Smart Learning Environments

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The effect of educational game design process on students' creativity

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Abstract

In the 2020s, it is clear that children now spend most of their days in front of the screen. During screen time, playing games is one of the most important activities of children. However, technology is developing day by day and innovations are quickly becoming a natural part of life. Therefore, children now need to be creative people who produce innovation, rather than just consuming themselves with the digital content offered to them. For this reason, students need to improve their creative thinking skills. Also, they need guidance for producing with technology. Considering this circumstance, this research, which was aimed at 5th and 6th grade school students designed educational games in a blended learning environment, employed a single group pretest posttest experimental design research. At the beginning and end of the research, the creativity level of students was examined by using the Torrance Test of Creativity. The study tries to seek an answer to the following question: "How does the educational game designing process affect 5th and 6th grade students' creative thinking development?". As a result, it was determined that there was a statistically significant difference in the creative thinking skill scores of those who designed their own educational game. This result is tangible evidence that the game is not only a drill and practice activity but it also presents a creative thinking environment for students.

Keywords: Educational game design, Game-based learning, Games, Creativity, Blended learning

Introduction

With the twenty-first century introducing many innovations and conveniences into the mainstream of human living, it also presented challenges that need to be overcome. For example, as the borders between countries are disappearing, multiculturalism, being able to do multiple tasks at the same time, and most importantly, being able to think creatively, have become the most basic characteristics that define individuals living in this century. It is possible to say that creative thinking skills have become much more important for new generations, especially since creative thinking has been chosen as the innovative field for the 2021 International Student Assessment Program (PISA) by the Organization for Economic Cooperation and Development (OECD, 2019). Additionally, creative thinking skills come to the fore among the future transformative competencies that are determined (OECD, 2018; Vincent-Lancrin et al., 2019). What makes the

creative thinking skill so important is the need for creative and innovative solutions in order to achieve the Sustainable Development Goals determined by the United Nations (UN, 2015). Therefore, it can be said that many countries have to aim for the new generation to develop creative thinking skills. Along with that educators and teachers need to design a new learning experience which aims to develop these skills. However, creative thinking skills is a multidisipliner content, that's the reason why designing this kind of learning experience is a complex procedure. While designing a learning activity for this skill, support can be obtained from the contexts that today's students are interested in. For example, digital games are a very popular issue among children (Cömert & Akgün, 2021). Because the children of today do not have the opportunity to play outdoors as much as their own parents due to unplanned urbanization, increasing population and security issues (Karsten, 2007; Samur & Özkan, 2019). That's the reason why, it can be argued that children start to get acquainted with digital games at an early age. According to Rideout (2017), children aged 0–2 play a digital game for 25 min every day, while children aged 5–8 amuse themselves with a digital game for 42 min every day. Similarly, children aged 8–12 relax playing games for about 90 min every day (Rideout, 2015). Therefore, as children get older, they spend more time playing digital games. Considering that digital technologies are used much more profusely in human life today, it seems likely that children's digital game playing time will increase even more.

On the other hand, families have become strangers to many of the digital games that stand out among the game preferences of children today. This situation induces anxiety for families, educators and experts. In addition, there are studies in the literature that suggest digital games having a bolstering effect on children's violent behavior and an adverse effect on their physical health (Carnagey et al., 2007; Swing et al., 2010). Naturally, these results instigate concern about digital games. However, there are also studies verifying that playing digital games with content suitable for the age of the child supports the development of many different skills such as problem solving, strategic thinking, time and resource management, large-small muscle harmony, verbal expression, and quick decision making (Blumberg & Fisch, 2013; Bunt & Gouws, 2020; Flynn et al., 2019; Majid & Ridwan, 2019).

Considering the constructive and supportive effect of games on the development of the individual, even before reaching the first quarter of the twenty-first century, the question of "Can digital games be used in education?" dissipated (Öztürk, 2007). As a concrete example of this situation, the use of games developed by teachers in accordance with the learning content or adapted to the learning environment can be given. A perusal of the literature yields many studies that report that game-based learning activities have a positive effect on variables such as academic achievement, class participation, motivation and attitude when compared to traditional methods (Becker, 2017; Khenissi et al., 2015). In fact, Mayer (2020) emphasizes the need for more in-depth research by stating that a saturation point has been reached in the studies comparing traditional methods and game-based learning activities in the literature. In other words, for today's educators, the question of "How can games be used more effectively in the learning-teaching environment?" must be answered. At this point, van Eck (2006) suggests that in addition to the games conceived by the teachers, game-based learning activities can be created by enabling students to design their own games. However, when the literature is

