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Effect of Web-Based Collaborative Learning Method with Scratch on Critical Thinking Skills of 5th Grade Students

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This study aimed to investigate the effect of web-based collaborative learning method with Scratch software on the critical thinking skills of 5th grade students and to create materials in Scratch software on the biodiversity subject. This study, in which a quasi-experimental design with pre-test - post-test control group was used, was carried out with 96 fifth grade students selected using convenient sampling method. In the implementation of the study, in addition to the education and training activities on biodiversity in the control groups, the students in the experimental group created products using the web-based collaborative learning method with Scratch in science and information technologies and software courses. As a result of the t-test for the independent samples of the post-test data obtained from the critical thinking questionnaire, it was determined that the critical thinking skills of the experimental group students were higher than the control group students. It is recommended for younger individuals to use Scratch to come up with solutions by using critical thinking skills to cope with complex problems affecting the whole world such as global warming, wars, and pandemics, and to choose the right solution amongst the given ones. Teachers can get an idea about students' opinions, conceptual errors, and their capability to express themselves, and they can reorganize the educational activities by taking these variables into consideration.

Introduction

Faced with a rapidly changing world with pandemics, global disasters, biological wars and new inventions, individuals need to acquire certain skills from a very early age so that they can be beneficial to humanity and their societies in the future. With the competition in many fields due to the rapid increase in population, it has become increasingly important to equip students with the skills they will need in the world of tomorrow. Countries such as the USA, Australia, Finland, Singapore and technology companies came together and carried out various projects in order to train qualified individuals for the 21st century in the business world. As a result of these projects, which aimed to promote new teaching-learning and assessment methods

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that are suitable for the use of digital resources in the education curriculum with the participation of companies such as Cisco, Microsoft and Intel, 21st-century learning frameworks were developed (Griffin, & Care, 2015). When the frameworks of Partnership for 21st Century Skills [P21], National Research Council [NRC], the Assessment and Teaching of 21st Century Skills Project [ATC21] are examined, it is seen that critical thinking and collaboration dimensions of 21st-century skills are included separately and in a similar manner (Lai & Viering, 2012; NRC, 2012; P21, 2009). Critical thinking is emphasized in the knowledge construction dimension in the cognitive domain of 21st-century skills that young people will need throughout their lives (Kang, Heo, Jo, Shin, & Seo, 2010). In the systematic study of Van Laar, van Deursen, van Dijk, and de Haan, (2017), the 21st-century digital skills that individuals should acquire were stated as knowledge management, communication, cooperation, critical thinking, creativity, flexibility, and self-direction. The International Society for Technology in Education (ISTE) has set some standards for students to learn efficiently in digital life. The National Educational Technology Standards (NETS) set by ISTE are divided into seven components: 1. Creative communicator 2. Global collaborator 3. Digital citizen 4. Computational thinker 5. Knowledge builder 6. Innovative designer 7. Empowered student (ISTE, 2016). The Future of Education and Skills Learning Compass 2030 Project, which aims for students to determine their own paths in every case, emphasizes the importance of critical thinking in relation to the competence of taking responsibility. For the competence of creating new values in the project, curiosity, and a critical thinking mind focused on development and cooperation are emphasized (Organization for Economic Cooperation and Development [OECD], 2018). The Next Generation Science Standards (NGSS) Project aims to help students develop collaborative learning and critical thinking skills in line with 21st-century education strategies (NRC, 2015).

There are many definitions of critical thinking, which involves a process that requires thinkers to develop a sound criterion for analyzing and evaluating their own thinking (Elder & Paul; 1994). According to Eggen and Kauchak (2001), critical thinking is the ability of individuals to evaluate and draw conclusions based on evidence, while according to Hudgins and Edeman (1988), it is an intellectual skill in which a person consciously and consistently implements solutions when faced with a problem. The origins of the word “critical” are traced back to the Greek words “kriticos” meaning “to recognize and distinguish” and “krition” meaning "standard" (Jones, McCreery, Judge, & Eales-Reynolds, 2013). The philosophical roots of critical thinking date back to Socrates, who emphasized the importance of seeking evidence 2,500 years ago. The method known as “Socratic Questioning” used by the Greek philosopher Socrates, who is well-known for revealing the importance of asking questions that force people to think, is a critical thinking strategy that is still used today. It is known that Socrates was executed in 399 BC because of his consecutive questions. Francis Bacon, Thomas More and René Descartes, with their books “The Advancement of Learning”, “Rules for the Direction of the Mind” and “Utopia”, delivered the discourses that laid the foundations of critical thinking (Bacon, 1828; Descartes, 1701/2012; More, 1890). In the 20th century, Dewey emphasized the importance of a critical approach to real-world problems in his book “How We Think” (Dewey, 2022).

Seymour Papert, who introduced Scratch to the literature, first mentioned the relationship between coding and thinking skills in his book “Mindstorms: Children, computer, and power ideas” in 1980. Bringing original ideas to life, creating something new and solving problems in the digital world are possible with coding (Nouri, Zhang, Mannila, & Norén, 2020). Critical thinking is a skill related to coding as it includes the processes of applying solutions, making decisions, evaluating according to criteria and creating them. Conditional expressions used by designers while coding, repeating operator concepts, testing, debugging, abstracting, questioning, connecting processes are related to thinking skills (Brennan & Resnick, 2012).

