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Effect of the 5E model enriched with coding and digital game design activities on gifted students' academic achievement and problem-solving skills

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Abstract
Coding and digital game design activities have been used in recent years to contribute to students' academic achievement and twenty-first century skills. This study aimed to investigate the effect of the 5E model enriched with coding and digital game design activities (5EECD) on gifted students' academic achievement and problem-solving skills. A quasi-experimental design with pre-test post-test control group was used in the research. The sample of the study consists of 80 3rd grade gifted primary school students studying at a Science and Art Center affiliated to the Ministry of National Education in Türkiye. The study was completed in a five-week treatment period. The experimental group studied the force and motion concept with the 5EECD and the control group studied it with the proposed conventional method. Academic Achievement Test and Problem-Solving Skills Scale were used as pre and post-tests as measuring tools. The data were analyzed by descriptive and inferential statistics. The descriptive statistics results revealed that the experimental group students showed higher performances in science achievement and problem-solving skills. Inferentially, MANCOVA results showed that the 5EECD had a statistically significant effect on the collective dependent variables of the academic achievement and problem-solving skills. The ANCOVA findings also supported the above outcomes and it indicated that each of the academic achievement and problem-solving skills of experimental group was significantly higher than those of the control group. Therefore, the findings of the current research suggest that the 5EECD would be used for 3rd grade gifted students' science education.

Keywords Coding · Digital game design · 5E Model · Gifted students · Problem-solving skills

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1 Introduction

Gifted individual is someone who exhibits high performance in one or more of the following areas such as academic ability, intellectual ability, creativity, leadership, and visual arts (Gubbins et al., 2012). In Türkiye, the gifted students are identified through a two-stage intelligence tests (VISC-R) at primary school age (MEB, 2018) and the ones who score 130 and above are identified as gifted (Ersoy & Avcı, 2004). They receive at least six hours of education per week at Science and Art Center (SAC) in addition to their regular school education (MEB, 2020). The SACs are public schools that provide advanced education to gifted individuals. The students take courses in mathematics, science and social sciences according to their interests.

One of the fields that gifted students are most interested in is science (Höffler et al., 2019). Since gifted individuals have high learning capacities, the classical course contents in their regular schools may be boring for them and reduce their interests (Morris et al., 2021). Therefore, enriched content and learning environments are needed to increase their enthusiasm, imagination, academic achievement, positive attitudes, and high-level skills such as problem-solving, critical thinking and creativity (Sak, 2014).

In Türkiye, Ministry of National Education has investing for the development of gifted students' academic achievement and higher order thinking skills in the last decades (Çitil, 2018). It is expected that gifted individuals are more creative, problem-solving and critical thinking individuals (MEB, 2020). But, achieving this goal with traditional method and learning environments seems to be difficult.

When the developments in the field of education are examined, it is also seen that the educational environments have begun to be enriched with technological developments in recent years (Theodorio et al., 2024). Especially, coding and digital game activities have been included in educational processes and many positive feedbacks were received in this sense (Erol & Çırak, 2022; Mitrakas et al., 2023). However, when the education of gifted students is investigated closely, it is seen that there exist few studies using coding and digital game design activities with contemporary methods for their education. In addition, the students mostly play previously developed games rather than enabling them develop their own games via coding (Ke & Clark, 2020).

In this study, gifted students were encouraged to do coding activities and designing their own games within the scope of 5E which is one of the constructivists learning models. An enriched educational environment was provided by integrating coding and digital game design activities into the 5E model (5EECD). The effectiveness of the 5EECD on gifted students' academic achievement and problem-solving skills were tested by designing a quasi-experimental research in which the experimental group studied science with the 5EECD while the control group studied it with the proposed conventional method. The development and application of the 5EECD for gifted students' science education and investigating the effect of it on concerning learners' academic achievement and problem-solving skills is the most significant innovation of the current study.