reviewed, it can be found that the number of studies that explore students' level of learning by designing games is quite restricted. For example, Robertson and Howells (2008) revealed in their research that when 10-year-old students designed their own educational games for eight weeks, success and motivation in the course increased. Similarly, Baytak and Land (2010) also ascertained in their research that developing their own educational game impacted positively on students' success and motivation. In addition, in the same research, it was demonstrated that the game design process also supported the formation of classroom culture and the cooperation of students (Baytak & Land, 2010). An (2016), on the other hand, revealed in his research with secondary school students that developing their own educational computer games improved students' multidimensional thinking skills. On the other hand, Ruggiero and Green (2017) described in their research involving students aged 14–17 that students' problem solving skills have improved. In addition, both Walfisz et al. (2006) and López and Fabricatore (2012) studies indicated that the creative thinking skills of university students who designed their own educational games improved. Lastly, Kalmpourtzis (2019) states that after the game design experience of preschool children, not only their creative thinking skills are supported, but also their skills such as harmonious and collaborative work.

The results of the studies discussed up to this point accentuate the positive effects of having the students create their own games on the formation of the classroom climate, the development of cooperation and problem-solving skills as well as their academic success. The positive effects stem from the fact that the game design is a process that requires interdisciplinary teamwork, multidimensional thinking and creativity. In addition, considering the society's need for individuals who not only consume the content offered to them, but also devise the content and produce added value (Tor & Erden, 2004), it becomes clear that assigning game design tasks to students turns out to be a potent implementation. However, in order to raise individuals who can innovate, it is necessary to cultivate creativity in education (Aktamış & Ergin, 2006). In the traditional education system, which is called the education system in which technological opportunities are utilized minimally, creative thinking skills are blunted by accepting that all students possess the same qualifications (Ngeow & Kong, 2001). Within the scope of this study, it is aimed to examine the effect of designing educational games on the development of students' creative thinking skills, taking into account the above-mentioned need. For this purpose, "(1) How is the effect of game design on the creative thinking skills of middle school 5th and 6th grade students?" and "(2) How is the effect of game design on the sub-dimensions (fluency, flexibility, elaboration, originality) of students' creative thinking skills?" answers to the questions were sought. It is envisioned that the results obtained as a result of the research will present a roadmap to teachers and parents who will design learning activities to develop students' creative thinking skills.

Methodology

This section covers the research design, participants, application process, data collection tool and analysis process.

Research design

This study, which was carried out with the participation of secondary school 5th and 6th grade students, employed a single group pretest posttest experimental design research. It subsumed the steps of comparing and analyzing the measurements related to the study group before and after the experimental procedure in single-group pre-test post-test experimental design research (Büyüköztürk et al., 2016). The activities to be carried out within the scope of the study are designed as an after-school activity for volunteer participants. For this reason, the number of participants in the study is limited to 23 students.

Participants

This study was carried out with the voluntary participation of 5th and 6th grade students of a private school in Istanbul who were members of a "Game Design Club" that included 23 students, conducting their extra-curricular activities.

Application process

As a pre and post-test, Torrance Test of Creative Thinking (TTCT) Figural-A form was administered to the volunteering 5th and 6th grade students who agreed to participate in the research. After the pre-test application, the game design curriculum was followed for 14 weeks. With this curriculum, students designed games on three different platforms: (1) on paper, (2) Pixel Floors, and (3) Prototyping. After the completion of all learning activities in the curriculum, TCFT was applied to the students as a post-test. The products produced by the students as a result of this learning experience are presented in Figs. 1, 2 and 3. The research was completed in a total of 15 weeks, including one class-hour per week, pre-test and post-test applications.

Data collection tool

Torrance Test of Creative Thinking, semi-structured observation and semi-structured interview form were employed within the scope of the research.

Torrance test of creative thinking

Consisting of a paper and pencil test, it measures creativity from different dimensions. The duration of the TorranceTest of Creative Thinking is approximately 75–80 min and incorporates two parts, verbal and figural (Aslan, 2001). Torrance Test of Creative Thinking figural-A activities 2 and 3 are employed for data collection and were applied by the researcher to the participating 5th and 6th grade students. In this study, the figural form A of the TCTT was employed and this was administered to the students who were urged to complete it in 30 min as a pre and post-test. Figural form A test comprises three different types of questions: Drawing Activity, Figure Completion Activity and Repeated Shapes Activity (Torrance, 1974). Additionally, within the scope of the study, the pre and post-test responses of the students to the figure completion are presented in Figs. 4 and 5.