Nowadays, it has become important to understand the opportunities and threats presented by technology and attention has been drawn to raising individuals who can communicate with information technologies by using coding skills (Falloon, 2016; Kanbul & Uzunboylu, 2017). With coding, students are familiarised with the disciplines used by computer engineers, game and graphic designers (Hutchison, Nadolny, & Estapa, 2016). While programming refers to solving a problem, designing and implementing a solution more comprehensively, coding refers to implementing a solution in a programming language (Armoni & Gal-Ezer, 2014; Duncan, 2014). It is obvious that students who are new to coding have difficulty in changing variables and detecting their mistakes (Aivaloglou, Hermans, Moreno-León, & Robles, 2017; Fields, Vasudevan, & Kafai, 2015; Hermans & Aivaloglou, 2017; Moreno-León, Robles & Román-González, 2015). For example, Moreno-León, Robles, and Román-González (2015) introduced a web application called “Dr. Scratch” in their research. The authors point out that this application is useful for detecting errors in Scratch projects, improving their codes, and improving "computational thinking skills". In another study conducted by Aivaloglou, Hermans, Moreno-León, and Robles (2017) in which Dr. Scratch projects were selected as the data set, emphasized that the evaluation of students' progress in programming skills over time and the problems related to the quality of the programs should be investigated.

When the other two studies completed on Scratch are examined, it is seen that Fields, Vasudevan ve Kafai, (2015), explored ways to support the creation of engaging digital media in Scratch, a visual-based programming language and community. They analyzed the work of a class of high school student collectives programming music videos as part of a collaborative challenge in the online Scratch community. As a result of the research, they highlighted the innate social aspects of media creation, highlighting a shift from a computational focus to computational participation. Similarly, Hermans and Aivaloglou (2017) organized an online course on Scratch programming and software engineering concepts, which lasted 6 weeks, with students aged 7-11. In their research, they aimed to teach software engineering principles to students, and as a result of the research, they concluded that students over the age of 12 were more successful in programming.

Scratch is a coding program that is increasingly being used in the field of education as it avoids common challenges such as typos and consistency errors encountered in the beginner level of traditional programming languages (Chang, Tsai, & Chin, 2017; Niemelä, 2017). Users are able to share their projects with other users on Scratch's online community pages (Weintrop, Beheshti, Horn, Orton, Jona, Trouille, & Wilensky, 2015). In addition, users are also able to communicate with the project creator and other users by commenting on the posted projects (Almeida & Pessoa, 2017; Niemelä, 2017). It is recommended that Scratch software be used as a tool to develop digital competence and 21st century skills (Nouri et al., 2020).

Problem Status

In today's globalized world, individuals are exposed to an infinite amount of information every hour of the day. It has become a necessity for individuals of all ages to develop a thinking system in which they can question and evaluate the information they encounter. Trends in International Mathematics and Science Study (TIMSS) emphasizes thinking skills while assessing the problem-solving and reasoning processes of 4th and 8^{th}-grade students in mathematics and science (Mullis & Martin, 2017). The International Association for the

Evaluation of Educational Achievement (IEA) carries out (PIRLS) studies to evaluate the reading skills of 4th grade students. In order to form an opinion regarding the critical thinking of students in digital texts on the internet, ePIRLS has been implemented since 2016 (Mullis & Martin, 2019). According to Glaser (1984), critical thinking skills need to be gained through specific disciplines. This approach, in which critical thinking is not taught as a separate course, is referred to as the subject-based teaching model. Another model that argues that it is more functional to teach in a way that is integrated with the subject area and is quite similar to Glaser's approach is the subject integration teaching model (Paul & Erder, 2001, as cited in Yeşilyurt, 2021). According to Ennis (1991), when critical thinking is taught in a skills-based way, it is more practical to apply the gained cognitive skills to other subjects. Authentic tasks given to students in lessons support deep cognitive thinking when they are used in an engaging context (Stobaugh, 2013). The teaching of the scientific thinking method is not sufficient to encompass critical thinking (Dowd, Thompson, Schif, & Reynolds, 2018).

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report (2019) states that approximately one million species are at risk of extinction due to the fact that 85 per cent of wetlands and 75 per cent of terrestrial areas in the world have been altered by humans and lost their naturalness. These changes in ecosystems lead to the emergence and spread of infectious diseases World Wildlife Fund for Nature (WWF) (2020). Critical thinking skills of students need to be developed in order to create solutions while struggling with environmental challenges and to test whether the solution is indeed an appropriate one (Lesest & Wolbers, 2020; Ristanto et al., 2022). One of the aims of science education is to develop sustainable development awareness, positive attitudes, and behaviors towards the environment and to create solutions to the challenges encountered in human-environment interaction (Ministry of Education [MoNE], 2018b; Mongar, 2022). In the enGauge 21st Century Skills [EnGauge] report prepared by the North Central Regional Educational Laboratory (NCREL), it is emphasized that it is necessary to educate students who can develop appropriate solutions to global problems, who are productive and open to collaboration with the aim of raising students who can easily adapt to changes (NCREL, 2003).

The loss of biodiversity and the collapse of the ecosystem is one of the vital threats that humanity will face in the near future (World Economic Forum [WEF], 2020). Biodiversity is important for agricultural productivity, the economy and ensuring global food security. Conservation of nature or biodiversity, regulates the climate, normalizes losses and temperature changes in habitats. The decrease in biodiversity brings disasters such as floods and forest fires. Such disasters cause loss of medicinal drug resources and economic losses in many areas (Food and Agriculture Organization [FAO], 2019; The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [IPBES], 2019). In our country, which is one of the countries rich in biodiversity, it is necessary to educate students who are aware of biodiversity and know how to protect natural life and living things (Haydari & Coştu, 2021). In the literature on biodiversity, it is seen that there are studies examining the effects of teaching based on the common knowledge construction model and the biodiversity museum tour activity on the academic achievement of secondary school students (Bolat, Karamustafaoğlu, & Karamustafaoğlu, 2020; Haydari et al., 2021). There are studies in which learning modules aiming to increase the willingness to protect honeybees, a lesson plan on biodiversity based on 5E, an achievement test on the ecosystem, biodiversity, and environmental problems were developed and a biodiversity literacy assessment tool was adapted (Aydın & Selvi, 2020; Efe & Efe, 2022; Keleş & Özenoğlu, 2017; Schönfelder & Bogner, 2018). Studies examining the value of local biodiversity (Harvey, Montgomery, Harvey, Hall, Gange, & Watling, 2020; Schaal, Schaal, & Lude, 2015) or the benefits of a biodiversity-based outdoor learning program on students' psychology have been found. However, only one of these studies conducted on secondary school students on biodiversity is related to technology use (Schaal, et al., 2015).

