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ARTICLE

The Effects of Designing Scientific Experiments with Visual Programming Language on Learning Outcomes

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Abstract
When the studies on the effectiveness of visual programming language are examined, it is seen that studies on coding teaching have been carried out frequently recently. In this study, Scratch was used as a teaching tool in teaching science lessons. In this way, a new perspective has been brought to Scratch applications. In the related study, the effects of designing science experiments with visual programming language (Scratch) on students' beliefs of self-efficacy related to computational thinking (CT) skills, metacognitive awareness levels, and motivation levels for science learning are examined. This study was carried out using a single-group research design based on pretest and posttest applications. Students attending the fifth grade participated in this study. Sixty-five students attending the fifth grade participated in the research. Research data were obtained using "Self-Efficacy Perception Scale for CT Skills (SEP_CTS)," "Metacognitive Awareness Scale (MAS)," and "Motivation Scale for Science Learning (MSSL)." The research process is 10 weeks and 3 days in total. It was determined that designing science experiments in visual programming language applications based on Scratch improved students' CT self-efficacy perceptions, but did not have the expected effect on students' science learning motivation and metacognitive awareness. This research provides evidence that some skills can be improved by using Scratch as a teaching tool in different courses. With the focus of research on this subject, it can contributed to the development of new understandings of Scratch in teaching processes.

1 Introduction

1.1 Virtual Environments

Virtual experiments are the preparation of virtual experiment setups with computer software for learning-teaching purposes that allow learners to question, discover, prove, or

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visualize scientific knowledge using virtual laboratory materials (Özdemir, 2019). In another definition, virtual experiments are defined as carrying out scientific experiments in digital and virtual environments using computer and network technologies (Huang et al., 2010). Virtual environments provide many opportunities for students to individually design and implement experiments, learn by doing and experiencing, use various technologies, get rid of many experimental equipment, and be protected from various security risks (Faulconer & Gruss, 2018; Gerhátová et al., 2021; Heradio et al., 2016; Peffer et al., 2015). Cao and Hsu (2023) discussed the advantages of virtual experiments in four basic aspects: cost, independence, security, and interaction. The fact that high-cost equipment needed in traditional experiments is not needed when performing virtual experiments may suggest that virtual experiments will be advantageous in terms of cost. Through virtual experiments, students are offered unlimited repetition opportunities and the opportunity to experiment as they wish, regardless of time and place (Kavlak & Birhanlı, 2023). Conducting science experiments in virtual environments provides a significant advantage in terms of safety due to students not having direct contact with chemicals and no interaction with sharp or flammable materials (Çelik & Karamustafaoğlu, 2016). It can be said that, thanks to the safety provided by virtual experiments, it has become possible for students to carry out dangerous experiments individually. Thus, it can be thought that it will contribute to the students being active and gaining equal opportunities during the experiment process. On the other hand, it can be said that students are provided with two-way interactions while both designing virtual experiments and using these experiments for learning purposes.

1.2 Visual Programming Language

Looking from the past to the present, it is seen that complex and difficult skills are made easier for students with the development of technology, and thus they gain experience in these skills from an early age. Coding is also among these skills. Although coding was seen as a difficult skill in the past, nowadays these skills can also be performed by younger students. Therefore, the twenty-first century requires all students not only to have sufficient knowledge about computers, but also to reach a sufficient level in computer applications. Accordingly, in order to allow students carrying the productive potential of the future needed by countries to reach the intended level, to gain more experience with computers, and to increase interest thereof in this field, they have been given coding training from an early age. Thus, students starting in primary school and continuing up to 12th grade will learn new problem-solving approaches that will benefit from computational thinking, to develop their basic computer knowledge and to be both a user and creator of programming technology (K12 Computer Science Framework Steering Committee, 2016). But learning programming may not be easy for a beginner regardless of their age (Kelleher & Pausch, 2005). Beginner programmers not only have to produce solutions to problems and understand the working system of programs, but also have to learn programming syntax and commands, which can be difficult for them (Kelleher & Pausch, 2005). In contrast, visual programming language overcomes the technical and syntax-related difficulties of text-based programming languages and provides an important opportunity for students to experience introductory programming/coding activities and meet computer science (Bers et al., 2014; Brown et al., 2016; Effenberger & Pelánek, 2018).

It can be said that visual programming language is easy to use (Mohamad et al., 2011a), because these programming environments allow coding as if the students were putting together puzzle pieces (Weintrop & Wilensky, 2015). Programming using visual

programming language is accomplished by dragging and dropping programming instructions together (Maloney et. al., 2010b; Akcaoglu, 2014; Brown et al., 2016; Weintrop, 2019). In such environments, students put together the instructions and can receive visual feedback that lets the user know if a particular construct is valid (Weintrop & Wilensky, 2015). A natural language tag that conveys the shape, color, and function of the block provides convenience to the user about how and where the block can be used (Weintrop & Wilensky, 2015; Brown et al., 2016; Weintrop, 2019). As a result of these conveniences provided by visual programming language, young children with no experience or knowledge of programming can be supported and get a coding experience to create their own games or mobile apps (Akcaoglu, 2014; Brown et al., 2016; Effenberger & Pelánek, 2018; Weintrop, 2019). Besides not requiring professional computational thinking (CT) skills, other advantages of visual programming language/coding are that it allows refactoring of existing applications and rapid application development (Mohamad et al., 2011b).

