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The effects of using collaborative digital storytelling on academic achievement and skill development in biology education

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Abstract
The purpose of the study is to investigate the effect of the use of digital storytelling on academic achievement, critical thinking dispositions, co-regulation, and narrative skills of 10th grade students. To this end, the study was conducted using a semi-experimental design with a convenience sample. The participants consisted of 64 students (33 in experimental and 31 in control group) who were studying in a high school. After the groups were trained, a two-week pilot study was conducted by forming collaborative groups among the students. This was followed by eight weeks of main implementation, during which students presented their projects to the class every two weeks. Following the digital story presentations in the experimental group, feedback was provided by the course instructor and peers. In addition, rubric scores were generated by the researchers for each digital story. Academic achievement test, critical thinking disposition scale, co-regulatory skills scale, and digital story evaluation rubric were used as data collection tools at the end of the process. Independent samples t-test, repeated ANOVA, and regression analysis were performed on the collected data. According to the results, digital story activities had moderate positive effects on students' academic achievement and critical thinking, and high positive effects on co-regulation. In addition, the narrative skills of the students in the experimental group increased significantly over the weeks with a difference of 27.44 points. There was also evidence that storytelling ability was a significant predictor of academic achievement and that this ability increased significantly over the weeks. The results showed that the collaborative creation of a digital story by the students had a positive effect on their academic achievement and the development of their skills.

Keywords Digital storytelling · Biology education · Academic achievement · Critical thinking disposition · Co-regulation skill · Narrative skill

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1 Introduction

With the technological explosion of communication and globalization, there is a shift from traditional understandings of literacy to exploring different forms of meaning-making. In this direction, it has been noted that today's students, referred to as Generation Z, use information technologies to create information, transform data into information and share it, and also learn in different ways compared to previous generations (Malita & Martin, 2010; Toki & Pange, 2014). These students, who have grown up with digital technologies, prefer multimedia content that is rich in visual and auditory terms to content that is mainly textual (France & Wakefield, 2011). Therefore, it is becoming increasingly important to use contemporary learning methods to attract students' attention (Ohler, 2006; Smeda et al., 2014). Appropriate teaching approaches supported by contemporary technologies and original teaching methods that create the desired skills for students come to the fore as a need in this sense (Seferoğlu, 2015). Digital storytelling, which is considered as one of these teaching methods, has emerged as a result of the combination of today's transformative technologies and traditional stories (Sadik, 2008; Yang & Wu, 2012).

In this study, the digital storytelling method was used, which is an innovative pedagogical method that attracts the attention of today's youth who tend to use technology (Smeda et al., 2014). Potential positive aspects such as digital storytelling providing a student-centered, fun and interactive collaborative environment (Chan et al., 2017; Çetin, 2021; Lantz et al., 2020), encouraging critical thinking in the product design process (Hung et al., 2012; Malita & Martin, 2010), improving narrative skills through efforts to create an original scenario (Dogan & Robin, 2008; Foley, 2013), and improving learning performance as a result of active interaction (Figg & McCartney, 2010) guided this study. Digital storytelling makes this study important because it is a student-centered innovation that combines the power of both traditional storytelling and technology, and its use in education has grown in recent years. The integration of the digital storytelling method, which is economical and easy to implement, into learning environments, especially with the help of existing technologies in the field of education, will have an important place in students' acquisition of many 21st century skills (Yuksel-Arslan et al., 2016). In this regard, it is believed that examining academic success variables along with 21st century skills such as critical thinking dispositions, co-regulation, and narrative skills that are expected of today's students provides a holistic and broad perspective to the study.

2 Theoratical framework

2.1 Digital storytelling

Digital stories are powerful learning and teaching tools that combine traditional storytelling skills with digital components such as text, images, sound recordings, music, and video (Robin, 2016). Digital stories revolve around a chosen topic and often have a specific point of view, similar to traditional storytelling. Digital stories consist of personal perspective, interesting question, emotional content, sound effects, musical

power, economy, and pacing (Bull & Kajder, 2004; Robin, 2006). Although there are different types in the literature covering many disciplines at different educational levels, it is possible to divide the most common types into three categories in terms of content: personal, historical, and didactic stories (Robin, 2008).

Digital storytelling, which is a student-centered and constructivist approach, is seen as an educational technology and literacy learning tool that uses almost all the skills expected of 21st-century students (Dogan & Robin, 2009; Lantz et al., 2020; Yuksel-Arslan et al., 2016). It is often mentioned in the literature that it provides a strong foundation for 21st-century literacy, such as digital, global, technological, media, visual, and information literacy (Chan et al., 2017; Çetin, 2021; Di-Blass et al., 2009; Robin, 2008; Xu et al., 2011, Yang & Wu, 2012). Due to the potential impact of digital storytelling on skill development, the current study focuses on critical thinking dispositions, narrative skills, and co-regulatory skills in addition to academic achievement.

It is stated that when students collaborate, the learning process can become more interesting and enjoyable despite the repetitive nature of the learning process (Laal & Ghodsi, 2012). At this point, it is seen that digital storytelling comes to the forefront as an effective collaborative tool in learning environments. Students who participate in digital storytelling activities perform a dual function of learning and having fun together (Toki & Pange, 2014). It is argued that in almost all processes of digital storytelling, from the idea stage to the sharing of products, it often creates an environment for collaboration, communication, and interaction among students (Nam, 2017; Ming et al., 2014). Technology becomes the focus in the background as students work together to develop their projects. Thus, the process also provides an opportunity to interact with the content and each other while creating digital stories (Lantz et al., 2020). When digital stories are created in a collaborative environment, students can take on different roles such as designers, listeners, commentators, readers, writers, communicators, artists, and thinkers (Bull & Kajder, 2004). Within the group, students can actively exchange ideas and give and receive feedback. Sharing and evaluating digital stories among peers also allows students to express themselves, talk critically with each other, develop tolerance, and take responsibility (Hung et al., 2012; Malita & Martin, 2010). Their efforts to synthesize the information they have gathered about the topic into an original scenario also contribute to the development of narrative skills. On the other hand, it is argued that the process of cooperation and communication within the group is effective for students to build the content together, provides more meaningful learning and supports their academic success (Figg & McCartney, 2010; Jenkins & Lonsdale, 2007).