Fig. 1 Participants' game design product on paper

While evaluating the activities of the test, the total scores of the participants in four different dimensions, namely, fluency, flexibility, originality and elaboration were calculated. Evaluation was carried out according to the criteria in the scoring guide for Torrance Tests of Creative Thinking, Figural Test, Booklet A (Torrance, 1974).

Semi-structured observation

The observation form was developed to determine the classroom learning behaviors of the students. For the observation form, the opinions of 2 faculty members and experts from various universities and faculties were taken. With this data collection tool, a group of 34 students were observed. The students were observed in the classroom where the application was made. The form was examined by field experts, corrections were made in line with their recommendations and the final version of the observation form was attained. With the observation form prepared by the researcher to be used in the follow-up evaluation phase, 23 students in the 5th and 6th grades were observed for 15 weeks.

Semi-structured interview

In this study, interviews were held with each student in order to get the opinions and suggestions of the game design workshop students about the game design course. Audio recordings of 10–15 min semi-structured interviews with 23 students in total were made. The data coded were reviewed and interpreted by the researcher.

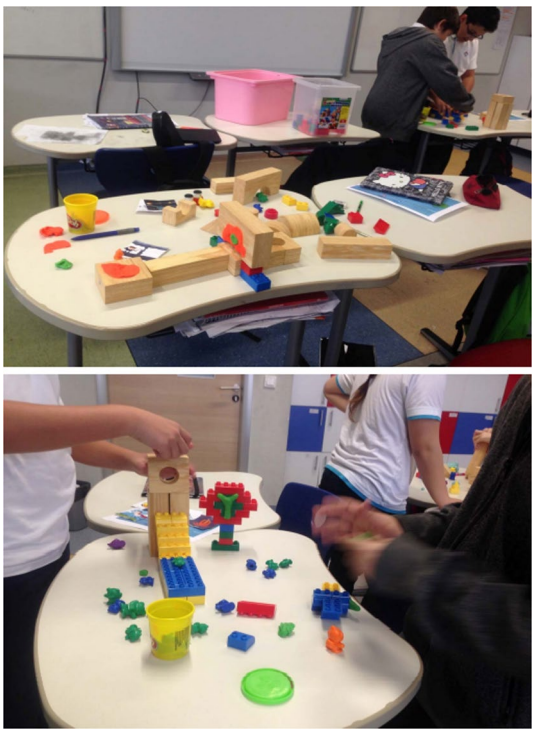

Fig. 2 Participants' game prototype

Analysis process

In this section, the tests used in the analysis of research data, namely the Wilcoxon signed-rank test and the paired sample T-test, are explained.

Paired samples T-test

When the measurements of the dependent variable of the same subjects are taken before and after an experimental procedure, repeated measurements of the subjects over time are needed and these measurements are related (Büyüköztürk, 2010). The researcher assessed the change in the creative thinking skills of the students before (pre-test) and after (post-test) the program he applied, and investigated whether the observed change was significant, and such a repeated measurements pattern was obtained with the related samples t-test. Since the Kolmogorov–Smirnov test results should be taken into account in cases of large sample population, this test was used to decide normality. As a result of the Kolmogorov–Smirnov test, it was determined that the data showed normal distribution ($p > 0.05$).

Findings

In this section, the findings secured as a result of the statistical analysis applied to each subscale of the data obtained from the students participating in the research were presented and comments on these findings were included. First of all, the scores