It is seen that studies on critical thinking in the field of education are mostly conducted with university students (Du & Zhang, 2022; Goodsett, & Schmillen, 2022; Hazaymeh & Alomery, 2022; Karanja, 2021; Moonma & Kaweera, 2022; Ouhıba, 2022), pre-service teachers (Ali & Awan, 2021; Fikriyatii, et al, 2022; Khalid, Bucheerei, & Issah, 2021) and teachers (Al-Kindi & Al-Mekhlafi, 2017; Lombardi, Mednick, De Backer, & Lombaerts, 2022; Nouri et al., 2020). However, there are also studies conducted in mathematics and social studies subjects with the participation of secondary school students in which the effects of activities based on subject-based education (Arısoy & Aybek, 2021), mobile applications (Gezer & Ersoy, 2021) and reasoning (Kaçar & Çakmak, 2020) on critical thinking are examined. In the literature, there are studies showing that the use of problem solving (Hidayati, Zubaidah, & Amnah, 2022; Istikomah, Basori, & Budiyanto, 2017; McDonald, 2017; Quattrucci, 2018) and project-based learning approach (Cortázar, 2021; Mutakinati, Anwari, & Kumano, 2018; Ridlo, 2020; Sasson, Yehuda, & Malkinson, 2018) positively affects the critical thinking skills of students. Barriers that prevent critical thinking: Overconfidence, prejudiced and hasty attitudes, overgeneralisation, lack of attention, misunderstanding and lack of strategy (Cottrell, 2017, p. 10; Ruggiero, 2012, p. 115). It is stated that it will be difficult for people who can also be defined as egocentric with an understanding of “mine is better” to think critically (Ruggiero, 2012, p. 94). In this respect, there is a need for further studies in which collaborative teaching method requiring communication skills such as empathy is used so as to help students develop an understanding that will improve their critical thinking.

In Zhang and Nouri’s (2019) systematic review, it is stated that Scratch is used in computer science or programming courses in the vast majority of studies on Scratch for K-9 students. In the literature, it is seen that there are studies investigating the effect of Scratch on computational thinking in courses such as computer science and mathematics (Dickson, Kotsopoulos, & Harris, 2022; Gadanidis, Hughes, Minniti, & White, 2017; Oluk & Korkmaz, 2016; Oluk, Korkmaz, & Oluk, 2018; Rodríguez-Martínez, González-Calero, & Sáez-López, 2020; Ma, Zhao, Wang, Wan, Cavanaugh, & Liu, 2021; Miller, 2019; Nouri et al., 2020). In online STEM courses, coding workshops and clubs, there are studies conducted with K-9 students where Scratch is used for teaching computer science abstraction, integration of mathematics-computer thinking, creativity or encouraging participatory culture (Israel & Lash, 2020; Statter & Armoni, 2020; Weng 2022a; Weng 2022b). There are studies focusing on how to use Scratch in numbers, polygons, divisibility, setting up equations and problem solving to teach and popularize mathematics (Benton, Hoyles, Kalas, & Noss, 2017; Calao Moreno-León, Correa, & Robles, 2015; Chiang & Qin, 2018; Dickson et al.; 2022; Dohn, 2020; Israel & Lash, 2020; Rodríguez-Martínez et al., 2020). The findings of these studies indicate that; 1. middle school students show their mathematical concepts by creating mathematical representations through Scratch (Israel & Lash, 2020); 2. there are improvements in their equation solving performance and attitudes towards technology (Chiang & Qin, 2018); 3. their interest in coding decreases in the face of the difficulty of the tasks (Dohn, 2020); and 4. solving and computational thinking skills improved (Benton et al., 2017; Calao et al., 2015; Rodríguez-Martínez et al., 2020). Based on the literature cited above, it is necessary to create exemplary processes that will create a plethora of knowledge by enabling students to approach a specific topic in the unit from different perspectives. In this context, the development of critical thinking skills needs to be explored in teaching environments where students plan products in Scratch, evaluate these products by presenting them to their friends, and edit them when necessary. When the literature was examined, no studies examining the effect of web-based collaborative learning method with Scratch on critical thinking skills in science course were found. However, teachers are in need of education and training environments that include critical thinking components (Jatiningsih & Dewi, 2022).

Students learn Scratch during elementary school years in information technologies and software courses in many countries, especially in the USA. It is considered that this study, which is an example of an interdisciplinary approach in which the information in science and information technologies and software courses are utilized together, will contribute to this field. Stobaugh (2013) argues that individuals who understand other people's perspectives, review different opinions, are aware of their prejudices, and can change their decisions possess advanced critical thinking skills. Within the scope of this study designed in parallel with this direction, it is thought that students who work with web-based collaboration on biodiversity will have the opportunity to review their own and their friends' thoughts and this will contribute to their critical thinking skills. Classroom organization, time anxiety and preparation time prevent the implementation of activities aimed at developing critical thinking skills (Al-Kindi & Al-Mekhlafi, 2017; Kanmaz, 2022). It is necessary to help teachers in developing critical thinking along with the content without leaving them feeling helpless (Khalid, et al., 2021). It is seen that applications for critical thinking skills are not sufficiently included in the curriculum (Kanmaz, 2022). This research is important in terms of designing exemplary teaching activities that will help science teachers develop critical thinking of students based on web-assisted collaborative teaching method through Scratch software. According to Krathwohl’s revised Bloom’s taxonomy, evaluation skill requires critical thinking and decision-making according to certain criteria, and creation skill requires creating a new product by combining parts (Krathwohl, 2002). In this context, it is considered that the creation of products by the students with Scratch, a block-based program, on biodiversity, which has a significant part in courses such as science and social sciences, and the exploration of their own critical thinking skills in this process are important in terms of scientific field. In addition, creating digital products to support programming gains is also emphasized in 2018 Information Technologies and Software Curriculum (MoNE, 2018a). For all these reasons, in this study, the Scratch software and web-based collaborative learning method were used together in order to improve the critical thinking skills of fifth grade middle school students on the subject of “biodiversity”.