2.2 Critical thinking and digital storytelling

Critical thinking, defined as a judgment process that guides problem solving and decision making, has two dimensions: ability and disposition. While critical thinking skill is the ability to think critically easily and skillfully with mental effort, critical thinking disposition is seen as the desire, sense of responsibility, and attitude necessary for a person to think critically (Facione, 1990). Because it is a factor that affects performance in all areas of social life, the development and promotion of students'

critical thinking skills is considered one of the main goals of today's educational process (Facione, 2011; Giancarlo & Facione, 2001).

The literature emphasizes that digital storytelling has an important place in promoting critical thinking (Lampert, 2007) and students' critical reflection on what they have learned (Robin, 2016). The digital storytelling process provides students with opportunities to think critically, from identifying topics to sharing, inspiring, encouraging thinking, creativity, interaction, reflecting on their knowledge, and problem solving (Jenkins & Lonsdale, 2007; Ohler, 2006; Robin, 2008; Xu et al., 2011). In the process of creating a digital story, students have the freedom to be critical in the selection of content that will support their story in a meaningful way (Chan et al., 2017; Czarnecki, 2009). As a contemporary, student-centered pedagogy, this study suggests that digital storytelling can be effectively integrated into the learning environment to enhance students' critical thinking dispositions.

2.3 Cooperative learning and digital storytelling

Collaborative learning is defined as an interactive process in which authority and responsibility are shared among group members and all members are united around a common goal (Laal & Ghodsi, 2012; Tezci & Perkmen, 2016). During collaborative learning, the organization of activities takes place at different levels of social interaction: individual, pair, and group levels (Hadwin & Oshige, 2011). Co-regulation at the group level is expressed as a dynamic regulation process and interaction that coordinates the self-regulation processes between two or more peers in the learning process (Didonato, 2013).

Digital storytelling is known to be a powerful method and collaborative tool that promotes classroom collaboration and student knowledge construction (Boase, 2008; Hung et al., 2012; Yuksel et al., 2011). When students are asked to create their own digital stories, either individually or as members of a small group, it has been found that the greatest benefits of digital storytelling can be realized and that team building, cooperation, and other interpersonal skills can be improved (Reinders, 2011; Sadik, 2008). It is argued that students who create digital stories in a collaborative learning environment improve their communication skills, learn to ask questions, and express their ideas more easily (Hafner & Miller, 2011; Malita & Martin, 2010; Wang & Zhan, 2010). In this direction, it is believed that the digital story activities implemented in the current study will facilitate students' acquisition of the collaborative skills required today.

2.4 Narrative skill and digital storytelling

When individuals construct stories, many cognitive and linguistic skills play a role in their writing processes (Bumgarner, 2012; Ohler, 2013). Therefore, narrative skill is seen as a complex product creation process that requires a high level of thinking and interaction in the human mind (Karadağ & Maden, 2013; Özbay & Barutçu, 2013). The many benefits of storytelling are highlighted, allowing listeners to effortlessly assimilate information and incorporate it into their existing schemas (Csikar & Stefaniak, 2018). Although narrative skill plays an important role in the transfer of

information and its transformation into gains in learning processes, this skill does not develop spontaneously (Temizkan, 2011).

It is argued that the use of various tools and techniques offered by modern technologies, such as digital storytelling, provides important opportunities to improve narrative skills in this sense (Bumgarner, 2012; Campbell, 2012; Dogan & Robin, 2008; Foley, 2013; Ohler, 2013; Oskoz & Elola, 2014). Digital storytelling helps students to manage and understand their story writing processes (Yamaç & Ulusoy, 2016) and positively affects their narrative skills, ideas, organization, and sentence fluency (Ohler, 2006; Sylvester & Greenidge, 2009). Particular emphasis has been placed on the impact of scriptwriting, which is considered the first and most important step in the digital storytelling process, on narrative skills (Ohler, 2006; Robin, 2008; Xu et al., 2011). In this research, it is believed that with the effective integration of digital storytelling into the learning environment, students will increase their academic achievement and improve their narrative skills.

2.5 Significance of the study

Its potential to mobilize and develop 21st century skills (Smeda et al., 2014; Wang & Zhan, 2010) has made digital storytelling the focus of the current study. In the literature, the pedagogical effects of digital storytelling on students' academic achievement (Figg & McCartney, 2010; Yang & Wu, 2012), collaboration (Hung et al., 2012; Yuksel et al., 2011), attitudes (Sadik, 2008; Smeda et al., 2014; Yang & Wu, 2012), motivation (Chan et al., 2017; Di-Blas et al., 2009), critical thinking (Czarnecki, 2009; Yang & Wu, 2012), active learning (Boase, 2008; Ohler, 2006; Xu et al., 2011), writing skills (Oskoz & Elola, 2014; Tanrıkulu, 2021), communication (Malita & Martin, 2010; Sarıca & Usluel, 2016a), problem solving (Abdel-Hack & Halwa, 2014; Yang & Wu, 2012), creativity (Bedir-Erişti, 2016; Nordmark & Milrad, 2012), reflection (Kim & Li, 2021), interest (Ivala et al., 2013), social learning (Ming et al., 2014; Robin, 2006), and deep learning (Barber, 2016) were examined. Foreign language teaching comes to the fore as a discipline of study (Fu et al., 2021; Hafner & Miller, 2011; Ming et al., 2014).