2 Literature review

2.1 5E model

The 5E model is a contemporary learning model based on the constructivist theory. It was initially developed as 3E consisting the steps of exploration, explanation and elaboration (Joswick & Hulings, 2023). Later, two more steps were added and it was called as the 5E model with five stages of the engagement, exploration, explanation, elaboration and evaluation (Bybee, 2014). In the engagement stage, students' interests are focused on the topic by asking intriguing questions, showing pictures or telling interesting scenarios (Schallert et al., 2022). In the exploration stage, the teacher makes students active through various activities and allows them access information on their own by asking guiding questions instead of informing directly (Ruiz-Martín & Bybee, 2022). In the explanation stage, the teacher first gives students opportunities to make explanations and express their thoughts in their own words and then s(he) makes detailed explanations of the concept (Coşkun, 2011). In the elaboration stage, students apply their previously learned knowledge and skills to new situations they encounter (Schallert et al., 2022). At this stage, the use of different materials within the framework of possibilities also supports learning and permanence (Öztürk, 2013). The evaluation stage, which is the last step of the model, provides opportunities to see and evaluate whether students have achieved their educational goals and their progress in a concrete way by including open-ended questions, multiple-choice questions and worksheets (Büyükkarci & Taşlidere, 2024). It is noted that the 5E model uses a constructivist approach to increase learners' concern, help them to develop lesson-related potential and assess their abilities and understanding (Yonyubon et al., 2022).

The related literature presents that the 5E model is effective for gifted students' education and supports their academic achievement, motivation, creative thinking and problem-solving skills (Sak, 2014; Ürek, 2017). It motivates students by ensuring their active participation in learning process (Desouza, 2017). The model enables to use technological tools while teaching course contents and integrate them in learning environments (Taşlıdere, 2015; Joswick & Hulings, 2023; Şahin et al., 2009).

In the literature, there exist studies which integrates the 5E model with other technologies or methods for students' education. For example, Ceylan Eliyeşil and Tuna (2023) enriched the 5E model with Cabri 3D program activities. They reported that the model increased 7th grade students' geometry achievement compared to traditional method. Yenil and Gökkurt Özdemir (2023) conducted a study to eliminate students' misconceptions about decimal notation using the 5E model enriched with digital concept cartoons. The results showed that the treatment reduced 8th grade students' misconceptions about ordering, place value, addition-subtraction, marking numbers on the number line and rounding in decimal notation. Büyükkarci and Taşlidere (2024) integrated scratch coding activities into the 5E model while teaching mathematics to the 4th grade students.

The researchers reported that the developed model was found to be significant for increasing students' achievement in and attitudes towards mathematics. Likewise, Gökalp and Adem (2020) examined the effect of the 5E model enriched with the REACT strategy on university students' science achievement. They found that the model was effective for increasing students' achievement in the concepts of acids, bases and salts.

Similarly, Guven et al. (2022) integrated robotics activities into the 5E model and investigated the effect of it on 6th grade students' creativity, attitude and motivation levels in science course. Their findings showed that there were increases in the creativity, attitude and motivation levels. Hew et al. (2020) examined the impact of fully online flipped classrooms on learning performance using the 5E model. Quantitative analysis of students' final course grades revealed that participants in fully online flipped classes performed as effectively as participants in traditional flipped learning classes. İzci (2020) investigated the effect of science, technology, engineering and mathematics (STEM) approach based on the 5E model on 7th grade students' academic achievement and science process skills concerning transformation of electrical energy concept. The findings revealed that the applications designed according to the STEM approach in the 5E model increased students' achievement and improved their scientific process skills compared to the conventional method. Gürleroğlu (2019) used web 2.0 applications in accordance with the 5E model in middle school students' science course. The researcher reported that although the treatment did not have a significant effect on participants' achievement, attitude and digital literacy, there was a significant difference in their motivation towards science.

Likewise, Daşdemir (2017) examined the effect of different teaching methods on 7th grade students' science achievement. The researcher found that the 5E model enriched with animation had a significant effect on students' science achievement posttest scores compared to those of both cooperative learning and control groups. Taşlıdere (2015) investigated the effect of the 5E model enriched with simulations on science education students' achievement in photoelectric effect and the results showed a significant increase in learners' achievement. Hançer and Yalçın (2009) searched the impact of the computer-aided 5E model on 7th grade students' problem-solving skills in the subject of force and motion. The findings showed that there was a significant increase in participants' problem-solving skills. To sum up, it can be stated that the enriched 5E model is effective in terms of students' achievement (Taşlıdere, 2015; Büyükkarci & Taşlidere, 2024; Ceylan Eliyeşil & Tuna, 2023; Daşdemir, 2017; Gökalp & Adem, 2020; Hew et al., 2020; İzci, 2020) and their problem-solving skill (Hançer & Yalçın, 2009) in various disciplines. It should be noted that the above studies were all conducted with non-gifted students. The literature also underlines that integration of technological development with the 5E model would be effective for gifted learners' education (Yoon et al., 2020). Hence, it is though that enriching the 5E model with the latest contemporary approaches such as coding and digital game design activities would affect gifted students' academic achievement and problem-solving skills positively.