Aim of the Study

This study had three main purposes. These are to:

1) create material related to the subject of “Biodiversity” at the 5th grade level of science with the Scratch software by students,
2) create material related to the subject of “Biodiversity” at the 5th grade level of science with the Scratch software by researcher, and
3) study the effect of web-based collaborative learning method with the Scratch software on the critical thinking skills of 5th grade students.

In line with these purposes, answers to the following questions will be sought in this study:

(1) Is there a statistically significant difference between the pre-test critical thinking scores of the experimental group and the control group?

(2) Is there a statistically significant difference between the post-test critical thinking scores of the experimental group and the control group?

Methods

Research design

In this study, “quasi-experimental design with pre-test - post-test control group” (Çepni, 2018, p. 144), which is one of the quantitative research methods, was used. In experimental designs that aim to determine cause and effect relationships between variables, data are produced under the control of the researcher (Büyüköztürk, 2018). The independent variables of this study are the web-based collaborative learning method with the Scratch software applied in the experimental group and the presentation-based activities based on the national science curriculum applied in the control group. The dependent variable of the research is the critical thinking skills of 5th grade students.

Population and sample

The population of the study includes all elementary school 5th grade students studying in Bursa province. The research was carried out in a public school in Bursa in 2018 with a total of 96 students, with two 5th grade classes as the experimental group and two 5th grade classes as the control group. Of the students participating in the study, 47 were girls and 49 were boys. In this study, convenience sampling, one of the non-random sampling methods, was used. In this sampling type, due to the limitations in terms of time, money and labor force, the sample is selected from easily accessible and applicable units (Büyüköztürk, 2018). The secondary school where the data were collected in the study was the implementation school where the researcher was placed within the scope of the "teaching practice" course taken during his undergraduate education. Therefore, since the researcher was familiar with the environment and functioning of this school and was in contact with its teachers, it was deemed appropriate to select this implementation school for the study.

Instrument

Critical thinking questionnaire (CTQ)

In this study, the “Critical Thinking Questionnaire” used by Kazancı (2014) in his master’s thesis study was used as a data collection tool by obtaining permission. The Critical Thinking Questionnaire is a 16-item questionnaire administered to all participants in the study to determine whether there is a significant difference in the critical thinking skills of students before and after the experimental intervention. In this study, the Cronbach's Alpha reliability coefficient of the CTQ was calculated as .82. The statements in the questionnaire were associated and scaled with the phenomenon of “Basic Intellectual Assets” proposed by Paul, R. and Elder, L. (2009) in his book "The miniature guide to critical thinking concepts and tools". In the CTQ, participants are expected to mark “Always”, “Usually”, “Sometimes”, “Rarely” and “Never” for behaviors that require critical thinking skills. Items 2 and 6 aim to apply “fair-mindedness”, one of the emotional viewpoints. Paul, R. and Elder, L. (2009) define fair-mindedness as being conscious of the need to treat all points of view in the same way, without considering the feelings or interests of one's friends, society and oneself. Items 1 and 5 are “intellectual empathy”, which is the awareness of the need to put oneself in the shoes of others in order to understand the facts. Items 11 and 14 are related to “intellectual humility”. Intellectual humility is the recognition of the fact by a person that one should not claim to know more than one actually knows. Items 8 and 13 are related to “intellectual integrity”, which means honestly recognizing inconsistencies in one’s own thoughts and actions. Items 7 and 12 are related to "intellectual courage", which entails recognizing the need to challenge and deal fairly with views on which we have not given a serious consideration. A person with intellectual courage should be able to recognize that their beliefs may be wrong. Items 3, 9, 10, 15 and 16 are "reliance on logic", a cognitive strategy that requires the individual to reach his/her own conclusions by exploring his/her own reasoning (Kazancı, 2014).

Experimental process

The study was conducted in 2018 with all the 5th grade classes in a public school within the scope of science and information technologies and software courses. The researcher first visited the implementation school with the permission of the Ministry of National Education dated 01.12.2017 and informed the school administrators, teachers and students regarding the thesis study. A consent document for the study was obtained from the parents and teachers. The researcher, who worked in coordination with the information technologies and software course teacher on programming with the Scratch software, contributed to the creation of a Scratch teaching plan for the students. To achieve the second purpose of the study, the researcher created Scratch software materials related to the subject of "Biodiversity" at the 5th grade level of the science course. Ten games were developed for science curriculum with Scratch software before the implementations. Four experts in the fields of curriculum development, instructional technologies and science were consulted to determine the suitability of the games prepared in the Scratch platform to the cognitive achievements specified in the national curriculum and the level of students. A pilot study was conducted with six students to determine the problems that could arise during the implementation of the Scratch games. The Scratch games were given their final form by making the necessary changes based on the expert opinions and the pilot application. These games, which were developed by the researcher with the support of the information technologies and software teacher, were introduced to the students and science teachers in the last week of implementation. In order to explore the effect of the Scratch software and web-based collaborative learning method on the critical thinking skills of 5th grade students, an experimental process covering 10 weeks was carried out. The pilot studies of the experimental process were carried out in the computer laboratory with 25 students for a total of 6 lessons. In addition, before administering the CTQ, 5 students were asked for their opinions regarding the comprehensibility of the items in the questionnaire and it was decided that one lesson hour was sufficient to administer the questionnaire. Table 1 below illustrates the design process of the study:

Table 1. The design process of the research

Group	**Pre-experimental process**	**Experimental process**	**Post-experimental process**
EG	CTQ1	Lessons in SC and ITSC courses conducted with the Scratch software and web-based collaborative learning method	CTQ2
CG	CTQ1	Lessons in the SC course conducted through presentational activities based on the national science curriculum	CTQ2

* In the table above, ITSC stands for the information technologies and software course, SC stands for the science course, EG stands for the experimental group, CG stands for the control group and CTQ stands for the critical thinking questionnaire.