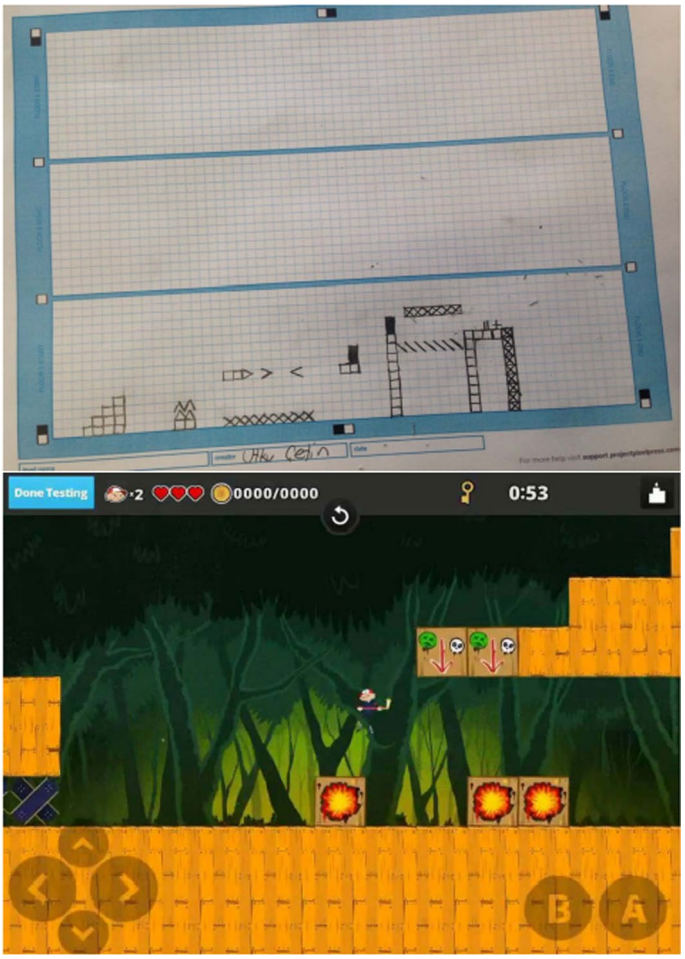

Fig. 3 Participants' Pixel floors game design example

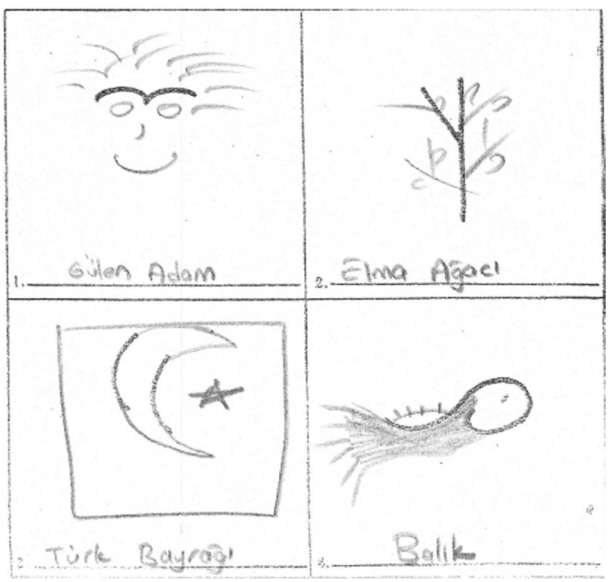

Fig. 4 Pre-test responses of the figure completion

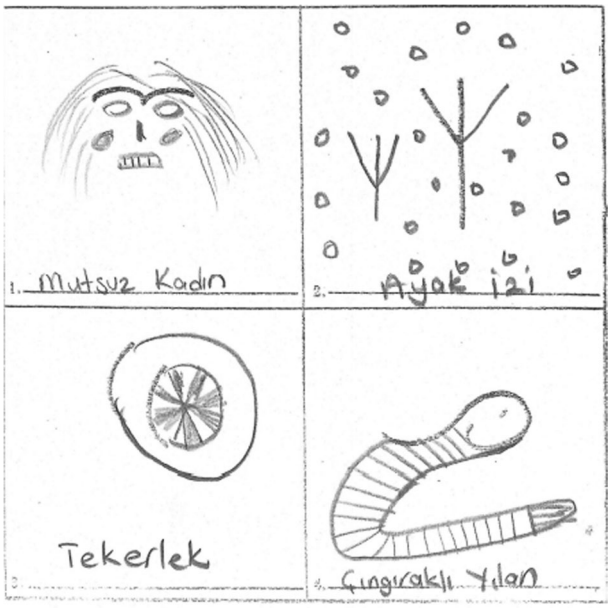

Fig. 5 Post-test responses of the figure completion

Table 1 T-test analysis results of students' TCTT pre-test and post-test scores

	N	X	S	Sd	t	*P*
Pre-test	23	92.91	24.55	22	5,263	0.000
Post-test	23	140.17	33.31			

of the participants were analyzed with Kolmogorov–Smirnov test which verified that they showed a normal distribution ($p > 0.05$), and then t-test analysis was applied to the dependent sample groups. Table 1 presents the data for this process.