1.2.1 Scratch

Scratch is a programming tool that offers young users the opportunity to improve their computer programming skills while working towards a goal (Maloney et. al., 2010b). Saving and shareability of Scratch projects allows people to discuss, edit, and share them, creating an online community (Ouahbi et al., 2015; Resnick et al., 2009). Scratch, offering programming in 70 different languages, can be accessed free of charge at https://scratch.mit.edu/. Scratch allows creating or importing various types of media such as music, pictures, and sound, so that the developed projects can be more interesting and motivating (Maloney et al., 2010a, 2010b). This means that programmers are not limited to the images or sounds that exist in Scratch. Also Scratch offers opportunities for more interaction via Universal Serial Bus (USB) (Malan & Leitner, 2007).

According to Maloney et al., (2010a, 2010b), although Scratch was initially used in out-of-school learning environments, its use in schools has gradually increased. Because Scratch aims to facilitate programming for people who do not have programming experience, and to prepare various applications such as animations or simulations in online environments and to provide the opportunity to share these applications (Resnick et al., 2009), thus, it is targeted to encourage creativity, increase the motivation to interact with computers, and reduce the level of anxiety (Meerbaum-Salant et al., 2011). In this process, Scratch users can develop the reasoning, creativity, and collaboration skills that are considered essential for individuals in the twenty-first century (Resnick et al., 2009). Along with these effects of Scratch, there are also different studies dealing with the effect of Scratch in learning environments. The result of a study on Scratch showed that Scratch encourages students to learn algorithms (Tekerek & Altan, 2014). In another study, it was examined whether Scratch had an effect on students' algorithm development and CT skills, and it was determined that Scratch improved both skills (Oluk et al., 2018). Rodríguez-Martínez et al. (2020), on the other hand, revealed that Scratch can be used to support students' both their CT skills and their mathematical ideas. As a result of a different study on Scratch-based game activities, it was seen that students' attitudes and self-efficacy perceptions were not affected in a meaningful way, but the academic success of students in C++ programming language increased (Korkmaz, 2016). In a study examining the effect of Scratch use on primary school students' problem-solving skills (PSS), it was seen that programming with Scratch did not make a significant difference on their PSS (Kalelioğlu & Gülbahar, 2014). It is seen that a similar study was done by Jiang and Li (2021). With the related research, it

has been revealed that although Scratch has a positive effect on students' creativity, cooperation, and critical thinking skills, it does not have a similar effect on algorithmic thinking skills and PSS. Contrary to the results of this study, it was revealed by Erol and Çırak (2022) that Scratch-supported game design activities increase students' PSS. In the study conducted by Lai and Yang (2011), the effect of Scratch on both PSS and logical reasoning skills was examined. With the study carried out, it has been determined that Scratch did not cause a significant change in students' logical reasoning skills, but positively affected their PSS. The research results of Çoban Budak et al. (2021) have shown that Scratch improves students' reflective thinking skills.

1.3 Computational Thinking

With the development of technology in recent years, it can be said that one of the skills expected from individuals is CT. Although there are many explanations in the literature for the definition of CT, the definition made by the International Society for Technology in Education and the Computer Science Teachers Association (ISTE & CSTA, 2011) is widely accepted. The content of this accepted definition is presented in Fig. 1.

CT emerges as an important feature of the twenty-first century for students in the digital age (Yadav et.al., 2011; Labusch et al., 2019). For this reason, the continuous development of CT continues to be more accepted as an essential skill in today's living spaces (Kevin Keith et al., 2019). As it is seen as a skill that students should have in the twenty-first century (Angeli & Giannakos, 2020), it is suggested that CT, as a central part of problem-solving, should be passed on to future generations, by expanding access to new technologies (Patton et al., 2019). In addition to CT skills, students are expected to have an awareness of how to use these skills and when to apply them (Yadav et. al., 2011). For this, it is argued that a teaching related to CT should be done from the primary school process (Sanford & Naidu, 2016). It is possible to say that CT has many advantages for students throughout the learning process. Because it is argued that students can learn a basic subject thanks to CT (Tan et al., 2019). Additionally, it is argued that CT can significantly improve students' PSS (Yadav et.al., 2011), abstract thinking, pattern recognition, and logical reasoning (Yadav et.al., 2014; Angeli & Giannakos, 2020). However, it has been determined that various elements in learning-teaching environments affect students' CT skills. In a study, it was found that students' academic self-efficacy has a significant effect on their CT skills (Lee & Lee, 2021). The meta-analysis study by Hwang and Hwang (2020) showed that software education, while the meta-analysis study by Sun et al. (2021), showed that the use of educational games could improve students' CT skills.