The implementation process, excluding preparation, included 25 hours of science (SC) and 22 hours of information technologies and software (ITSC) lessons for a total of 47 lessons hours.

In the implementation process of the study, in addition to the education and training activities on biodiversity in the control groups, the experimental group students mostly used the web-based collaborative learning method with the Scratch software in the computer laboratory in SC and ITSC courses. The collaborative groups were selected by lot in such a way that there were 2 people in each group. Some of the groups worked with 3 people each due to class size and absences. In order to ensure that the lesson process was the same in each class, the researcher was personally present in all lessons and participated in the entire implementation process. During the implementation, a teacher evaluation form was used by the science teachers to determine whether the researcher conducted the SC lesson in the experimental and control groups in the same way and to determine the deficiencies. In Table 2 below, all the activities carried out by the researcher during the implementation process in the experimental (EG) and control (CG) groups are listed respectively:

Table 2. Data collection process

Week/ Date	**Lesson**	**Lesson hour**	**Group**	**Course content**
1st week/ 16.02.18	ITSC	2	EG	• Creating algorithm and flowchart
2nd week/ 23.02.18	ITSC	2	EG	• Completion of the coding course available at https://studio.code.org/s/course4
3rd week/ 02.03.18	SC ITSC	4 2	EG and CG EG	• Administering the CTQ • Using biodiversity slide with presentation method • Practicing basic exercises in Scratch
4th week/ 09.03.18	SC ITSC	4 2	EG and CG EG	• Students introducing their model animals, magazines, books and posters on biodiversity in the classroom, and drawing pictures • Using biodiversity slide with presentation method • Designing of games by students that require correct answers to questions about biodiversity in order for the character they will create in Scratch to reach the finish line
5th week/ 16.03.18	SC ITSC	4 2	EG and CG EG	• Using biodiversity slide with presentation method • Designing biodiversity-themed games in Scratch by students in which changing the scene is required
6th week/ 23.03.18	SC ITSC	4 2	EG and CG EG	• Using biodiversity slide with presentation method • Preparation of live presentation cards by the students • Designing games on biodiversity by students using the drag and drop feature in Scratch
7th week/ 30.03.18	SC ITSC	4 2	EG and CG EG	• Using the biodiversity slide with question-answer method) • Conducting the midterm exam on biodiversity • Designing of quiz-format games by the students on biodiversity in Scratch

8th week/ 06.04.18	SC ITSC	4 2	EG and CG EG	• Revision of the subject and practicing exercises • Designing of biodiversity themed games in Scratch by the students where a basketball is scored in the basket or goal is scored in the goal
9th week/ 13.04.18	ITSC	4	EG	• Designing of award-winning games on biodiversity in Scratch by the students • Presentation by all groups on one of the games designed to their friends on the smart board
10th week/ 20.04.18	SC ITSC	1 2	EG and CG EG	• Administering the CTQ as a post-test • Students playing Scratch games on biodiversity prepared by the researcher

* In the table above, ITSC stands for the information technologies and software course, SC stands for the science course, EG stands for the experimental group, CG stands for the control group and CTQ stands for the critical thinking questionnaire.

In Table 2 above, it is stated that the students in the experimental group practiced algorithms, flowcharts, loops, and parametric functions for a total of six lesson hours in the first three weeks. Experimental group students were given the task of preparing quiz format games that required click, drag and drop and manual answering on the keyboard between the third and 10th weeks. Students were suggested to design games in which they could score points when they scored a goal and a basket, but the codes of the games were not given. The students who worked cooperatively during the game design were provided with support when necessary, by the first researcher and the information technologies and software teacher. Information about the biodiversity games prepared by the students is given in Table 3 below:

Table 3. Scenarios in students' games

Name of the game	**Scenarios**
Who is telling the truth?	On the stage, there are three characters, one of which is the presenter. The stage starts with the words of the presenter: “Who is telling the truth? Click on the correct character.” Next, the characters take turns saying statements about biodiversity. When you click on the character that tells the truth, feedback is received as “Well done!”, and when you click on the character that says wrong, the feedback is “Sorry wrong!”. In the next stage, the game continues with different characters and different backgrounds.
Arrival at the finish line	There are at least 3 characters. Character 1 and character 2 take turns saying statements about biodiversity. In order for character 3, who is on the far left at the beginning of the game, to reach the finish line at the end of the game, it is necessary to click on the character that tells the truth. When the wrong character is clicked, the character 3 goes back.
Let's catch the truth	There is a character 1 in the middle of the stage, and a living species on the left and right below. Character 1 says that only the living species in our country should be clicked on. When the correct species is clicked, the living character goes to 1 and disappears and the next stage is passed. Different living creatures appear in the next stage. When the wrong creature is clicked, the creature returns and character 1 says “You should think again”.
Living things coming together	In the first stage, the presenter asks the players to collect the endangered creatures in our country on a plate/basket. 2. The presenter disappears on the stage, and the living creatures come to the stage one by one with their names. When an endangered species