2.2 Coding and scratch

Coding, which is the starting point of computer software, means writing commands electronically to interact between people and technological instruments (Sayın & Seferoğlu, 2016). With the development of Industry 4.0 and new generation technologies, coding ability has become an important skill for employees in many fields. Hence, coding skill has been one of the significant twenty-first century skills (Balanskat & Engelhardt, 2015).

The related literature presents that approaches such as coding, robotics, stem-based design etc. contribute to students' learning-by-doing (Ching et al., 2019; Hayes & Games, 2008). Coding and design-based activities develop students' analysis, problem-solving and spatial skills (Resnick, 2013). It is also noted that the use of coding up to primary school level is important for the development of high-level skills at early age (Lye & Koh, 2018). Students can design their own projects and develop creative solutions to daily-life problems through coding (Karabak & Güneş, 2013). However, Resnick (2013) warns that coding programs should be suitable for children's developmental characteristics and stages.

In the last decades, many programs are developed to make coding fun for children. They have important goals such as sparking curiosity in coding, simplifying coding education by making it visible and reducing the difficulty of writing codes (Bosova, 2023). Scratch is one of the coding programs that is suitable for younger students. It is a block-based coding program developed by the Massachusetts Institute of Technology to teach programming for learners aged 8–16. Users can create interactive stories, games, animations and publish them on their own websites (Brennan & Resnick, 2013). They can perform mutual activities on the program and develop their problem-solving and creative thinking skills, as well as working together in an enjoyable environment (Balouktsis & Kekkeris, 2016).

The literature indicates that the number of studies using coding activities via scratch has increased in the last decade. For example, Gökçe and Yenmez (2023) examined ingenuity of scratch programming on reflective thinking towards problem-solving and computational thinking. They reported that the use of coding significantly strengthened 5th and 6th grade students' reflective thinking for problem-solving and computational thinking skills. Iskrenovic-Momcilovic (2020) conducted an experimental study with 3rd grade primary school students to investigate the effect of the use of scratch activities in geometry subjects. The results showed that the experimental group students had a significant achievement difference in geometric shapes. Alp (2019) investigated the impact of web assisted cooperative learning method via scratch on 5th grade students' conceptual understanding level in science and critical thinking skills. The findings showed that students' conceptual understanding level and critical thinking skills increased significantly. Keçeci (2018) examined the effect of scratch-supported teaching activities on 6th grade students' science achievement. The outcome was a significant positive effect on students' achievement in circulatory system. Yünkül et al. (2017) investigated the effect of coding education via scratch on 6th grade students' computational thinking skills. Researchers stated that the education had a positive effect in participants' problem-solving, algorithmic and creative thinking skills. Lai and Lai (2012) used scratch programming to enhance 5th graders' science learning. They presented that scratch coding activities contributed positively to students' science achievement. To sum up, the studies mentioned above were conducted with non-gifted learners and the coding activities via scratch supported their achievement (Alp, 2019; Keçeci, 2018; Iskrenovic-Momcilovic, 2020; Lai & Lai, 2012) and problem-solving skills (Gökçe & Yenmez, 2023; Yünkül et al., 2017) in various disciplines. Further, Erol and Çırak (2022) suggest using coding feature of scratch in developing game design activities in education. The related literature presents that using game design as a context for teaching problem-solving (Akcaoglu & Koehler, 2014; Ke, 2014; Ruggiero & Green, 2017) and supporting learning (Aksit & Wiebe, 2019; Chen, 2021; Puttick et al., 2024) has become popular by researchers in the last decade. Therefore, it is thought that both the coding and digital game design activities in science education would be beneficial for the development of success and problem-solving skills of gifted young learners.

2.3 Digital game design

Digital game design is a popular approach for students to experience the feeling of success and happiness (Kirriemuir & McFarlane, 2004), and has been used in educational environments in the last years (Hughes-Roberts et al., 2023). Involving students in game design activities during learning process increases their concentration, fosters higher-order thinking skills and leads to effective learning (Yang & Chang, 2013). During game design process, an environment is created where ideas about the content and purposes of the game are discussed, problems are revealed and tried to be solved (Kirriemuir & McFarlane, 2004). This environment can accelerate the acquisition of knowledge and provides students with a sense of achievement (Ke et al., 2019). Thus, students can achieve the objectives of the courses by designing their own games (Kapp, 2012; Wang et al., 2022).