1.4 Metacognition

Although metacognition is mostly defined as "thinking of thinking" (Flavell, 1979; Kuhn & Dean, 2004; Lai, 2011a; Martinez, 2006), it refers to upper-level thinking that provides control of cognitive processes (Livingstone, 2003). According to Kuhn and Dean (2004), metacognition is defined as the awareness and management of the individual's thoughts, while according to Martinez (2006), it is defined as the control and monitoring of consideration. Planning for a particular learning task, evaluation by monitoring progress is metacognitive (Livingstone, 2003).



Fig. 1 Definition content of CT

Flavell (1979) expressed that metacognitive experience, metacognitive knowledge, actions, and goal form metacognition. The knowledge that is reached about cognitive processes and the knowledge that will be used to control cognitive processes are explained as

metacognitive knowledge (Livingstone, 2003). Metacognitive knowledge includes information on how existing information can be used in line with the determined purpose, which strategies can be used should be used, and when and where cognitive strategies should be used (Clarebout et al., 2013). Metacognitive experiences are defined by Flavell (1979) as cognitive or emotional experiences that accompany or relate to a mental activity. Clarebout et al. (2013) emphasized that metacognitive experiences are related to the conscious awareness of how much progress a person has made in the cognitive process to reach learning goals. While goals are related to the goals of cognitive enterprise, actions are related to cognition or behavior employed for this purpose (Flavell, 1979).

Since metacognition will support success in learning, it is considered important to examine metacognitive activity and development for the students' metacognition (Livingstone, 2003). The effects of various practices in the learning-teaching processes on students' metacognition have been examined by different studies. Various studies have examined how students' metacognitive awareness is affected by practices such as argumentation (Ulu, 2019; Kalemkuş et al., 2021), experimentation (Kalemkuş et al., 2021), inquiry-based learning (Varlı & Uluçınar Sağır, 2019), and academic coaching (Howlett et al., 2021).

1.5 Motivation

Motivation can be defined as the driving force behind all the actions of an individual (Rabideau, 2005). This driving force directs the individual to perform or not perform a behavior (Gredler et al., 2004). Based on this definition, it is thought that there is a reason behind every action (Zubaydullayeva, 2023). These reasons vary as internal or external reasons. Therefore, motivation is also divided into internal or external. While an individual's doing something in line with her or his personal pleasures and interests is defined as intrinsic motivation, an individual's doing something with the expectation of encountering a reinforcing situation is defined as extrinsic motivation (Lai, 2011b; Reiss, 2012). The internal and external reasons that students have can be considered an important element in the realization of learning. Because in order for students to be successful in any field, they must be able to motivate themselves sufficiently or be motivated by the teacher (Asror et al., 2023). Student motivation is affected by factors such as the role of teachers, classroom organization, interaction, and classroom climate (Vatansever Bayraktar, 2015). In addition to these factors, various studies have shown that student motivation is positively affected by various methods and techniques. These methods and techniques include different applications such as drama method (Ormancı & Özcan, 2014), blended learning (Ünsal, 2012), online robotic coding (Dağlı et al., 2022), Web 2.0 tools (Maraşlı & Değirmencioğlu, 2023), and digital story (Yılmaz & Özden, 2022). It has been determined through research that although motivation is affected by some variables, it also has effects on different variables. For example, motivation has an impact on situations such as cognitive awareness (Arslan, 2023), academic success (Alkan & Bayri, 2017), attitude (Kahyaoğlu & Pesen, 2013), reading comprehension (Yıldız & Akyol, 2011), and anxiety (Müezzin & Özata, 2019).

The COVID19 epidemic, which affected 91.3% of students worldwide (UNESCO, 2020), significantly changed the functioning of educational institutions (Cucinotta & Vanelli, 2020) and caused face-to-face learning environments to shift to online environments (Evans et al., 2020; Woolliscroft, 2020). Therefore, it can be said that the ability to practice science experiments carried out in traditional environments in virtual environments has become a need for students and teachers. When the literature is examined, it can