The results of the dependent sample test in Table 1 show that there is a significant difference between the pre- and post-experiment scores of the students from the Torrance Test of Creative Thinking ($p < 0.05$). In other words, according to the results, it is clear that the post-test scores were significantly higher than the pre-test scores. TCTT.

Then, in the statistical analysis of the collected data, the mean values and standard deviations of the fluency, flexibility, originality and elaboration scores of the students, which are the subscales of the TCTT scale, were found, and the normality assumptions were examined to understand whether there was a difference between the scores (fluency, flexibility, originality and elaboration). It was ascertained that the subscale scores of the participants also showed a normal distribution in line with the Kolmogorov–Smirnov test ($p > 0.05$) results. The dependent sample t-test was repeated in order to compare the mean scores of the students for the subscales of the TCTT scale, and the data related to this analysis are presented in Table 2.

If the statistics presented in Table 2 are examined respectively, it might be determined that the students' post-test fluency mean scores were significantly higher than

Table 2 T-test analysis results of students' pre-test post-test scores for TCTT scale sub-fields

	N	X	S	Sd	t	*P*
Fluency						
Pre-test	23	26.13	7.04	22	4,298	0.000
Post-test	23	34.34	8.77			
Flexibility						
Pre-test	23	21.17	6.05	22	3,708	0.001
Post-test	23	27.56	5.79			
Originality						
Pre-test	23	21.30	15.73	22	7,666	0.000
Post-test	23	68.60	18.17			
Elaboration						
Pre-test	23	36.49	17.58	22	3,495	0.002
Post-test	23	49.69	13.97			

their pre-test fluency mean scores ($p < 0.05$). Then, when the flexibility scores were examined, it might be observed that the post-application scores of the students were significantly higher than before the application ($p < 0.05$). From this perspective, it was concluded that after the application, the students were able to think multi-dimensionally, they had no difficulty in evaluating the different items, and they were able to express their thoughts comfortably. When the statistics on the originality dimension, which is associated with the students' ability to think in detail, were analyzed, it was established that the post-application scores were statistically significantly higher than the pre-application scores, since $p < 0.05$. Finally, the participants' pre- and post-application score averages regarding the elaboration dimension were explored. In the light of these examinations, the effect of the application was found to be significant in terms of the "Detailing" dimension ($p < 0.05$). Therefore, one finding validated was that the students made a statistically significant improvement in all sub-dimensions of the TCTT scale.

Findings from the observation form

During the implementation process of the research, 23 students were observed by the researchers using a semi-structured observation form for 14 weeks. According to the data obtained through observation, the students who voluntarily participated in this extra-curricular activity demonstrated positive behaviors during in-class equipment controls. Managing to keep the attention of the students at the same level throughout the lesson, the class teacher enabled the formation of a positive observation that the students assimilated the course material. During the lesson, it was observed that the students followed the lesson well and took notes.

Findings from the interview

Student opinions about the application process were documented using a voice recording system. Audio recordings were analyzed by the researchers after they were transcribed. In the answers obtained from the students, codes such as 1 k and 2e were given to the students in order to keep the identity information of the students confidential.

First of all, the question "What are your impressions about the game design application?" was posed to the students who participated in the interview. Themes and frequencies related to the analyzed data obtained from the answers given by the students are presented in Table 3.

More than half of the students stated that the practice was both entertaining and pleasant, and that it contained instructive activities. Nearly half of the students indicated that they continued to participate in the practice with great enthusiasm without getting bored, that the content of the applied course was easy and understandable, and that they might recommend this course to others. They asserted that it was different from the games played in digital environments, and that the educational digital game used included Science course topics and instructive information. One student expressed that the game design course was different from the usual courses and therefore he had difficulty in adapting. The students were asked the question "*What did they like about the practice*?" The themes and frequencies related to the analyzed data obtained from the answers given by the students are presented in Table 4.

It was observed that the students generally liked the facts that the course was not offered in form of lecturing, that the students' perspectives were sought after via video presentations and that game designing was recognized as a creative and collaborative effort. It was also discerned that some of the students especially liked the game activities at the end of the lessons and the opportunity to work as a group during the game design phase. Two of the students stated that they gained very interesting information about games and game design during the course.