The current study was conducted in a high school biology course. It is known that due to the high cognitive load and the excess of scientific concepts and principles, students encounter difficulties in science-based lessons and have difficulties in understanding and remembering the concepts taught (Condy et al., 2012; Csikar & Stefaniak, 2018). From this perspective, the process of creating a digital story has the potential to improve learning as a result of students' active interaction with the content, their groupmates, and the teacher, and is well suited for group work (Figg & McCartney, 2010; Jenkins & Lonsdale, 2007). It was considered important to examine the variables of co-regulatory skills and academic achievement. In addition, although there are digital story-oriented studies in secondary school science education (Çiçek, 2018; Dewi et al., 2018; Hung et al., 2012) and university biology education (Frisch & Saunders, 2008; Karakoyun & Yapıcı, 2016) in the literature, no study was found to investigate the effect of the digital story, especially in high school biology education. However, although critical thinking is considered as an important educational goal (Facione, 2011), there are few studies in the literature on

the effect of digital storytelling on critical thinking, and current studies focused on the skill dimension of critical thinking (Csikar & Stefaniak, 2018; Yang & Wu, 2012). The fact that the high school period coincides with the age range of 12–18 years, when thinking skills mature, makes critical thinking education important during this period (Erdem & Genç, 2015). In the current study, investigating the effect of digital storytelling on the critical thinking dispositions of high school students is considered valuable in this sense. On the other hand, the prominence of digital storytelling as a powerful approach that can develop narrative skills by initiating a high level of interaction and thought process in the minds of individuals (Abdel-Hack & Helwa, 2014; Ohler, 2006; Sylvester & Greenidge, 2009) has guided the variable preferences in this study. The story scenarios that high school students construct during digital story activities are believed to activate many cognitive skills and enhance their academic performance. In this direction, the current study aimed to examine the effect of digital storytelling on 10th grade students' academic achievement, critical thinking dispositions, co-regulation, and narrative skills. To this end, answers to the following sub-problems were sought:

1 10th grade students in the experimental and control groups

1.1 Is there a significant difference in levels of academic achievement?
1.2 Is there a significant difference in levels of critical thinking disposition?
1.3 Is there a significant difference in levels of co-regulation skills?

2. Is there a significant difference between the narrative skills of the experimental group students according to the weeks?
3. Is there a correlation between academic achievement, critical thinking disposition, co-regulation, and narrative skill levels of students in the experimental group?

3 Method

3.1 Research design

The study used a quasi-experimental design with a pretest-posttest equivalent control group. The quasi-experimental design is often used in educational and psychological studies due to the difficulty in determining unbiased samples (Büyüköztürk et al., 2013; McMillan & Schumacher, 2010). In the quasi-experimental design with paired pretest-posttest control groups, two of the prepared groups are attempted to be equal on certain variables. Then, the equal groups are randomly assigned to the treatment groups and the experimental and control groups are determined. Equivalence is tested by applying pre-tests to the study groups, then the implementation process begins. At the end of the process, post-tests are conducted and the results are compared (Creswell, 2012; McMillan & Schumacher, 2010). Although the inability to impartially assign the participants seems to be the main problem of this design, the use of pre-

tests for the qualifications to be examined in the groups makes the design useful and appropriate. In the current study, since there is no specific grading system among the classes in the selected school, the academic achievement pre-test was conducted to all branches of the 10th grade before the implementation process. The Academic Achievement Test was conducted as a pretest to determine if the students were equal in terms of academic achievement. The two classes with the closest pre-test mean scores were assigned as the experimental and control groups (10/A class control, 10/D class experimental group). At the end of the experimental process, post-tests were administered to the groups. Figure 1 illustrates the paired quasi-experimental design preferred in the study. The fact that the sample group was in the same school as the researcher facilitated communication and coordination with the students and the biology teacher. In addition, the researcher was able to quickly intervene in technical problems that arose in the computer science class.

3.2 Sample group

The study group of the research was selected from the 10th grade students of a high school using the convenience sampling method, one of the non-random sampling methods. In order to determine the equivalence of the groups, the academic achievement pre-test was conducted to the branches. The two classes with the closest pre-test mean scores were assigned as the experimental and control groups. One-factor ANOVA analyses were conducted on the pre-tests of academic achievement, and it was determined that the groups were equivalent to each other ($p > .05$). In the current study, the class size of the experimental group was 33 and the class size of the control group was 31, for a total of 64 students. Demographic information about the sample group is presented in Table 1.

The demographic characteristics of the sample group were collected using an information form prepared by the researchers. It can be seen that most of the partici-

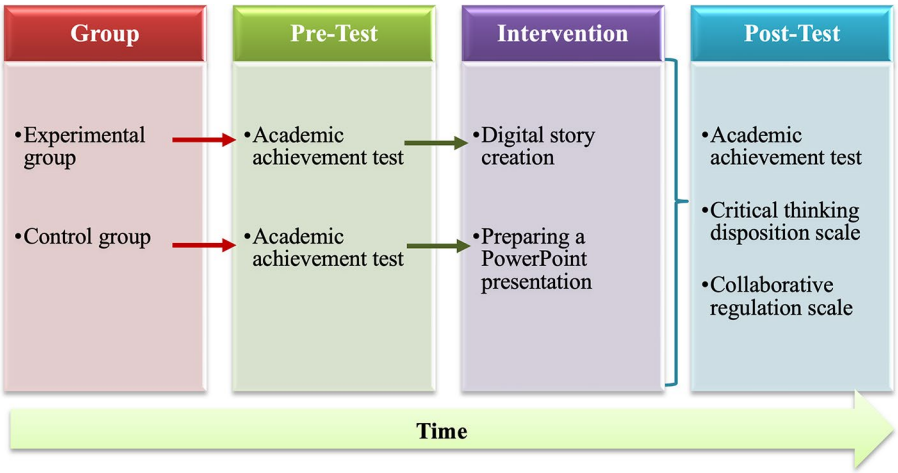

Fig. 1 Quasi-experimental design in this study

Table 1 Demographic characteristics of the sample group

Gender distribution			Previous digital story creation status	
	Female	Male	Female	Male
Experiment	20	13	4	29
Control	21	10	1	30
Total	41	23	5	59
Computer proficiency status				
	Very good	Good	Intermediate	Bad	Very bad
Experiment	3	9	19	2	0
Control	2	7	15	6	1
Total	5	16	34	8	1
Possession of digital devices					
	Desktop Computer	Laptop	Tablet	Smartphone	Other
Experiment	6	5	9	21	3
Control	1	7	10	20	4
Total	7	12	19	41	7