be said that studies on virtual science laboratories (Achuthan et al., 2021; Diwakar et al., 2016, 2023; Elmoazen et al., 2023; Hurtado-Bermúdez & Romero-Abrio, 2023; Moosvi et al., 2019; Serrano-Perez et al., 2023; Sun et al., 2023) are mostly carried out using augmented reality, virtual reality, online simultaneous video application, and simulation technologies. CT skills have an important place in ensuring that twenty-first century students are not only individuals who use technology effectively, but also take an active role in technology production (Yadav et al., 2017). However, CT skills cannot develop naturally and training is needed for this (Sanford & Naidu, 2016). Metacognitive skills, another variable discussed in the research, help students take responsibility for their own learning and increase the meaningfulness of their learning (Blakey & Spence, 1990). Metacognition is considered very important in the twenty-first century due to its potential to empower students with responsibility for learning (Blakey & Spence, 1990; Mahdavi, 2014). It can be argued that motivation, which is another variable that affects and affects the teaching process, is a determining factor in increasing the quality of teaching. Therefore, it can be thought that it is necessary to determine the teaching practices that are effective in developing these skills and to raise the awareness of teachers about these teaching practices. Scratch, a visual programming language, can be used as a teaching tool in different courses (Costa et al., 2016; Iskandar et al., 2023; Julia et al., 2020; Lu, 2021; Molina-Ayuso et al., 2022; Papadakis et al., 2016; Rodríguez-Martínez et al., 2020; Sarasa-Cabezuelo, 2019; Sjöberg et al., 2018; Tekerek & Altan, 2014).

However, there are limited studies on how the perception of self-efficacy for CT skills, metacognitive awareness, and motivation for learning science are affected when virtual experiments are carried out using a visual programming language. Therefore, it is aimed to reveal a scientific basis on how the perception of self-efficacy for IT skills, metacognitive awareness, and motivation for learning science will be affected if Scratch is used as a teaching tool. In addition to this aim, we are trying to give teachers and students a new perspective so that they can conduct science experiments in virtual environments. Therefore, in this study, the effects of designing science experiments with visual programming language (Scratch) on students' perceptions of self-efficacy towards CT skills, motivation levels for science learning and metacognitive awareness levels, are examined. The subproblems of this research are listed as follows:

1. Does designing science experiments with the Scratch program have an effect on students' CT self-efficacy perceptions?
2. Does designing science experiments with the Scratch program have an effect on students' metacognitive awareness levels?
3. How are students' motivation levels affected by the process of designing science experiments with the Scratch program?

2 Study Method

In this study, the effects of designing science experiments with visual programming language (Scratch) on students' perceptions of self-efficacy towards CT skills, motivation levels for science learning, and metacognitive awareness levels are examined. Among the experimental research designs, a single group pretest–posttest has been used and the effect

of the experimental procedure was examined with applications made on a single group (Büyüköztürk et al., 2015).

2.1 Sampling

The sample of the study was composed of students attending the fifth grade in a school in the northeast of Turkey. In order to determine the sample of the research, criterion sampling, which requires the sample group of the research to consist of participants with certain qualifications, was used (Büyüköztürk et al., 2015). Qualifications determined for the formation of the sample group in the study, on the other hand, are that students take an information technology course and have the necessary background (Internet, tablet, computer, and basic Scratch knowledge) to participate in study applications. Data collection and application processes were carried out considering the students' voluntary participation in the study. Participant student information is given in Table 1.

The research was carried out with 65 fifth grade students, 45 girls (69.2%) and 20 boys (30.8).

2.2 Data Collection Tools

2.2.1 Self-Efficacy Perception Scale for CT Skills

Self-Efficacy Perception Scale for CT Skills (SEP_CTS), developed by Gülbahar et al. (2019), was used in both pretest and posttest to determine students' self-efficacy perceptions about CT skills. The developed scale is in 3-level Likert scale and consists of the following sub-dimensions: "Self Confidence Competency, Algorithm Design Competency, Basic Programming Competency, Data Processing Competency and Problem Solving Competency." Cronbach alpha was calculated as 0.898 in this study.

2.2.2 Metacognitive Awareness Scale

This scale, developed by Sperling et al. (2002), was adapted into Turkish by Karakelle and Saraç (2007) in order to determine the metacognitive awareness of students between the 3rd and 9th grades studying in Turkey. Form A of the scale, which consists of two different forms, is for 3rd, 4th and 5th grade students; form B is used for 6th, 7th, 8th, and 9th grade students. In the research conducted by us, form A was used considering the grade level of the students. This scale, developed as a 3-level Likert scale, consists of 12 items. Additionally, the scale consists of a single dimension. While the Cronbach Alpha value of form A was found to be 0.64 by Karakelle and Saraç (2007), it was determined to be 0.638 in this study.

Table 1 Information about participating students

Gender	*f*	%
Girls	45	69.2
Boys	20	30.8

2.2.3 Motivation Scale for Science Learning

Motivation Scale for Science Learning (MSSL), developed by Tuan, Chin, and Shieh (2005) and rearranged in Turkish by Yılmaz and Huyugüzel Çavaş (2007), was used as a data collection tool in both the pretest and the posttest to determine students' motivation levels for learning science. The Cronbach Alpha value of this 5-level Likert scale, which includes 6 sub-dimensions, was calculated as 0.858. These sub-dimensions are Science learning value, Self-efficacy, Achievement goal, Active learning strategies, Performance goal, and Learning environment stimulation.