The question "Would you like other lessons to be taught with educational games?" was put to the students and the themes and frequencies related to the analyzed data obtained from the answers given by the students are shown in Table 5.

Table 3 Data from the interviews

Themes	f
Provides entertaining and pleasant learning environment	14
Provides simple and comprehensible learning environment	8
Different from the accustomed courses	1

Table 4 Data from the interviews

Themes	f
Class is not didactic	11
Game activities during class	5
Allows group work	5
Contains instructive information	2

Table 5 Data from the interviews

Themes	f
Yes, I would	19
No, I do not	3

Most of the students advocated that learning other lessons that incorporate educational games can be both fun and easier to understand. Three of the participating students expressed the idea that they got used to the working order of other lessons and that processing other lessons with the help of educational games would distract their attention.

When the question "Which lessons would you like to study by playing games like this?" was put to the students, it appeared generally that it would be more entertaining to process the lessons they learned at school by playing digital games. They especially said that mathematics courses can be easier to grasp with the help of games. One of the students stated that physical activities in Physical Education classes can be both visual and more fun with games.

Finally, the views of the students about the improvement that the course contributed to their creative thinking skills were explored. The majority of the students indicated that their creative thinking skills improved compared to the pre-application. Two of the students declared that they did not think that their creative thinking skills had improved compared to the pre-application. Students who thought that their creative thinking skills improved reported that their ability to instantly generate ideas in the face of a problem in their social life and school environment was enhanced, their communication skills especially with their friends in school, and their ability to use different objects and things for different purposes were upgraded.

Discussion and conclusion

The results of this research exploring the effects of having an individual design his/her educational games on creative thinking skills was the increase in participants' post-test scores. Similar to the research of Meishar-Tal and Avital Kesler (2021), in this study, after the students designed their own educational games, when the pre and post-test scores were compared, a significant difference in favor of the post-test scores was established with the related sample t-test. Across the sample of 23 people, the post-test scores of creativity in the dimensions of fluency, flexibility, originality and elaboration were found to be significantly higher than the pre-test scores ($t = 5{,}263$, $p < 0.05$). When the students' fluency scores, one of the sub-dimensions of creativity, were examined, their post-test scores were found to be significantly higher than their pre-test scores. The increase in fluency scores indicates a progress in students' ability to produce a lot of ideas on a topic ($t = 4.298$, $p < 0.05$). Flexibility post-test scores, which is another one of the sub-dimensions of creativity, were found to be significantly higher than the pre-test scores ($t = 3{,}708$, $p < 0.05$). This result demonstrates that students' abilities to bring different approaches to a problem has proliferated. When the originality scores, which is the third sub-dimension of creativity, were examined, the post-test scores were found to be significantly higher than the pre-test scores. This result reveals that students' thinking skills have advanced positively ($t = 7.666$, $p < 0.05$). When the students' elaboration scores, a fourth sub-dimensions of creativity, were investigated, their post-test scores were found to be significantly higher than their pre-test scores. This result indicates that the upturn in students' ability to think beyond the box has improved constructively ($t = 3{,}495$, $p < 0.05$). When the scores of 23 subjects in all 4 sub-dimensions of creativity were compared, it was ascertained that the increase in originality scores was higher than the other

sub-dimensions (X = 21.30; 68.60). The increase in the originality dimension indicates that the students' ability to produce new, unusual and rare ideas has increased compared to the pre-application (Torrance & Goff, 1989).

At the end of the application, the students' opinion and satisfactions about the application process were registered via semi-structured interviews. Short interviews of 10–15 min were held with all the participants and these were audio-recorded. The students were queried mostly for their thoughts on the sub-dimensions of creativity, and their perceptions about the application following which the coding phase was initiated. In general, students reported that their creativity increased compared to before the application and they started to get positive results of this increase in their school and social life. The participants declared that they enjoyed the activity very much and demanded the inclusion of the game design workshop to the curriculum as a lesson. This finding proves that game-based learning is an important tool to be used in the lessons, especially for teaching subjects that are considered difficult to understand. Studies in the literature indicate that students display a positive attitude towards game-based learning. For example, Triantafyllakos et al. (2011) state that the educational game design process supports students' ability to develop rational solutions for the difficulties they encounter in the learning process. Similarly, Kafai and Peppler (2012) also emphasize that educational game design helps students to use their academic knowledge by transferring them to different situations. Also, Guha et al. (2013) state that the game design process is important for the development of communication skills, as it directs students to communicate with different individuals such as both their peers and field experts. Lastly, Baytak and Land (2010), who used game design to help students gain nutritional habits, resolved that students were positively motivated by the games they made to gain their eating habits at the end of the study. Considering this situation, games can be delineated as auxiliary materials for students to develop positive attitudes towards the course or learning content.

