 5, pp. 1965–1980, 2021, doi: 10.1111/bjet.13092.

[63] L. D. Miller *et al.*, "Improving learning of computational thinking using creative thinking exercises in CS-1 computer science courses," *2013 IEEE Frontiers in Education Conference (FIE)*, 2013, doi: https://doi.org/10.1109/FIE.2013.6685067.

[64] V. E. Bennett, K. H. Koh, and A. Repenning, "Computing creativity. Divergence in computational thinking," *Proceedings of the 44th ACM Technical Symposium on Computer Science Education*, 2010, doi: https://doi.org/10.1145/2445196.2445302.

[65] S. Manske & H. U. Hoppe, "Automated indicators to assess the creativity of solutions to programming exercises," *2014 IEEE 14th International Conference on Advanced Learning Technologies*, 2014, doi: https://doi. org/10.1109/ICALT.2014.147.

[66] X. Tang, Y. Yin, Q. Lin, R. Hadad, and X. Zhai, "Assessing computational thinking: A systematic review of empirical studies," *Computers & Education*, vol. 148, pp. 103798, 2020, doi: https://doi.org/10.1016/j.compedu.2019.

[67] A. Oluk, Ö. Korkmaz, and H. A. Oluk, "Effect of scratch on 5th graders' algorithm development and computational thinking skills," *Turkish Journal of Computer and Mathematics Education*, vol. 9, no. 1, pp. 54–71, 2018, doi: 10.16949/turkbilmat.399588.

[68] F. Ke, "An implementation of design-based learning through creating educational computer games: A case study on mathematics learning during design and computing," *Computers & Education*, vol. 73, no. 1, pp. 26–39, 2014, doi: 10.1016/j.compedu.2013.12.010.

[69] M. Homik and E. Melis, "Reflective Journaling," 2006. [Online]. Available: https://www.niu.edu/citl/resources/guides/instructional-guide/reflective-journals-and-learning-logs.shtml (November 1, 2022)

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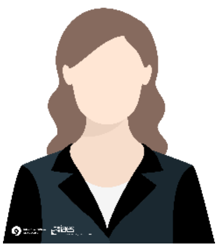

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