	such as the Salep orchid is dragged onto the plate, the orchid remains on the plate and feedback is given as “Well done!”. When a living thing that is not in danger of extinction is dragged onto the plate, “False!” feedback is given, and it goes back to where it was from the plate.
Labyrinth	There are creatures located in certain parts of the maze in the game. There are parts of rights and points on the stage. When the hero seal clicks on an endangered creature, he earns points. When clicking on a creature that is not in danger of extinction, feedback is given as “I am not an endangered creature.”. Three rights are given in the game. When the remaining right is 0 “Sorry, you lost. You have to play again” feedback is given. When the player has a certain score, the stage and the hero's costume change and the “You won the game!” command is given.
Let's score	The game takes place on the football field. At the beginning of each stage, a question that needs to be answered by typing “Yes” or “No” is presented to the player about biodiversity. When the player writes the correct answer in the relevant space and clicks on the checkmark, the ball returns to the stage and the goal is scored. In addition, the command “Well done, correct answer!” comes with voice and text. The game is completed when a certain score is reached.
Let's play basketball	The game takes place on the basketball court. In each stage, the player is faced with a question that needs to be answered by writing “True” or “False” about biodiversity. When player writes the correct answer in the relevant space and clicks on the checkmark, the character jumps, the ball moves to the northeast, passes through the pot and falls down. The ball is in three different positions in each question. The user is entitled to a certain number of, for example, two wrong answers. The game ends when a certain score is reached.
Yes- no game	The play begins with the character in the stage asking questions. Players are expected to write “Yes” or “No” to the box on the stage and press the checkmark. When the correct answer is written, feedback is given as “Correct!” and the stage and question changes. When the wrong answer is given, the character in the stage gives feedback as “Wrong!” and the next stage is passed.
Let's catch the flag	The game takes place in the racing area. In order to reach the checkered flag at the end of the stage, it is necessary to answer the questions asked by the character correctly. When the user writes the correct answer in the relevant space, the character advances by a certain step. The harder the question, the further the character goes. When he gives the wrong answer, the character goes back. When the user reaches a certain score, feedback is given as “You won the game!” and the flag is reached.

The games named “Who is telling the truth?”, “Arrival at the finish line” and “Let's catch the truth” in Table 3 above are based on users using the mouse click feature. In games called "Living things coming together" and "Labyrinth", users must use the drag and drop feature with the mouse. Finally, game users are expected to manually type their answers on the keyboard for the games “Let's score”, “Let's play basketball”, “Yes-no game” and “Let's catch the flag”.

Data Analysis

The ability of quantitative analyses to yield generalizable results depends on the ability of the data to reflect the characteristics of the population (Can, 2018, p. 88). Shapiro-Wilk normality test results are analyzed for the compatibility of the data used in the study with the normal probability distribution and the results are presented in Table 4 below. According to the results of the Shapiro-Wilk normality test, it is seen that the p values indicated by (Sig) in Table 4 are greater than .05. This means that normality is ensured (p>.05).

Table 4. Shapiro-Wilk normality table

	Shapiro-Wilk		
Group	**Statistic**	**df**	**Sig**
Experimental	.98	48	.77
Control	.96	48	.07

Results

1. Findings related to the sub-problem

The t-test results for independent samples in this study examining the effect of web-base the collaborative learning method with the Scratch software on the critical thinking skills of 5th grade students are presented in Table 5. When Table 5 is examined, it is seen that there is no statistically significant difference (p=.44) between the pre-test scores of the experimental group students ($\bar{X}$=60.48) and the pre-test scores of the control group students ($\bar{X}$ =61.82).

Table 5. Comparison of critical thinking pre-test totals of experimental and control groups

Group	N	$\bar{X}$	S	sd	t	p	α
Experimental	48	60.48	7.24	94	-.77	.44	.05
Control	48	61.82	7.49				.05

2. Findings related to the sub-problem

The t-test results for independent samples in this study examining the effect of web-based collaborative learning method with the Scratch software on the critical thinking skills of 5th grade students are presented in Table 6:

Table 6. Comparison of critical thinking post-test totals of the experimental and control groups

Group	N	$\bar{X}$	S	sd	t	p	α
Experimental	48	72.72	2.49	94	6.66	.00	.05
Control	48	67.02	5.31				.05

When Table 6 is examined, it is seen that there is a statistically significant difference (p=.00<.05). between the post-test scores of the experimental group students ($\bar{X}$ =72.72), and the post-test scores of the control group students ($\bar{X}$ =67.02). In this case, it is seen that web-based collaborative learning method with the Scratch software in the Science course has a positive effect on the critical thinking skills of the students. While the t-test for unrelated samples reveals whether there is a significant difference between the groups compared, the magnitude of the effect needs to be calculated separately since it does not provide information about the magnitude of this difference. When the magnitude of the effect is calculated, this value is found as d=1.37 in the t-test for unrelated samples. According to Green and Salkind (2005, p. 169), this value is considered as a "large" effect.

Conclusion and Discussion

In this study, it was aimed to investigate the effect of Scratch software and web-assisted cooperative learning method on the critical thinking skills of 5th grade students and to create material on the subject of biodiversity in Scratch software. For this purpose, the subject of biodiversity was explained to the 5th grade students in the experimental group using the web-assisted cooperative learning method with Scratch software, and the same subject was explained to the students in the control group using traditional methods in accordance with the achievements in the science curriculum. The statistical analyses showed that there was no statistically significant difference between the pre-test critical thinking scores of the experimental and control groups, but there was a significant difference between the post-test critical thinking scores of the two groups in favor of the experimental group. The findings show that the increase in the critical thinking skills of the students who experienced the web-assisted cooperative learning method with Scratch software and created material on the subject of biodiversity using this software was higher than the increase in the critical thinking skills of the students in the control group who did not experience the web-assisted cooperative learning method with the Scratch software and did not develop the material.