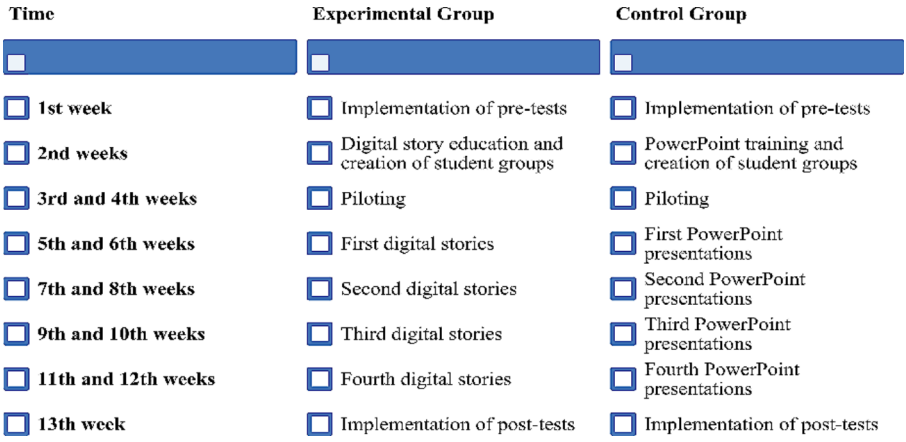

Fig. 2 Experimental implementation process by week

pants have mobile devices such as tablets and smartphones, and a significant number of them do not have their own computer. Only 5 of the students had created a digital story before this study. 34 students indicated that they could use computers at an intermediate level and 16 students stated that they could use computers at a good level.

3.3 Implementation process

The implementation process of the study, including the administration of pre-tests, training of groups, pilot implementation, main implementation, and post-tests, took a total of 13 weeks. Figure 2 summarizes the stages of the experimental implementation process by week.

Lectures were given by the same teacher in both experimental and control groups. Before the implementation, the groups were informed in the first week and the training plans were made. Four-hour (2+2) training sessions were given to the experimental group to create a digital story and to the control group to create a PowerPoint presentation. After the training, the students in both the experimental and control groups were divided into 7 groups. The decision of who would be in the groups was left to the students and they were divided into groups of 4–5 people with their friends whom they thought could work in harmony with each other. After the preparation and planning process, a two-week pilot implementation was conducted to test the system and identify problems before the main implementation. In the pilot implementation, small groups of students in the experimental group were asked to create digital stories by distributing the topics and developing solutions to the problems they encountered. After the pilot implementation, another 8-week implementation was carried out. The topics addressed in the experimental and control groups during the implementations are shown in Fig. 3. The Cell Division unit, in which digital stories were created during the implementation process, includes the subtopics of Mitosis and Asexual Reproduction and Meiosis and Sexual Reproduction. The related topics cover a period of 10 weeks in the curriculum (Ministry of Education, 2018). Due to the length of time required for this unit, only this unit was focused on in the study.

In this process, which was carried out in collaboration with the students, the researchers mostly followed the story development processes, provided guidance where needed, and ensured data collection. The researchers were actively involved in all processes of group determination, pre-testing, training of experimental and control groups, implementation, and post-testing.

3.4 Data collection tools

The Critical Thinking Disposition Scale, the Co-regulation Skills Scale, and the Digital Story Evaluation Rubric were taken from sources in the literature, and the Academic Achievement Test was developed by the researchers. The relationship between the data collection instruments and the research questions is shown in Table 2.

3.4.1 Academic achievement test

First, the objectives and outcomes related to the “cell division” unit in the current 10th grade biology curriculum of the Ministry of National Education were identified to determine the behaviors to be measured in the academic achievement test. Then, a pool of 36 multiple-choice questions was created in the first stage at different levels according to Bloom’s cognitive taxonomy to cover the acquisitions. Based on expert opinion, 18 additional questions were added to the pool of questions for the test form, and the levels of some questions were changed. To ensure the content validity of the test, specification tables were created before and after the item analysis. For the construct and content validity of the prepared achievement test, opinions were obtained from an assessment and evaluation specialist, a biology faculty member, a Computer and Instructional Technologies Education (CEIT) faculty member, and two biology