The related literature shows that there are studies using digital game design activities in education. For example, Meishar-Tal and Kesler (2023) conducted an action research in which a digital game generator was used to develop thinking skills of 4th grade students with learning difficulties. Their research revealed that use of game generators led to the improvements in learners' thinking skills and performances. Erol and Çırak (2022) investigated the effect of game design activities via scratch on middle school students' problem-solving skills. They reported that game design activities improved participants' problem-solving skills. Bulut et al. (2022) examined the effect of educational game designing process on 5th and 6th grade learners' creative thinking development. Their research findings revealed that creative thinking skill scores of the students who designed their own educational games improved significantly. Wu and Sung (2021) designed a digital game-based review system for 4th grade students and investigated the effect of it on learning effectiveness, motivation, attitude, and interest. They concluded that the findings may serve as a reference for improving elementary school social science education.

Likewise, in the study of Seralidou and Douligeris (2021), students learned the basics of programming though creating games via block-type programming environment. The researchers reported that there were improvements in participants' knowledge and skills in programming through game creation process. Laakso et al. (2021) examined how 98 students across Finland experience the game design project and how the project foster connected learning. They reported that the learners experienced game design as inspiring and challenging activity, and designing game engaged learner teams in sustained, collaborative efforts to create shared digital artifacts. Çubukluöz (2019) analyzed the effect of game design activities on eliminating 6th grade students' difficulties in mathematics. The results showed that students' learning difficulties decreased. Akcaoglu et al. (2017) examined whether middle school students improved their problem-solving skills through an innovative game design or not. The researchers reported that students' problem-solving skills improved significantly. Hwang et al. (2014) used a peer assessment-based game development approach to improve 6th grade students' learning achievement, motivation and problem-solving skills in science course. The results indicated that the approach improved participants' learning, motivation and problem-solving skills. Ke (2014) conducted a case study to investigate the effect of designing math game activities on middle school children's mathematics learning. The researcher stated that the participants developed significantly higher positive dispositions toward mathematics after making game activities.

The related literature also shows that there exist studies which used digital games in various disciplines (Deng et al., 2020; Reynolds & Kao, 2021; Soyoof et al., 2023, 2024; Wang & Zheng, 2021). For instance, Soyoof et al. (2024) examined incidental vocabulary acquisition through serious games. Their findings showed that using games is effective for students gaining vocabulary and content knowledge. Likewise, Soyoof et al. (2023) explored the use of multiple games in English language learning. The findings highlight the potential of the multiplayer online role-playing game environment for language learning. Reynolds and Kao (2021) investigated the impact of digital game-based instruction in language learning. The researchers state that just-in-time grammar feedback provided during game play provided learners with opportunities to participate in language-related episodes that raised awareness and improved their academic performance. Wang and Zheng (2021) examined the effects of game-based learning on middle school students' science learning and their self-efficacy. Findings showed that learners in game-based learning groups performed significantly better in the content knowledge assessment and reported higher self-efficacy. Deng et al. (2020) examined the perceptions and experiences of a teacher and students in a public primary school when digital games were used in math class. They report that digital gameplay enhanced student engagement and interest in learning when used once daily over a 6-day period.

In conclusion, the studies mentioned above all were conducted with non-gifted participants, and the related literature presents that conducting game design activities in the educational process in various fields improved students' learning and achievement (Çubukluöz, 2019; Erol & Çırak, 2022; Hwang et al., 2014; Ke, 2014; Seralidou & Douligeris, 2021; Wu & Sung, 2021) and enabled students develop their problem-solving skills and creativity (Bulut et al., 2022; Ke et al., 2019; Laakso et al., 2021; Ruggiero & Green, 2017; Smith et al., 2020).

In Türkiye, it is aimed to reveal gifted students' talents via educational processes supported by contemporary teaching methods, materials and technological tools (Ataman, 2004). But, the limitations of the framework programs designed for science education in gifted students, along with challenges during with program implementations, diminish students' motivation and hinder the full development of their academic abilities (Bozan & Savi Çakar, 2020; Ülger & Çepni, 2020). It is thought that enriching the 5E model with coding and digital game design activities and applying it in gifted students' science education would produce significant outcomes in terms of their science achievement and problem-solving skills. However, the detailed literature review indicated that although there exists studies which enriched the 5E model with other technologies as mentioned above (Büyükkarci & Taşlidere, 2024; Ceylan Eliyeşil & Tuna, 2023; Daşdemir, 2017; Guven et al., 2022; Hançer & Yalçın, 2009; Hew et al., 2020; İzci, 2020; Yenil & Gökkurt Özdemir, 2023), there are limited number of research (Büyükkarci & Taşlidere, 2024; Guven et al., 2022) which used the 5E model with coding activities, and none of them used game design activities in the 5E model. Also, the aforementioned studies were conducted with at least 4th grade non-gifted students. Hence the current study will be a new research that develops a unique model that integrates coding and digital game design activities together into the 5E model and investigates its' effectiveness on 3rd grade gifted students' academic achievement in science and problem-solving skills.