Implementation Process In order to design science experiments through visual programming language (Scratch) applications, first of all, plans for the related science experiments were prepared by the first researcher who works on science teaching. These prepared experiments consist of floating or sinking in water, being attracted or not attracted by the magnet, and electrical circuits. Before these experiments were presented to the students in line with the prepared plans, they were tested in the Scratch program by the two researchers. During the tests, an exchange of ideas was provided between the researchers, and measures were taken for the disruptive situations.

After all the experimental plans were tested by the researchers in the Scratch program, the application stage was started with the students. In the application step, firstly, the tools to be used to collect data were applied to the students as a pretest. Then, studies on designing science experiments in Scratch was started with the students. These studies in Scratch were conducted by both researchers. Examples of screenshots taken during the studies are given in Figs. 2, 3, and 4.

After the pre-planned science experiments in the Scratch program were implemented by the researchers, the same experiments were asked to be designed by the students again in the Scratch program. Students carried out these experiments individually in Scratch. During this process, students were allowed to interact with each other and with the second researcher, who was the practitioner. However, after the completion of the

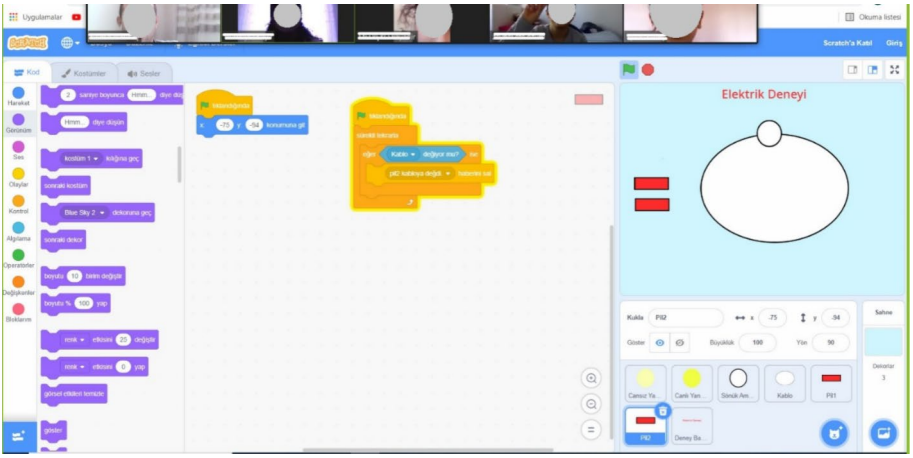


Fig. 2 Electricity experiment carried out by students in Scratch program (stage 1)

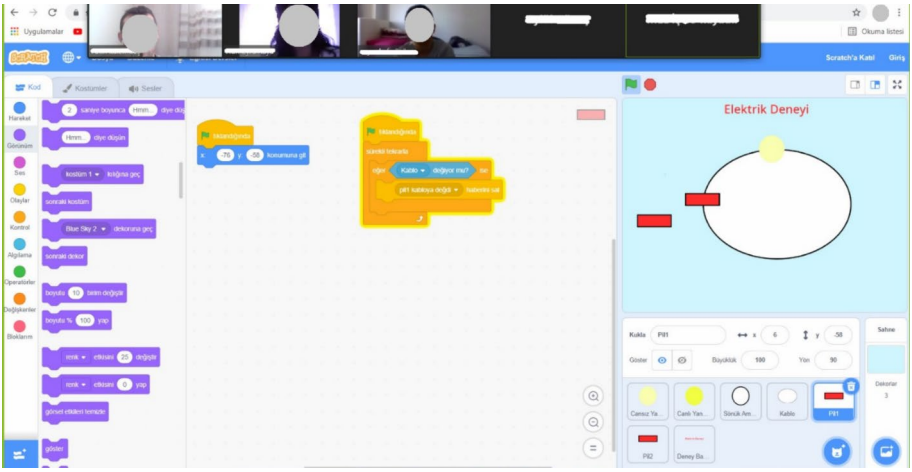


Fig. 3 Electricity experiment carried out by students in Scratch program (stage 2)

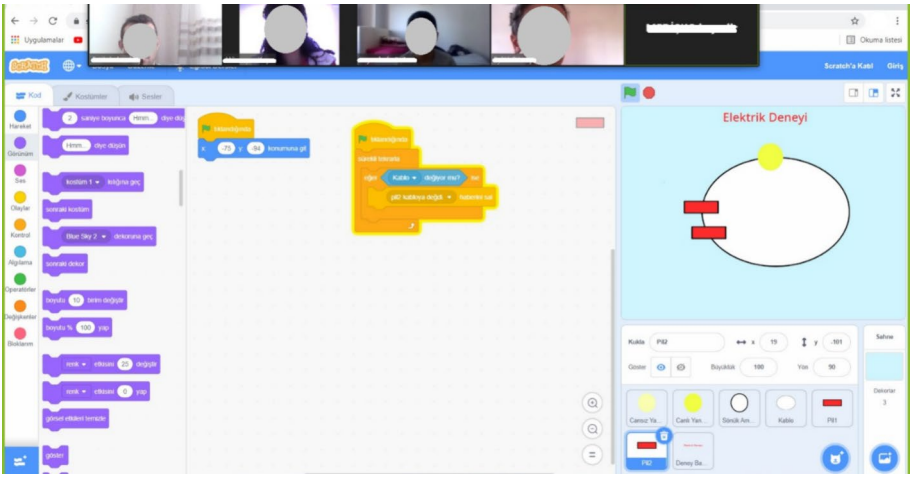


Fig. 4 Electricity experiment carried out by students in Scratch program (stage 3)