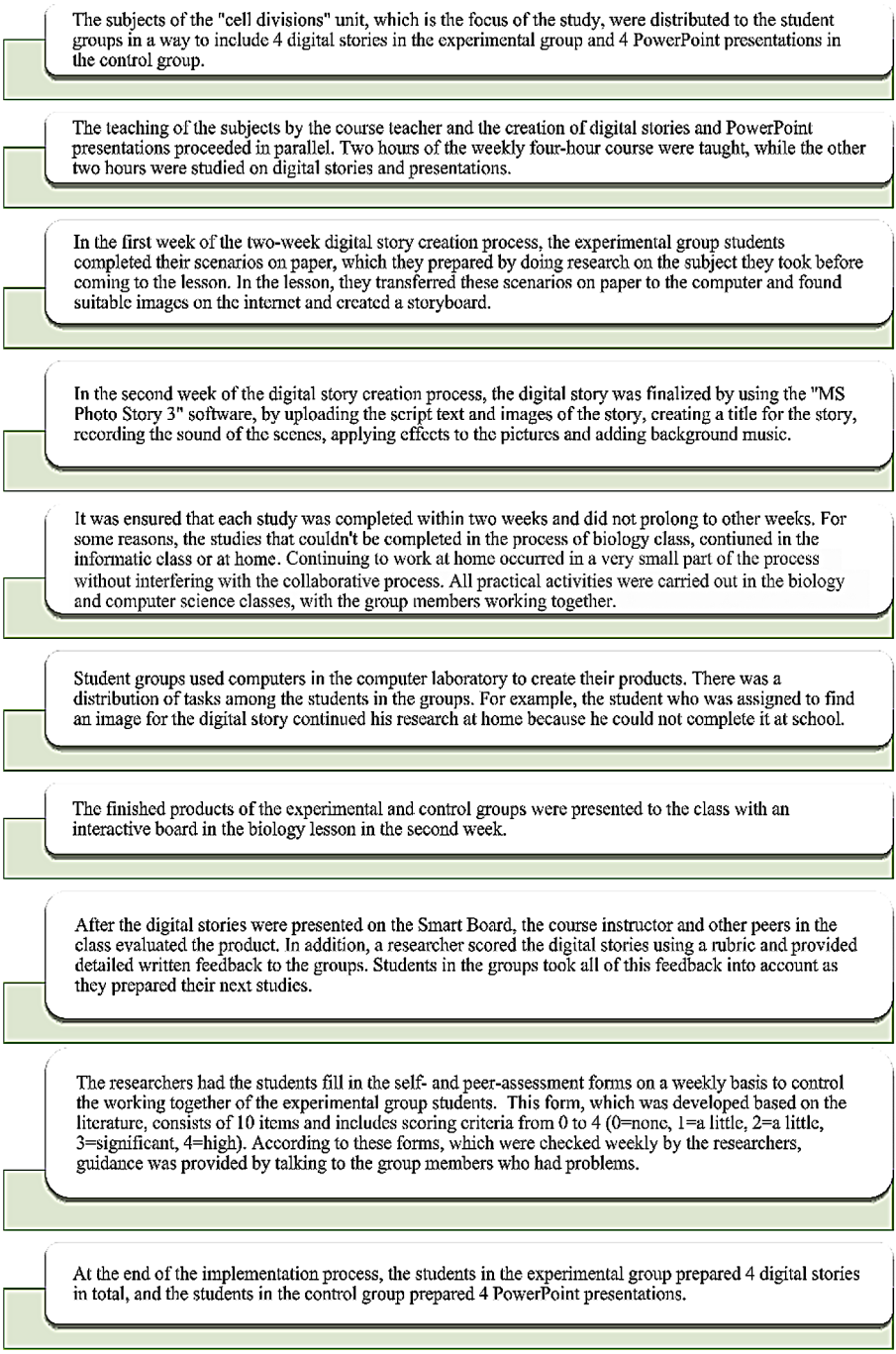

Fig. 3 The implementation process flow in the experimental and control groups

Table 2 Relationship of data collection tools with research questions

Research questions	Data collection tools
Differences between academic achievement levels	Academic achievement test
Differences between critical thinking disposition levels	Critical thinking disposition scale
Differences between co-regulation skill levels	Co-regulation skill scale
Change of narrative skill levels by week	Digital story assessment rubric
The relationship between academic achievement and other variables	Academic achievement test, critical thinking disposition scale, and co-regulation skill scale

teachers. The control form of the test was conducted to a total of 121 students in the 11th grade who had been exposed to the same unit of study the previous year.

In evaluating the item difficulty index and item discrimination index, the values specified by Turgut and Baykul (2015) were taken as a reference. As a result of the analyses performed on the test form, 25 items with item discrimination index (r) less than 0.30 were excluded from the test. 29 items with item discrimination index of 0.30 and above and item difficulty between 0.27 and 0.73 were included in the final test. The calculated mean difficulty index of the final test was 0.50, and the mean discrimination index was 0.38. These data show that the final test is at the average level of difficulty and can discriminate between those who know and those who do not know at a good level. The KR-20 value, which indicates the internal reliability of the test, was calculated to be 0.82.

3.4.2 Critical thinking disposition scale

The UF/EMI (University of Florida Engagement, Maturity, and Innovativeness Critical Thinking Disposition Instrument) critical thinking disposition scale used in this study was developed by researchers at the University of Florida and adapted into Turkish by Kılıç and Şen (2014). It is a five-point Likert-type scale consisting of three sub-dimensions; there are 11 items in the engagement sub-dimension, 7 items in the cognitive maturity sub-dimension, and 7 items in the innovativeness sub-dimension. It has been reported that the scale was tested by applying it to 342 students studying in the 9th and 10th grades of secondary education for the validity and reliability study. By applying confirmatory factor analysis for construct validity, X^2/sd ratio was calculated as 2.99 (813.66/272) and RMSEA = 0.08. The Cronbach's alpha internal consistency coefficient was calculated as 0.91 for the total scale, 0.88 for the engagement sub-dimension, 0.70 for the cognitive maturity sub-dimension, and 0.73 for the innovativeness sub-dimension. In the current study, Cronbach's alpha internal consistency coefficients were obtained as 0.89 for the total scale, 0.87 for the engagement sub-dimension, 0.68 for the cognitive maturity sub-dimension, and 0.65 for the innovativeness sub-dimension.

3.4.3 Co-regulation skill scale

The co-regulation skill scale used in the study was developed by DiDonato (2013) and adapted into Turkish by Pan and Tanrıseven (2016). Before it was used in this study, the scale was conducted to three 10th grade students to determine if the scale was appropriate for use with high school students. The students indicated that the scale was clear and easy to understand. After receiving a detailed evaluation from the students and consulting the opinions of two experts in the field, the scale was applied. This scale consists of 19 items and measures students' behaviors related to cooperative organization of the learning process. It was stated that the scale, which is a 4-point Likert type, was applied to 100 pre-service teachers for validity and reliability study. The researchers conducted confirmatory factor analysis to test the validity of the scale, which has a single factor structure. As a result of the confirmatory factor analysis, the fit indices of the model were found to be RMSEA=0.074 (>0.05); NFI=0.94 (>0.90); CFI=0.95 (>0.95); it has been reported to be detected as AGFI=0.87 and GFI=0.91. The factor loads of the scale items ranged from 0.26 to 0.70, and the root mean square error (RMSEA) was calculated to be 0.068. The Cronbach alpha internal consistency coefficient calculated to determine the reliability of the scale was 0.89. In the current study, the Cronbach alpha internal consistency coefficient was calculated to be 0.83.