Scratch software was preferred in the current study and 5th grade students were given a web-supported cooperative education using this programming language. Considering the widespread use of traditional programming languages such as Scratch in education today, it is necessary to investigate how to use Scratch more effectively (Chang et al., 2017; Niemelä, 2017). In a study conducted at an international K-12 school in Asia, programming languages called JavaScript, and Python were used in addition to Scratch, and the motivation of students to use these programming languages and the educational materials they produced were data collection tools such as questionnaires, interviews, and teaching materials was tried to be detected. As a result of this research, it was determined that Scratch software increased students' programming skills and positively affected the motivation of students of all age levels (Niemela, 2017). A study was conducted to improve the computational thinking skills of high school students within the scope of science and mathematics courses, and as a result of this research, it was determined that students' skills such as data collection, modeling and simulation, computational problem solving, and systems thinking practices improved (Weintrop, Beheshti, Horn, et al. Orton, Jona, Trouille, & Wilensky, 2016). In another study conducted with university students studying in the science education and psychology departments of a university in Portugal, it was determined that using Scratch software increased the students' interest and concentration on the subjects they were working on. In addition, in the same research, it is stated that using Scratch software is a tool that helps students produce educational materials by accelerating their professional development and concept learning (Almeida & Pessoa, 2017). In addition to the research mentioned above, in this study, Scratch software and web-based collaborative learning approach were used together with the students on the subject of biodiversity, which is becoming increasingly important today, and it was investigated whether this teaching method had an effect on students' critical thinking skills.

Countries aiming to rank high in international rating exams accepted all over the world should focus on improving students' critical thinking skills with coding support (Ala-Mutka, 2011). In our research conducted in this direction, the students thought about both how the product would be designed and the content of the subject while presenting a product. At the end of this research, it was determined that the students developed their critical thinking while designing and playing games in Scratch software. Designing and playing games on a vital issue affecting all humanity such as biodiversity is seen as a source of motivation that encourages critical thinking skills. This situation is also included in the study of Nouri et al. (2020) in which the digital competence of Scratch software is discussed, and it is recommended to use this software as an important tool in developing 21st century skills. Coding and playing coding games contribute to students' understanding of basic systemic concepts. When the results of studies on traditional programming languages such as Scratch are examined, it has been stated in some of these studies that students who have just started coding may have difficulties in performing certain skills in this process (Fields, et al., 2015; Hermans, et al., 1017; Aivaloglou, et al., 2017). In our research, students used the processes of changing and controlling variables, creating problems, solving problems, creating flow charts, and making decisions in Scratch software. These processes are known to develop critical thinking. This finding is in line with the issue addressed in Brennan and Resnick's (2012) article. In the games whose features are specified in Table 3, the students used the "looks, control, motion, sensing, sound, operators" code blocks. They created the steps to be followed in order to reach the goal, and they developed materials using loops and various commands that allow repeating these steps. Students used drag and drop, click feature, character, background change, time, sound and location settings while playing games created by themselves or by the researcher. Students' development and use of algorithms containing linear logic, decision, and loop structures are compatible with the achievements of the current information technologies and software course (MoNE, 2018a). One of the remarkable results obtained in this research is that all groups working cooperatively in the experimental group successfully fulfilled their duties. The factors contributing to this result are that the information technology and software teacher attended the course together with the science teacher and researchers, and that long-term science course was carried out together with the information technologies and software course in a way that supports each other.

One of the problems faced by students in daily life is the decrease in biodiversity brought about by environmental problems. During the experimental process in this research, the students developed a digital product on the intellectual topic of biodiversity by using technology responsibly. It is thought that students develop positive relationships with their teammates during the product development processes, especially during the planning and implementation of the project. In this direction, it is thought that the results obtained after the experimental group students' experience of using Scratch with the web-assisted cooperative learning method coincide with the dimensions of effective communication, digital age literacy, and high productivity in NCREL's EnGauge (2003) report. In this respect, it can be said that the findings are similar to the P21 framework proposed for being successful in life in terms of interdisciplinary global consciousness, environmental literacy and harmony in human relations. While creating products with Scratch within the scope of this research, students gathered information about biodiversity, made decisions about the format of the game they would design, supported the learning of themselves and their friends, and presented their products in the classroom and in digital environments in accordance with ethical rules. In this respect, it can be said that the experimental group of students take part in the educational processes in accordance with the creative communicator, knowledge creator, digital citizen, empowered student and innovative designer standards determined by ISTE (2016). Throughout the process, students expressed their ideas with respect to their groupmates, listened to different ideas, and developed products within a certain discipline, taking into account time management. It is thought that the experimental group used interpersonal, cognitive, and internal skills in this process in accordance with NRC (2012).

It is seen that the findings obtained from this study support the studies in the literature that include the conclusion that the problem-solving approach, project-based approach, mobile applications, writing and inquiry-based activities improve critical thinking (Cortázar, 2021; Gezer & Ersoy, 2021; Goodsett, & Schmillen, 2022; Hidayati et al., 2022; Istikomah, et al., 2017; Kaçar & Çakmak, 2020; McDonald, 2017; Mutakinati, et al., 2018; Ridlo, 2020; Sasson, et al., 2018; Quattrucci, 2018). As a matter of fact, the students who created products on the extinction of living things, the importance of biodiversity and their conservation, analyzed real life problems, produced solutions, and applied to critical thinking. In this respect, this process experienced by the students is compatible with the revised Bloom taxonomy and the national science course curriculum (Krathwohl, 2002; Ministry of Education, 2018). The results of this research are also similar to studies reporting the significant positive effect of thinking-based teaching practices on critical thinking skills (Ali & Awan, 2021; Arısoy & Aybek, 2021; Du & Zhang, 2022; Hazaymeh & Alomery, 2022; Ouhiba, 2022). The results of this research, which offers students the opportunity to search for ways to contribute to the product while working collaboratively, are similarly in line with the studies of Moonma and Kaweera (2022), who share the conclusion that collaborative writing activities for English learners encourage university students to use their critical thinking skills.