science experiments in Scratch, the students did not interact with each other. Therefore, although students interact with each other during the applications, a limited interaction can be said since they do not interact at the end of the applications. In addition, students were supported to find solutions to the problems they encountered while trying to design science experiments in the Scratch. The students shared the screenshots of the experiments they implemented in the Scratch with their researchers. Thus, it is aimed that students participate more actively in the practices carried out in Scratch voluntarily.

After the implementation of all the experimental plans prepared in the Scratch program, posttest data collection practices were started. The research process is 10 weeks and 3 days in total.

2.3 Analysis of Data

The pre-application and post-application data of the research were analyzed using the SPSS 22.0 package program. The normality conditions of SEP_CTS, Metacognitive Awareness Scale (MAS), and MSSL were examined by the Kolmogorov Smirnov test and their statistical values are given in Table 2.

According to Table 2, the total scores obtained from SEP_CTS, MAS, and MSSL do not exhibit normal distribution ($p < 0.05$). From this point of view, non-parametric tests were deemed suitable for data analysis. Wilcoxon signed-rank test was used to examine the change in the mean score (pretest–posttest) of the students regarding SEP_CTS, MAS, and MSSL.

3 Findings

The SEP_CTS and sub-dimensions of SEP_CTS scores of the students were analyzed using the Wilcoxon signed-rank test to determine whether designing science experiments with visual programming language (Scratch) applications had an effect on improving students' self-efficacy perceptions regarding CT skills. The findings regarding the analysis performed are shown in Table 3.

Considering Table 3, it was evaluated that there was a significant difference between the scores the students got from SEP_CTS (pretest–posttest), and it was determined that the posttest scores were in favor ($z = -4.137$; $p < 0.05$). From this point of view, it has been revealed that designing science experiments with visual programming language (Scratch) applications has a positive effect on students' perceptions of CT skills. Also it is understood that designing science experiments with visual programming language (Scratch) applications causes improvement in the sub-dimensions of Designing Algorithms, Problem Solving Competence, and Basic Programming Competence ($z = -5.775$, $p = 0.000$; $z = -2.285$, $p = 0.022$; $z = -3.005$, $p = 0.003$). However, when the findings of Data Processing Competence and Self-Confidence Competence sub-dimensions are examined, there is no statistically significant change ($z = -1.754$, $p = 0.079$; $z = -1.704$, $p = 0.088$).

The findings obtained by analyzing the Wilcoxon signed-rank test to determine whether the use of visual programming language (Scratch) applications to develop scientific experiments has an effect on increasing students' MAS scores are shown in Table 4.

In Table 4, it is seen that the average score of the students from MAS (pretest–posttest) did not change significantly at the end of the applications ($z = -1.036$; $p > 0.05$). Based

Table 2 Results of Kolmogorov–Smirnov tests

Scales		Statistic	df	*p*
SEP_CTS	Pretest	0.118	65	0.025*
	Posttest	0.121	65	0.019*
MAS	Pretest	0.128	65	0.01*
	Posttest	0.175	65	0.00*
MSSL	Pretest	0.149	65	0.001*
	Posttest	0.124	65	0.015*

*Significant at $p < 0.05$ level

Table 3 Wilcoxon signed-rank test results regarding pretest–posttest scores of SEP_CTS and sub-dimensions of SEP_CTS

Scale/sub-dimensions	Pretest–posttest scores	*N*	Rank average	Rank total	*z*	*p*
Scale	Negative rank	17	24.79	421.50	−4.137	0.000*
	Positive rank	47	35.29	1658.50		
	Equal	1				
Algorithm design competence	Negative rank	9	18.33	165	−5.775	0.000*
	Positive rank	54	34.28	1851		
	Equal	2				
Problem-solving competence	Negative rank	19	34.29	651.5	−2.285	0.022*
	Positive rank	43	30.27	1301.5		
	Equal	3				
Data processing competence	Negative rank	22	27.55	606	−1.754	0.079
	Positive rank	35	29.91	1047		
	Equal	8				
Basic programming competence	Negative rank	22	23.09	508	−3.005	0.003*
	Positive rank	38	34.79	1322		
	Equal	5				
Self-confidence competence	Negative rank	21	22.02	462	−1.704	0.088
	Positive rank	29	28.02	812.5		
	Equal	15				

*Significant at $p < 0.05$ level

Table 4 Wilcoxon signed-rank test results for MAS pretest–posttest scores

Pretest–posttest scores	*N*	Rank average	Rank total	*z*	*p*
Negative rank	22	31.66	696.50	−1.036	0.300
Positive rank	35	27.33	956.50		
Equal	8				

*Significant at $p < 0.05$ level

on this, it can be said that the design of visual programming language (Scratch) applications and science experiments does not have a remarkable effect on students' metacognitive awareness.