3.4.4 Digital storytelling evaluation rubric

This measurement tool, developed by Sarıca and Usluel (2016b), consists of a total of 30 criteria, 8 for the story section, 4 for the storyboard section, and 18 for the digital story section. It was reported that the created rubric was presented to the opinion of five experts working on digital stories and two experts in the field of measurement and evaluation, and weighted kappa coefficients were calculated by two independent raters for reliability. According to the results they obtained, it was stated that all the criteria of the story, storyboard and digital story sections showed a significant and good level of agreement.

3.5 Data analysis

The analysis types that meet each research question are given in Table 3.

Table 3 Types of analysis in line with research questions

Research questions	Applied analyzes
Differences between academic achievement levels	Independent groups t-test
Differences between critical thinking disposition levels	Independent groups t-test
Differences between co-regulation skill levels	Independent groups t-test
Change of narrative skill levels by week	One-factor repeated ANOVA
The relationship between academic achievement and other variables	Multiple linear regression analysis

Table 4 Differences between the academic achievement post-test scores of the groups

Groups	n	M	SD	df	t	p
Experiment	33	76.82	13.72	62	-2.224	0.030*
Control	31	68.35	16.68			

*$p<.05$

Table 5 Differences between groups' critical thinking disposition post-test scores

Factors	Groups	n	M	SD	df	t	p
Engagement	Experiment	33	44.90	6.22	62	-2.190	0.032*
	Control	31	41.25	7.10			
Cognitive maturity	Experiment	33	29.96	3.10	62	-3.736	0.000**
	Control	31	26.90	3.45			
Innovativeness	Experiment	33	29.18	3.66	62	-1.631	0.108
	Control	31	27.74	3.37			
Total	Experiment	33	104.06	11.92	62	-2.830	0.006*
	Control	31	95.90	11.08			

*$p<.05$, **$p<.001$

The analysis of the variables of academic achievement, critical thinking disposition, co-regulation, and narrative skills revealed no missing data or extreme values in the dataset. The normality analyses indicated that the data had a normal distribution. The kurtosis and skewness values of all variables in question were determined by Tabachnick et al. (2007) to be between +1.50 and −1.50. Analysis of variance assumptions were tested and it was found that the variances were homogeneously distributed ($p>.05$).

4 Results

4.1 Differences between academic achievement levels

The results of the independent group t-test analysis, which was used to determine whether there was a significant difference between the academic achievement post-test scores of the groups, are presented in Table 4.

According to Table 4, the post-test academic achievement mean of the experimental group students ($M=76.82$, $SD=13.72$) was significantly higher than the mean of the control group students ($M=68.35$, $SD=16.68$) ($t(62)= -2.224$, $p<.05$)

4.2 Differences between critical thinking disposition levels

The results of the independent group t-test analysis, which was used to determine whether there was a significant difference between the groups' post-test scores on critical thinking dispositions, are presented in Table 5.

According to Table 5, a significant difference was found between the experimental and control groups in the engagement factor ($t(62)= -2.190$, $p<.05$), cognitive maturity factor ($t(62)= -3.736$, $p<.001$) and total scale scores ($t(62)= -2.830$, $p<.05$)

Table 6 Differences between groups' collaborative organizing ability post-test scores

Groups	n	M	SD	df	t	p
Experiment	33	66.15	4.94	62	-4.862	0.000**
Control	31	59.00	6.73			

**$p<.001$

Table 7 Repeated ANOVA results showing the change of storytelling skill scores by week

Source of Variance	Sum of Squares	df	Mean Squares	F	p
Between subjects	2135.196	32	66.725	847.214	0.000**
Measurement	14042.458	2.142	6555.063		
Error	530.396	68.551	7.737		
Total	16708.05	102.693			

**$p<.001$

in favor of the experimental group. In the innovativeness factor, although there was no statistically significant difference between the experimental and control groups ($t(62)$= -1.631, $p>.05$), the mean of the experimental group ($M=29.18$, $SD=3.66$) was higher than the mean of the control group ($M=27.74$, $SD=3.37$) was higher.

4.3 Differences between co-regulation skill levels

The results of the independent group t-test analysis, which was used to determine whether there was a significant difference between the groups' post-test scores on co-regulationskills, are presented in Table 6.

According to Table 6, the post-test mean of the experimental group students' co-regulation skills ($M=66.15$, $SD=4.94$) was significantly higher than the control group students' mean ($M=59.00$, $SD=6.73$) ($t(62)$= -4.862, $p<.001$)

4.4 Change of narrative skill levels by week

The results of the one-factor repeated ANOVA test showing the change in narrative skill scores according to the weeks in the experimental group are presented in Table 7.

According to the findings in Table 7, there was a statistically significant difference between the students' digital story scores by week [$F(2.142, 68.551)=847.214$, $p<.001$]. The change in the mean score of narrative skill over time is shown in Fig. 4

4.5 The relationship between academic achievement and other variables

The results of the multiple regression analysis performed to determine the power of the variables in predicting the academic achievement of the students in the experimental group are presented in Table 8.