In conclusion, the current study aims to examine the effect of the 5EECD on 3rd grade gifted students' academic achievement and problem-solving skills. For this purpose, coding activities were included in the exploration phase and digital game design activities were included in the elaboration phases of the 5E model, considering the acquisitions of the force and motion concept. With the implementation of the developed model, answers of the following problems were sought.

1. What is the effect of the 5EECD on the collective dependent variables of 3rd grade gifted students' post-achievement (FMPS) and post-problem-solving skills (PSPS) when their pre-achievement (FMPR) and pre-problem-solving skills (PSPR) are controlled?
2. What is the effect of the 5EECD on 3rd grade gifted students' FMPS when their FMPR and PSPR are controlled?
3. What is the effect of the 5EECD on 3rd grade gifted students' PSPS when their FMPR and PSPR are controlled?

3 Methodology

3.1 Research model

Effect of the 5EECD on students' academic achievement and problem-solving skills was investigated via quasi-experimental design. In cases where the controls required by real experimental models cannot be provided, the quasi-experimental designs are utilized (Fraenkel et al., 2012). Pre-existing groups are assigned as experimental and control groups through random assignment. The measuring tools were administered to both groups as pre and post-tests concurrently by the researcher.

In the current study, the force and motion concepts were studied via the 5EECD in the experimental group and the same concepts were studied considering the existing traditional convenience method in line with the framework program. The researcher participated in the lessons of both groups to prevent the emergence of negative situations affecting reliability of the research. Quantitative data were obtained and analyzed at all stages of the research.

3.2 Population and sample

The sample of the study consists of 80 gifted students studying at the 3rd grade of primary school in one of the SACs in Antalya province of Türkiye according to the convenience sampling method. The accessible population consists of 148 students studying in five SACs operating in the same city. The number of students in the sample constitutes approximately 54% of the accessible population. The target population is all 3rd grade gifted students studying in all SACs in Türkiye.

There were four groups at the 3rd grade level in the SAC where the study was conducted. Average academic levels of each group are almost similar to each other due to fact that the students were selected for the SAC according to the results of two-stage examinations. Hence, two of the existing four groups were randomly assigned as the experimental group and remaining two as the control group. All students agreed to participate in the research by bringing signed parental consent forms. There are 40 (50%) students in the experimental group and 40 (50%) students in the control group. 15 (37.5%) students in the experimental group are female and 25 (62.5%) students are male. Similarly, 16 (40%) students of the control group are female and 24 (60%) students are male. According to this distribution, it can be said that the number of male and female participants in the groups are almost close to each other.

3.3 Measuring tools

Two measuring tools, namely the Academic Achievement Test on Force and Motion Concept (ACT) and the Problem-Solving Skills Scale (PSSS), were used. Information about the tools is given below briefly.

3.3.1 ACT

ACT was developed by researchers to measure the academic achievement of gifted students studying at the SAC concerning the force and motion concept. It consists of a total of 30 multiple-choice questions. In the development phase of the test, a draft test was created by first preparing 30 questions related to four objectives of force and motion concept. A table of test specification was prepared to ensure the content validity of the draft test. Then, the content and face validities of the draft test were ensured by obtaining expert opinions from four people, including an expert faculty member, two primary school teachers and a science teacher with master degree. Suggested corrections were made in line with the feedback. In the next stage, a pilot study was conducted by applying the draft test to 182 gifted students at the 4th grade level studying at the same SAC and item analysis was conducted. As a result of the pilot study, KR-20 reliability coefficient of the test was calculated as 0.78. Average difficulty index of the entire test was 0.51 and the average discrimination index was 0.47. According to Crocker and Algina (2008), these values are in almost acceptable ranges. Then the ACT was used as a pre-test before the implementation of the research and as a post-test afterwards. The KR-20 reliability coefficient of the post-test application was calculated as 0.71 in the main study.