In order to examine the effect of designing science experiments with visual programming language (Scratch) applications on students' science learning motivation, MSSL and MSSL sub-dimensions mean scores (pretest–posttest) were examined with the Wilcoxon signed-rank test and the findings are shown in Table 5.

It is seen that the scores the students got from MSSL before and after the application did not show a significant difference (Table 5) ($z = -1.160$; $p > 0.05$). Based on this, it can be said that designing science experiments through visual programming language (Scratch) applications does not have a statistically significant influence on students' motivation to learn science.

Also, designing science experiments with visual programming language (Scratch) applications significantly increased the posttest scores of the Active Learning Strategies,

Table 5 Wilcoxon signed-rank test results for MSSL and MSSL sub-dimensions pretest–posttest scores

Scale/sub-dimensions	Pretest–posttest scores	*N*	Rank average	Rank total	*z*	*p*
Scale	Negative rank	27	29.04	784.00	−1.160	0.246
	Positive rank	34	32.56	1107.00		
	Equal	4				
Self-efficacy	Negative rank	37	31.58	1168.50	−1.603	0.109
	Positive rank	24	30.10	722.50		
	Equal	4				
Active learning strategies	Negative rank	20	25.95	519.00	−2.279	0.023*
	Positive rank	36	29.92	1077.00		
	Equal	9				
Value of learning science	Negative rank	18	30.97	557.50	−2.481	0.013*
	Positive rank	41	29.57	1212.50		
	Equal	6				
Performance purpose	Negative rank	38	27.93	1061.50	−1.872	0.061
	Positive rank	19	31.13	591.50		
	Equal	8				
Achievement purpose	Negative rank	22	25.18	554.00	−2.343	0.019*
	Positive rank	36	32.14	1157.00		
	Equal	7				
Encouragement in the learning environment	Negative rank	22	28.66	630.50	−1.923	0.054
	Positive rank	37	30.80	1139.50		
	Equal	6				

*Significant at $p<0.05$ level

Value of Learning Science, and Achievement Purpose sub-dimensions of MSSL applied to students ($z=-2.279$, $p=0.023$; $z=-2.481$, $p=0.013$; $z=-2.343$, $p=0.019$). However, when the findings related to self-efficacy, performance goal, and encouragement in the learning environment sub-dimensions were examined, it was found that the difference was not significant ($z=-1.603$, $p=0.109$; $z=-1.872$, $p=0.061$; $z=-1.923$, $p=0.054$ respectively).

4 Discussion, Conclusion, and Recommendations

In this study, the effect of 5th grade students designing science experiments in Scratch, a visual programming language, on their computational thinking self-efficacy perceptions, metacognitive awareness, and motivation for learning science was examined. Although the findings obtained as a result of the research did not cause a significant difference in the "data processing competence" and "self-confidence competence" dimensions of these applications, the sub-dimensions of "algorithm design competence," "problem solving competence," and "basic programming competence" increased significantly. It has been determined that thinking improves the perception of self-efficacy. This result is consistent with other research findings examining the effect of Scratch teaching on computational thinking skills (Kert et al., 2020; Rodríguez-Martínez et al., 2020; Gökçe & Aydoğan

Yenmez, 2023). However, the relevant research is not about teaching Scratch, but about using Scratch as a tool for teaching. When the results obtained from this research and other research results are considered together, it can be thought that using Scratch for teaching purposes, like teaching Scratch, is effective on students' computational thinking skills. The research participants conducted by us consist of students who can already program in Scratch at a basic level. Therefore, it may be possible to further develop the "computational thinking skills" supported by Scratch teaching through Scratch-based teaching activities. The research conducted by Piedade and Dorotea (2023) showed that Scratch-based activities integrated into different disciplines support students' "computational thinking" skills. It can be thought that by using Scratch in educational environments, students' programming proficiency may be supported as they design algorithms to produce their target product, find possible solutions to solve the problems they encounter, test them and produce new solutions if necessary, and establish a cause-effect relationship between codes in the programming language. In addition, although Scratch is a tool for learning programming, it can also be used to create content, produce projects, and create simulations by visualizing experiments (Iskrenovic-Momcilovic, 2020). Considering these opportunities provided by Scratch, it highlights the importance of its use in educational environments. In addition, considering that student-centered applications affect computational thinking skills (Çimentepe, 2019; Jun et al., 2017; Angeli & Valanides, 2020; Kaya et al., 2020; Yanış Kelleci, 2020), Scratch, which is integrated into educational environments, is beneficial to students. It can be argued that the opportunity to be active also supports this result. Based on this, in addition to teaching Scratch, the use of Scratch as a teaching tool can be encouraged by using Scratch-based applications in the teaching process.