Mahalanobis distance values were examined in the dataset of the study for multiple regression analysis, and it was found that all values were less than the critical x^2 table value ($D^2<18.47$, $p>.001$) for three independent variables, were normally

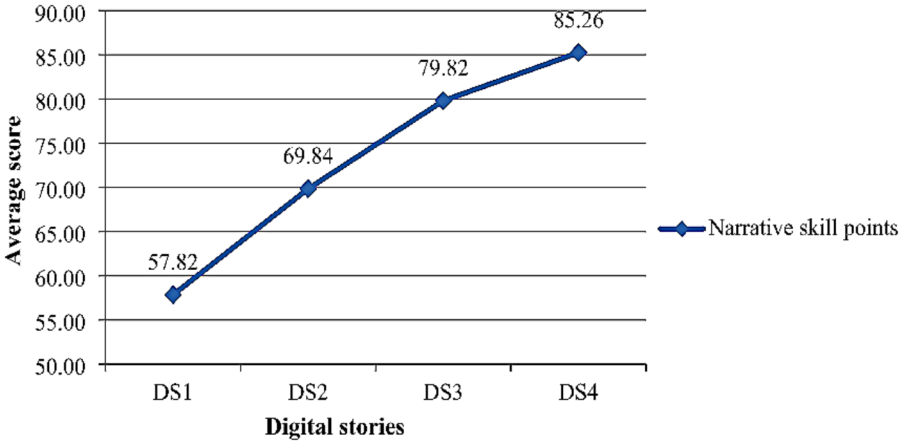

Fig. 4 Increase in narrative skill scores by week

Table 8 Multiple regression analysis results regarding the prediction of the academic achievement post-test

Variable	B	Standard Error$_B$	β	T	p	Dual r	Partial r
Constant	-73.889	37.605	-	-1.965	0.059	-	-
Co-regulation skill	0.543	0.509	0.196	1.067	0.295	0.484	0.194
Narrative skill	0.296	0.139	0.353	2.140	0.041	0.527	0.369
Critical thinking disposition	0.269	0.202	0.233	1.332	0.193	0.469	0.240
R=.625	R^2=0.390						
$F_{(3,29)}$=**6.185**	p=.002						

distributed, and did not contain extreme values. According to Seçer (2015), there should be at least 15 participants for each predictor variable. In this study, the number of participants is 64. The values of Durbin-Watson (1.783), tolerance (0.773), and VIF (1.293) show that there is no multilinear problem in the analysis. When examining the data in Table 8, the regression model that was established was statistically significant (F=6.185; p<.05). These three variables together explain 39% of the total variance in the academic achievement post-test. When the t-test results were analyzed for significance of the standardized regression coefficient (β), it was found that only narrative skill was a significant predictor of Academic Achievement Post-test scores (β=0.353; t=2.140; p<.05). The relative order of importance of the predictor variables on the academic achievement posttest: narrative skills, critical thinking disposition, and co-regulatory skills. The mathematical regression model that emerged within the conditions of this study regarding the prediction of the academic achievement post-test is "Academic achievement=-73.889+0.296 narrative skills".

5 Discussions and implications

This study aimed to examine the effect of using digital storytelling on 10th grade students' academic achievement, critical thinking disposition, co-regulation, and narrative skills. In the study, students in the experimental group actively interacted with their teachers, friends, and subject content throughout the collaborative digital storytelling process, produced creative products that reflected their perspectives, and became the heroes of their own stories. The study, which was conducted in such an environment where high levels of participation and motivation are effective, had important findings that are a contribution to the literature.

According to the results, students in the experimental group who created digital stories were more successful at the end of the process than students in the control group. This result shows parallelism with other studies in the literature (Çiçek, 2018; Figg & McCartney, 2010; Foley, 2013; Gömleksiz & Pullu, 2017; Hung et al., 2012; Korucu, 2020; Robin, 2006; Yang & Wu, 2012). The obtained results can be primarily explained by the constructivist environmental features revealed by the collaborative digital story creation activities. It is believed that the constructivist environment features such as cooperation, active participation, and interaction during the digital story creation process among the students in the experimental group positively affected the learning outcomes. It is known that digital stories are a teaching tool that supports learning, encourages cooperation, improves creativity and decision making, and enables students to actively participate in the learning process and learn from each other (Balaman-Uçar, 2016; Dogan & Robin, 2008; Robin, 2006; Smeda et al., 2014). It is argued that active interaction and communication with the content, peers, and teachers throughout the digital storytelling process provides students with more meaningful learning and supports their achievement (Figg & McCartney, 2010; Jenkins & Lonsdale, 2007). On the other hand, the fact that students who create digital stories create meaning with their perspective and add comments to their products (Malita & Martin, 2010; Robin & McNeil, 2012; Sadik, 2008; Yuksel-Arslan et al., 2016) may have affected their achievement by allowing them to take in more information.

The positive effect of digital storytelling on academic achievement can also be related to its multi-sensory and information embodiment aspect. In fact, it is emphasized that the flexible and dynamic nature of digital storytelling uses many cognitive processes by activating the senses. It can activate students' visual and auditory senses in different ways than printed textbooks and by integrating visual images with written text. It also improves and accelerates student comprehension (Dreon et al., 2011; Nordmark & Milrad, 2012; Sadik, 2008). It has been stated that digital stories can be used to transform soft information into concrete information and make difficult concepts more understandable, because some abstract information may be difficult for students to understand due to their cognitive abilities (Ohler, 2013; Robin, 2008; Yuksel-Arslan, 2016). On the other hand, the fact that digital storytelling facilitates the recall and retention of information, especially with its effect on memory, may be related to the increase of students' academic success (Bromberg et al., 2013; Csikar & Stefaniak, 2018; Di-Blas et al., 2009; Sarıca & Usluel, 2016b; Wang & Zhan, 2010). It is believed that students' active participation in the collaborative process

to improve their products and the repetition of similar processes in each product contribute positively to students' performance by supporting recall and permanence (Balaman-Uçar, 2016).