In addition, the results of the research on game-based learning denotes that game-based learning activities are more effective than traditional methods in terms of academic achievement, class participation, interest and motivation development (Bado 2019). When the designs of these studies are examined, it is observed that their purpose is to discern the difference between the effects of the games integrated into the learning environment by the teacher using pertinent applications and the effects of learning activities performed via the traditional methods on student achievement and motivation (Mayer, 2020). In addition, in these studies, games are used as a platform where the learning content is presented to the student or as a media that facilitates the learning behavior towards the learning goal. For this reason, the role of students within the scope of the research is limited to playing the game, in other words, they are not designers but consumers of the content offered to them. Considering all this, it is possible to surmise that different research designs are needed for research on game-based learning. Mayer (2020) advocates that as a starting point for researchers, establishing research questions for game design features or skill development of students may be beneficial for the development of the field.

According to current studies, in order for learning to be permanent, students must be involved by doing and living the experiences themselves during the learning practice

(Merrill, 1991). In addition, the world now needs individuals who not only consume the content presented to them, but also produce the content and create added value, and who can think creatively and multi-dimensionally (Aktamış & Ergin, 2006; Tor & Erden, 2004). Therefore, instructional designs are required to entice students into productive processes. At this point, games have been preferred as an effective solution partner in numerous experimental studies. A limited number of studies revealed the presence of positive effects on the development of multidimensional thinking, creativity and communication skills of students who can design their own educational games (An, 2016; Baytak & Land, 2010; López & Fabricatore, 2012; Walfisz et al., 2006). Since the game design process requires interdisciplinary work due to its nature, the development of students' computer literacy, research and collaborative working skills are also supported in the educational game design process (Edmonds & Smith, 2017; Matuk et al., 2020). On the other hand, in the research conducted by Meishar-Tal and Avital Kesler (2021), it became apparent that the self-confidence and self-efficacy of the students who participated in the game design activities improved positively. Therefore, game design can be defined as an experience that supports the development of the individual in many different areas.

Research shows that both children and adolescents spend a significant amount of time playing digital games in their daily lives (Işıkoğlu et al., 2021). However, games are not limited to the activities that students prefer to have a pleasant time in the last few years. For example, when the university preferences of young people in the past years are examined, the enrollment rates of "game design" programs transcend most other programs (Student Selection and Placement Center, 2020). Similarly, it is observed that some programs within the scope of computer science such as user experience design, graphic design and digital product development prevail over others in massive open online course platforms (Coursera, 2020). In that sense, it is possible to say that today young people are interested in being the party that produces games. Therefore, providing more opportunities for this field that students are interested in and curious about will also lead to the recognition of talented young people in game design.

Suggestions

As revealed in this study, designing games subsumes development of creativity in multiple dimensions, not just in one. For this reason, there is a need for road maps prepared with a systematic perspective in order to raise individuals who can think creatively. For example, students can be asked to design educational games in areas such as mathematics, history and geography, and studies can be conducted to gauge whether their learning about those areas have increased. A study can be formulated by means of a questionnaire which reveals the motivations and attitudes of the students in the game design process. Within the game design process, similar studies can be realized by investigating not only the creativity of the students, but also their problem solving or critical thinking skills.

In addition, the development of technology offers numerous advantages to the whole world such as employing games for educational purposes and also making games and game design a part of curricula. Furthermore, this research has established that the applied game design process has a positive effect on students' creativity. The instructional design developed within the scope of this study can be generalized by applying it

in more schools as an after-school activity. Professional development programs that support teachers' digital competencies can be enhanced and implemented so that teachers can better transfer the game-design course to students.

Finally, economic indicators around the world point out that technology companies are the most important drivers. In addition, with the 2020s, the investments made by technology giants in the game industry drew attention. For this reason, game design contents can be included in the curriculum both as a constructive step towards the national economy and to support the human capital of young people.

Abbreviation
TTCT: Torrance Test of Creative Thinking.

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Authors' contributions
We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us. All authors read and approved the final manuscript.

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Declarations

Competing interests
The authors declare that they have no competing interests.

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