In addition to the significant results that the Scratch software and web-assisted cooperative learning method had a positive effect on students' critical thinking skills, there are also some limitations of this study. For example, one of the limitations of this research is the fact that this research was conducted only in a single secondary school. The research school is a public school with experienced teachers and an information technology class, where various projects are carried out. All students and teachers at the school have given consent to the research permit. If this study had been done with administrators, parents, students, and teachers in a school that was not open to improvement for research, the results would likely have been different. It would be difficult to carry out a similar study in a school that does not have an information technology classroom or has few computers. Another limitation is that this study was conducted only with 5th grade students. Information technologies and software courses are only available at the 5th and 6th grade levels in Turkey. In order to be able to conduct the lesson in the same way in each class, the researcher determined only one class level. The research could have been carried out in a longitudinal structure with students at different grade levels if the science courses of other classes were not overlapping.

During activities that require students to practice their critical thinking skills, it is recommended that teachers respond immediately to their students' answers, apply rewarding positive reinforcement, and support group interaction (Al-Kindi & Al-Mekhlafi, 2017; Khalid, et al., 2021; Lombardi, et al., 2022). The results of this study, which showed that students working in collaboration with Scratch with web support increased their critical thinking skills, seem to support the authors' suggestions. The reason for this is that the code blocks give instant feedback while the students are creating products in the Scratch software and while they are playing the game, and the students say, "Well done, you won the flag!" at the end of the game. Thanks to the wide range of facilities offered by the Scratch software, it is seen that the work of the teachers in the process has become simpler. In addition, it is thought that the U-shaped arrangement of the computer laboratory enables students working in cooperation to focus better by overcoming the teaching barrier in crowded classrooms. Throughout this study, it was observed that the trial and error processes in which students produced products in the Scratch environment became practical and entertaining. It is thought that students who learn programming with Scratch by working with patience and perseverance will gain at an early age the skills they will need throughout their lives.

Implications

It is thought that sharing the results of this study will be a motivation to increase the applications for critical thinking skills based on the web-assisted collaborative method. Based on the results of this study, it is suggested that students be given performance tasks for the achievements in the science course, in which they will use the information they learned in the information technologies and software course. It is thought that the development of various products using Scratch will have a positive effect on the scores of students in international exams such as TIMSS and ePIRLS. According to the results of the research, Scratch, a block-based coding software, is thought to help students improve their decision-making skills in trial and error processes. It is recommended that young individuals use Scratch so that they can produce solutions by using their critical thinking skills to cope with complex problems affecting the whole world such as global warming, wars and pandemics, and choose the right solution from these solutions. In this study, the steps for using Scratch in teaching environments in parallel with each other within the scope of science and information technologies and software courses are explained in detail. Teachers who want to make similar applications in their classrooms in the future can follow the relevant steps in this study. While conducting activities designed based on critical thinking and collaborative methods, it may be useful to remember the importance of creating a democratic environment in the classroom. The fact that the teacher is a role model for the students, being a guide in the discussions and listening to the student can facilitate him in managing the teaching process. When teachers look at the products created by their students with Scratch, they can have an idea about their ideas, conceptual mistakes and ability to express themselves, and they can rearrange the education by taking these variables into account. More emphasis should be placed on the meanings and examples of if and if/if commands that students often confuse while learning Scratch. In addition, various activities can be organized by forming a Scratch club at schools. The results of this study showed that students can acquire science course content knowledge at the learning speed of themselves and their groupmates in the Scratch environment. It is recommended that science teachers focus on how they can develop their students' critical thinking skills in a holistic way, within and outside the school, within the process of the unit, without rushing to convey the information in the unit.

Students can be reminded that the algorithms used in Scratch are an important way to decide anything in life. The students said, “Which road do I walk less on when I go to the market? What steps should I follow to make my coffee sugary? How should I study to get a higher grade in science?” By generating questions in the form of questions, they can design their own solutions and reach the desired result. When students are programming with Scratch, they should know that when something goes wrong, they can find out what went wrong by checking the code blocks one by one so that they can correct their mistakes. Students should remember that they should save the game they designed while on the main screen, and that appropriate spaces should be left between words in the speech command. In addition, students should consider that when they want to click in the game, they must click without moving the mouse, otherwise the program may confuse the desired thing with the drag and drop command. In addition, students who are new to programming should know that their target will become more complex as the number of codes, characters and costumes increases, and they should be careful when rushing different and many commands together until they fully grasp the essence of the program.

It may be beneficial for researchers who want to carry out similar studies to know the educational approach, physical condition, and social environment of the school they have chosen. Being aware of the methods and techniques frequently used by the teachers in the school where the research will be conducted allows the researcher to plan correctly in advance how and in what way the relevant method will be used. Knowing in advance the academic performance, learning styles and attitudes of the students who will form the study group can create a situation in favor of the researchers. Based on the results of this study, the representation of intellectual events, facts or situations based on theoretical principles by turning them into products through Scratch can be included in the science curriculum. While students are learning to code with Scratch, they have also learned the relevant subject as they have prepared a project on an academic subject. It is recommended that researchers turn to qualitative studies in order to obtain more detailed information on how other thinking skills, especially critical thinking, can be developed in similar digital learning environments.

Note

This paper is extracted from the first author's master dissertation "The impact of Scratch program and web-assisted cooperative learning method on the level of conceptual understanding and critical thinking skills of 5th grade students" submitted to the Bursa Uludag University of Turkey.

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