According to the results obtained in the study, the digital storytelling process significantly increased the critical thinking disposition of the students. This result can be explained primarily by the desire and motivation (Giancarlo & Facione, 2001) generated by the digital storytelling process. It is stated that the relaxed atmosphere and lively environment created by digital storytelling encourages students to interact, talk, and discuss critically with each other more than traditional methods (Karami et al., 2012). It contributes significantly to the development of critical thinking, which is a desirable educational outcome for students, and to critically reflect on what they have learned (Jenkins & Lonsdale, 2007; Lampert, 2007; Robin, 2016). Students critically consider multiple perspectives when researching and selecting multimedia content that meaningfully supports their stories and ideas, and when deciding what information to include to convey their message (Chan et al., 2017; Czarnecki, 2009; Kulla-Abbott, 2006). It is expected that the presence of students with different abilities and different views will create a diversity of ideas. In this sense, the process of digital storytelling with the group can be seen as a process in which students see, accept, and respect each other's differences. In the current study, it is believed that students' constructive criticism of their peers' ideas and products and feedback on group activities (Balaman-Uçar, 2016; Wang & Zhan, 2010) also contribute to increasing their critical thinking disposition. Although there was no significant difference between the groups in the " innovativeness " dimension of the critical thinking disposition scale, the results in favor of the experimental group in terms of mean scores support the view that students with high innovative tendencies try to learn new information by researching, reading, questioning, and acting selectively thanks to their curiosity and impulses (Kılıç & Şen, 2014). From an educational perspective, it is emphasized that the stages of the digital story creation process are highly related to the transferable and applicable skills of critical thinking in innovative individuals, such as idea formation, selection, comparison, inference, organization, and review (Boase, 2008; Jenkins & Lonsdale, 2007; Lantz et al., 2020).

Another finding was that the co-regulation skills scores were significantly higher in the experimental group that created the digital story. In this sense, some studies in the literature (Hafner & Miller, 2011; Ming et al., 2014; Ohler, 2013; Robin, 2006; Smeda et al., 2014; Wang & Zhan, 2010; Yuksel et al., 2011) have found that storytelling leads students to communicate more with each other, teaches them to work with the group, prepares an environment for cooperation, and encourages them to work together to achieve certain goals. It is known that due to the nature of digital storytelling, it provides more opportunities for collaborative learning activities, communication and interaction between group members at almost every stage, from brainstorming ideas to the sharing step (Balaman-Uçar, 2016; Nam, 2017; Ming et al., 2014). It has been reported that thanks to this interaction provided by group work, students participate more in learning processes, knowledge construction is shared among group members, they have the opportunity to work more together, their responsibility skills develop, and they help each other more thanks to the responsibil-

ity they take on (Hung et al., 2012; Karakoyun & Yapıcı, 2016; Sadik, 2008; Smeda et al., 2014; Yang & Wu, 2012).

The study concluded that the narrative skills of students in the experimental group increased significantly over the weeks. Consistent with this result, various studies (Balaman-Uçar, 2016; Campbell, 2012; Dogan & Robin, 2008; Foley, 2013; Girmen et al., 2019; Yamaç & Ulusoy, 2016) have found that narrative skills improved over time in the digital storytelling process and that more skilled products were observed. By consistently organizing thoughts (Ohler, 2006; Oskoz & Elola, 2014; Sylvester & Greenidge, 2010), digital storytelling activates students' writing skills (Abdel-Hack & Helwa, 2014) and improves ideas, organization, and sentence fluency. It has been stated that it has a positive effect on IT and provides fluency in story writing (Yamaç & Ulusoy, 2016). However, it has been argued that a well thought out and well written script will make the digital story more effective and successful (Dogan & Robin, 2008; Ohler, 2006; Robin, 2008). In this regard, it is believed that especially the personal perspective and comments on the digital story narration make it interesting, give students a chance to make their voices or comments heard, and students adopt their stories more easily (Reinders, 2011; Robin & McNeil, 2012; Xu et al., 2011).

The regression results show that the variables in the model explain 39% of the dependent variable. The remaining 61% can be attributed to other factors. This result may be due to the small sample size and can be expressed as a limitation of the study. However, in future studies, researchers can strengthen the model by adding new variables to the model in addition to the independent variables used in this study. According to the model, the relationship between narrative skills and academic achievement can be explained by students' efforts to create effective and original narratives by combining the information they have researched on the topic in a scenario during the digital storytelling process. This is because it is emphasized that storytelling skills play an important role in transferring the information learned in the learning-teaching process and transforming it into an outcome (Temizkan, 2011). While the creation of a story scenario is a complex skill that involves the processes of continuous thinking, organizing, rethinking, and rearranging (Abdel-Hack & Helwa, 2014), it is stated that the iterative cycle of this process has a positive impact on student achievement (Balaman-Uçar, 2016). In particular, it can be said that the continuous peer feedback throughout the process (Kearney, 2009; Kulla-Abbott, 2006; Robin, 2016) allows students to see and develop their story constructions.

6 Conclusion

This study found that digital storytelling in a collaborative environment had a positive effect on high school students' academic achievement, critical thinking, co-regulation, and narrative skills. It also found that narrative skills were effective on academic achievement and that these skills developed throughout the digital storytelling process. In order to keep the students interested and engaged in the process, two weeks were allocated for the pilot implementation and eight weeks for the main implementation. During this process, several limitations were encountered. The first is that the scope of the study was limited to the Cell Division unit, since the main

implementation period was eight weeks in total. The second is that some technical problems were encountered in the process due to the lack of modern computer infrastructure in the Information Technology classroom of the implementation school. In addition, Microsoft (MS) Photostory 3 software was preferred for creating digital stories because of its ease of setup and use. Other mobile and online applications with animation creation and video editing features could not be preferred due to the lack of mobile devices in the entire working group and the lack of technical infrastructure. Some suggestions that could be beneficial in line with the results of the study are as follows:

- Given the significant impact of collaborative digital storytelling on academic performance, critical thinking, collaborative regulation, and narrative skills, incorporating digital story activities into the classroom may help high school students develop these skills.
- Students can be encouraged to use digital stories as a tool when preparing their homework and projects.
- The current study was conducted in a 10th grade biology class. An interdisciplinary study can compare data from different courses with numerical and verbal content to see which students are more successful or interested.
- The consistency of digital storytelling with other topics in biology courses can be examined with more comprehensive studies that include different biology topics.
- Unlike MS Photo Story 3 software, depending on the educational level of the sample and their ability to use information technology, other desktop, mobile and online tools can be used.
- Studies can be conducted to determine the difference between the processes of creating digital stories individually and in groups.

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Declarations

Ethical approval 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.

Informed consent 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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