3.3.2 PSSS

The PSSS was used to determine how teaching methods affect students' problem-solving skills. It was used as pre and post-tests. The scale was previously developed by Serin et al. (2010). The PSSS consists of 24 items in a five-point likert type scale and three factors. Half of the questions are positive and the remaining are negative. The items were rated as "Always", "Frequently", "Occasionally", "Rarely" and "Never". The authors verified content and construct validities of the PSSS by expert opinions and factor analyses (both explanatory and confirmatory) in the development period. Serin et al. reported that the scale explained 42.26% of the total variances and its' Cronbach alpha reliability coefficient was 0.80. For the current study, Cronbach alpha reliability coefficient was found as 0.87 according to the post application of the PSSS.

3.4 Lesson plans and materials

In the study, various teaching learning materials such as Lesson Plans, Coding Activity Sheets, Game Design Sheets and Worksheets were prepared. Information about the materials is given below briefly.

For the experimental group, four different lesson plans, covering four objectives of the force and motion subject within 15 h, were developed in accordance with the 5EECD. They were developed for the concepts of; (a) the motion properties of the entities, (b) push and pull force, (c) the effects of force on objects and (d) the dangers that moving objects can cause in daily life correspondingly. Expert opinions were obtained about the plans from an expert faculty member and three experienced teachers. For this purpose, an Information Form explaining the 5EECD in detail was prepared and given to the experts. Also, an Evaluation Form for the lesson plan was developed to evaluate the plans. The experts first read the Information Form explaining the 5EECD and then they were asked to evaluate the plans according to the Evaluation Form in terms of their conformity with the 5EECD, the appropriateness of the language and contents to the student level, and whether the plans cover the target contents, learning objectives and face validity. Finally, the plans were revised according to the suggested corrections and feedbacks.

A total of eight Coding Activity Sheets were developed for the experimental group to be used in the exploration stages of the 5EECD. These sheets are in structured format and include the codes of the scenes and characters needed to perform the coding activities related to the concepts of force and motion. They guide how students will proceed coding step by step while performing activities. One of them is given in Appendix-A as a sample example. For instance, this coding activity sheet was developed for students to discover the types of forces as push and pull. It includes short informative instructions for students about how to do coding and what codes they should use. In the whole study, it was aimed that the students would discover the motion properties of entities, push and pull force, the effects of force on objects and the dangers that moving objects can cause in daily-life via all eight Coding Activity Sheets. They were used in accordance with lesson plans.

Four Game Design Sheets were developed related with the objectives for the experimental group. Each includes a problem situation and asks students solve it by designing a game via coding. The sheets have sections where students can write the names, purposes, characters and rules of their games. It was aimed that each student specifies the features of his/her game by first filling the sections in sheet based on the given problem, and then designs the game. One of the sheets was given as an example in Appendix-B. For example, in this sheet, the problem was stated as; Buglem and Veli attended sports courses during the summer holidays. Buglem enrolled in the archery course and Veli enrolled in the football course. On the first day of the course, Buglem had problems in drawing the arrow with her fingers, while Veli had problems in sending the ball into the goal properly. Design a game to help Buglem and Veli solve the problems they had in the courses. Students are expected to apply their knowledge of pull and push forces to solve the given problem. Students should first decide which character should use which type of force and then design their games.

10 Worksheets were prepared for the experimental group. Five of them were used in the explanation stages of the 5EECD in the experimental group. The sheets include questions which aim to reveal what students have discovered previously at the end of coding activities. The students were also asked to write and explain briefly their understanding into the blanks given in the sheets. The sheets have also activities to enhance their learning. One of them is given as an example in Appendix-C. For example, in this worksheet students were expected to discover the types of forces as push or pull at the end of coding activity as mentioned above. It asks learners to write and explain briefly what they have discovered previously. Additionally, it provides activities to classify the objects that can/can't be moved by pushing and pulling in the classroom. Additionally, the remaining five worksheets were used to assess and evaluate students' learning at the evaluation stages. The worksheets include fill-in-the-blank type, multiple-choice type and open-ended type questions. One of them was given in Appendix-D. The concerning worksheet was developed to assess and evaluate what kind of force was required for the given situations. The situations are given in the left side and the students were expected to write the type of required force in the blank given in right side.

Likewise, four lesson plans, covering the same topics studied as in the experimental group, were prepared for the control group. They include 15 h of training.