In this study, it was determined that designing science experiments with the visual programming language (Scratch) did not improve students' metacognitive awareness levels, contrary to expectations. However, Daher et al. (2020) found that the metacognitive processes of teacher candidates improved in their study on solving mathematical problems in Scratch programming. In environments where both student–student and student–teacher interaction exists, students have the opportunity to think not only about their own cognitive states but also about the cognitive states of their friends (Frith, 2012; Martinez, 2006). Therefore, the importance of group work based on interaction and collaboration comes to the fore for the development of metacognitive capacity (Biasutti & Frate, 2018). Online environments can be seen as an important element in the development of metacognitive capacity, as they enable students to manage themselves and take responsibility for learning (Garrison, 2003) and create an environment of collaboration and interaction. Scratch, one of the online environments, can be used to develop metacognitive capacity by providing students with the opportunity for collaboration and interaction (Ntalakoura & Ravanis, 2014) starting from the preschool period, and also by allowing group work in online environments. In the study conducted by us, it can be said that the collaboration and interaction between students were extremely limited since the Scratch applications were carried out online through distance education and the students worked individually. Therefore, findings have been presented indicating that students' metacognitive awareness cannot develop in these environments. Considering Martinez's (2006) suggestion that the interaction between students should be increased in order to develop their metacognitive capacities, the lack of development of students' metacognitive awareness levels in this study can be attributed to the extremely limited cooperation and interaction. In addition, it is thought that not using metacognitive strategies in Scratch applications will be effective in reaching the relevant result. For this reason, it should not be thought that metacognition will develop without any intervention when using Scratch applications in the teaching

process, and plans should be made to develop metacognition before these applications. In order to make these plans, teachers' awareness of the concept of metacognition must be increased. Nevertheless, it is considered an indicator of metacognition that students suggest different methods to solve a problem during programming practices and monitor their own thoughts while searching for program errors (Gomez et al., 2019). Therefore, in addition to improving students' metacognitive abilities in the process of programming implementation, teachers can explore students' knowledge construction process, cognitive skills, and metacognitive abilities, and thus access important information to provide appropriate guidance to students (Jing et al., 2020). In order to learn students' metacognition levels, students' learning processes must be followed and supported by teachers.

Finally, thanks to the related study, it was revealed that designing science experiments in Scratch did not cause a significant difference in motivation to learn science of students. In line with this result, it is seen that the expectations (Sáez-López, et al., 2023) regarding the positive effect of Scratch applications on student motivation are not met. However, at this point, it may be necessary to distinguish between motivation to learn programming and motivation to learn any course. Because although Scratch is the goal in the first case, it is a teaching tool in the second case. In cases where Scratch is the goal, it has been determined that students' motivation to learn programming develops positively (Saygıner & Tüzün, 2023). However, it has been determined by this study that this expectation is not met when Scratch is a teaching tool. The fact that the use of Scratch for teaching science subjects is a new application for students can be seen as the reason for this situation. In addition, it is thought that students' self-efficacy levels for programming through Scratch may also affect their motivation to learn science. There may be a difference between students with high self-efficacy towards programming through Scratch compared low self-efficacy towards programming through Scratch in terms of motivation levels for learning science. In order to determine the validity of this idea clearly, it needs to be examined by carrying out different studies. In other words, the relationship between students' self-efficacy levels for programming through Scratch and their level of motivation to learn any course can be examined. As another reason for this result, it can be seen that the cognitive participation of the students did not change significantly with these applications (Qin et al., 2023).

It is suggested that not only Scratch teaching should be done in teaching environments, but also teaching for different disciplines can be done with Scratch. So Scratch can be used as a teaching tool. In this way, information for students can be visualized through simulations. It has been determined that there are differences between the two groups in learning basic geometric shapes among students who continue their education with traditional methods and those who continue to use the Scratch program (Iskrenovic-Momcilovic, 2020). Therefore, the result of this research supports the idea put forward. However, it can be said that there is a need for studies examining whether the use of Scratch supports the success of students in different disciplines.

Scratch can be used both as a tool for students to reflect on what they have learned and use the information, and for teachers to visualize information through simulations. Students can transform the knowledge they have acquired into a visual format through Scratch. Thus, an idea can be obtained about the information that the students have structured. In other words, it can be thought that Scratch can be an alternative technique in evaluating students. It is suggested by the authors to carry out researches for various purposes regarding the use of Scratch in teaching processes as a tool for evaluating students.

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Data Availability The datasets analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics Committee Approval This research was carried out by obtaining the Ethics Committee Approval with the decision number 21 of the Ethics Committee of Social and Human Sciences of Kafkas University, dated 21.04.2022 and numbered 32.

Ethical Statement All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent Statement Informed consent was obtained from all individual participants included in the study.

Conflict of Interest The authors declare that they have no conflict of interest.

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