The plans were developed according to the existing curriculum recommended for the SAC by Ministry of National Education. In the SACs, the lessons are carried out in line with framework programs prepared in modular structure. According to these programs, teachers have the opportunity to study lessons according to the interests and needs of gifted students (MEB, 2020). The teacher studied the lessons according to the lesson plans prepared based on the framework program developed in modular structure. In addition, eight worksheets were prepared to be used in teaching–learning process of the control group. They include fill-in-the-blank type, multiple-choice type and open-ended type questions. A sample one is given in Appendix-E. This worksheet presents some situations concerning push and pull forces. The teacher distributed and students first solved it by themselves after the topic of pull and push forces was studied. Then teacher explained the unsolved questions in the classroom.

3.5 Implementation process

The study was completed in a total of five weeks treatment period including three hours per week. The implementation process carried out in the groups are mentioned below briefly.

3.5.1 The implementation of lessons in experimental groups

In the experimental group, the lessons were studied according to the lesson plans developed for the 5EECD. Total four lesson plans were followed in the experimental group concerning four topics mentioned previously. In the engagement phases of the 5EECD, the teacher showed various visuals, read short passages and made the students play short games to take their interest towards contents. Meanwhile he asked questions related to conducted activities but no explanation was made about the questions by teacher in these stages. These phases took approximately 10 min. Then the exploration phases started and they lasted in approximately 30 min. In these stages, students carried out coding activities through Coding Activity Sheets to discover the objectives of the lessons via scratch. In the explanation phases, students first made verbal explanations about the situations they have discovered through coding in the previous phases and then wrote their explanations in worksheets as mentioned above. The teacher supported and encouraged students in expressing their own thoughts due to their discoveries in the exploration stages in classroom environment. Then, the teacher explained the concepts in detail by considering the missing points and erroneous parts which students presented. Meanwhile students took notes in their notebooks also. These phases also lasted in approximately 25 min. In the elaboration stages, a total of four Game Design Sheets were used during the whole study. Each consists of one problem situation for each objective. The sheets ask students design a game for the given problem situations. It was aimed that students elaborate their knowledge on concepts by designing their own games via the scratch program in about approximately 40 min. The students first defined the name, purpose, characters and rules of the games in the Game Design Sheets and then designed their games. Finally, in the evaluation phases, both the students and the teacher evaluated the learning outcomes. For these, previously prepared five worksheets were distributed to the students at the end of sub-topics and each student tried to solve it individually. After that, the worksheets were also projected on the smart board and each question was answered by one student on the board. The teacher tried to ensure that each participant took the floor and sometimes necessary feedback was given to learners when necessary. These phases also lasted in approximately 20 min.

3.5.2 Implementation of lessons in control groups

As mentioned above, the lessons are carried out according to the lesson plans developed based on the framework program offered by the Ministry of National Education for the SACs. The program serves as a guide in the SACs. The implementation process in the control groups was carried out in three lessons hours per week. The learning process of the same topics (motion properties of entities, push and pull force, the effects of force on objects and dangers that moving objects may cause in daily life) were completed smoothly in a total of five weeks. At the beginning of the lesson, the teacher conveyed the preliminary information about the concepts related to the subjects, and mostly used the lecture method, question and answer techniques in teaching. Students participated in the lessons by taking the floor during the parts where the teacher asked questions. Then, the teacher wrote the important points and explanations on the board and made sure that the students took notes in their notebooks. Then the worksheets were distributed and students solved the questions. The teacher made required explanations and corrections about the questions.

3.6 Data analysis

Descriptive and inferential statistics were used to reveal the effect of the 5EECD on students' academic achievement and problem-solving skills. As descriptive statistics, the mean, standard deviation, skewness, kurtosis values of the scores obtained from the ACT and PSSS applications were calculated. The values related to the groups were compared. Then, MANCOVA and follow up ANCOVA techniques were used as inferential statistics to investigate the effect of the 5EECD on the collective dependent (also on each dependent) variables of the FMPS and PSPS when the FMPR and PSPR are controlled. Because, MANCOVA enables researchers to test the statistical significance of the effect of independent variable(s) on a set of two or more dependent variables, after controlling for covariate(s). Likewise, ANCOVA enables to test the statistical significance of the effect of independent variable(s) on each dependent variable separately after controlling for covariate(s) (University of Miami, 2024).

Table 1 Descriptive statistics results of the groups regarding the tests

	Experimental group		Control group	
	FMPR	FMPS	FMPR	FMPS
N	40	40	40	40
Mean	7.52	18.55	8.95	14.95
SD	3.06	4.23	3.84	4.44
Skewness	−0.16	−0.85	0.31	0.56
Kurtosis	−0.62	1.40	−1.03	−0.12
	PSPR	PSPS	PSPR	PSPS
N	40	40	40	40
Mean	87.47	99.90	93.67	96.60
SD	13.32	10.42	12.16	12.71
Skewness	−0.33	−0.42	−0.13	−0.33
Kurtosis	0.10	0.35	−0.33	−0.54

4 Results

4.1 Descriptive statistics

The descriptive statistics results of the FMPR, FMPS, PSPR and PSPS test results of the experimental and control groups are shown in Table 1.

Students' ACT scores were calculated out of 30 points due to each correct answer was scored as 1 point. Table 1 shows that the mean FMPR of the experimental group was 7.52, while that of the control group was 8.95. The FMPS averages were calculated as 18.55 in the experimental group and 14.95 in the control group respectively. From pre to post-test, there was an increase of 11.03 points in the experimental group and only 6.00 points in the control group correspondingly. Students' PSSS scores were calculated out of 120 points. When the PSSS data are analyzed, it is seen that the average mean of the experimental group's PSSS scores increased from 87.47 to 99.90 from PSPR to PSPS with an increase of 12.43 points. Likewise, the average mean of the control group's scores increased from 93.67 to 96.60 points from PSPR to PSPS with an increase of only 2.93 points. It can be said that the experimental group students increased their academic achievement and problem-solving skills more with respect to those of the control groups descriptively. According to Table 1, it can be accepted that the skewness and kurtosis values of the FMPR, FMPS, PSPR and PSPS variables are within normal distribution ranges (Tabachnick & Fidell, 2013).

4.2 Inferential statistics

Effects of the 5EECD on the collective dependent variables of the FMPS and PSPS were investigated via MANCOVA and follow up ANCOVA analyses. Previously, it was considered that the independent variables of the FMPR and PSPR scores would be the factors affecting FMPS and PSPS scores. Hence, both variables were foreseen

Table 2 ANCOVA results

Source	DV	Type- III Sum of square	df	Mean square	F	Sig	Partial eta squared	Observed power
Treatment	FMPS	368.985	1	36898	23.55	0.00	0.23	0.99
	PSPS	1055.498	1	1055.49	15.24	0.00	0.16	0.97

as potential covariates and tested their correlations with the dependent variables. The findings showed that there were significant correlations between the FMPR and FMPS ($r = 0.309$, $p < 0.01$), and the PSPR and PSPS ($r = 0.643$, $p < 0.01$). Thus, the FMPR and PSPR were used as the covariates for the future statistical analyses. Each of the assumptions related to MANCOVA (normality, equality of variances, homogeneity of regression, multicollinearity, and independency of observation) was checked and no significant problem was met. Finally, the MANCOVA was conducted. Initially, it was hypothesized that there was no significant effect of the treatment, on the population means of the collective dependent variables of the FMPS and PSPS when the FMPR and PSPR were controlled. MANCOVA results revealed that the hypothesis was rejected for the treatment ($\lambda = 0.695$, $F(2, 75) = 16.42$, $p < 0.05$). The effect size (partial eta squared) and power were found as 0.305 and 1 respectively. According to Cohen and Cohen (1983), the effect size corresponds to a large value and the 5EECD explained 30.5% of variance on the collective dependent variables of the FMPS and PSPS. The effect of the treatment on each dependent variable was investigated with ANCOVA and the results are reported in Table 2.

Field (2005) suggests researchers divide alpha level by the number of dependent variables to decrease the experiment-vise errors. Hence, significance level (0.05) was divided by two and the ANCOVA results were evaluated considering the new value of 0.025. The results indicate that the treatment has significant effects on the FMPS ($F(1, 76) = 23.55$, $p = 0.00$) and PSPS ($F(1, 76) = 15.24$, $p = 0.00$). The effect sizes for the FMPS and PSPS were 0.23 and 0.16 respectively. These values correspond to large effects (Cohen & Cohen, 1983) indicating that 23% of the variance on the FMPS and 16% of the variance on the PSPS were explained by the treatment. The observed powers were 0.99 and 0.97 for the FMPS and PSPS respectively. These corresponding values present that the study has also practical significance as well as the theoretical significance. To sum up, the statistical results showed that the 5EECD has increased 3rd grade gifted students' academic achievements in force and motion concept and problem-solving skills significantly compared to the suggested framework program when the FMPR and PSPR were controlled.

5 Discussion

The current research aimed to develop the 5EECD by integrating the 5E model with coding and digital game design activities, and investigate its' effectiveness on 3rd grade gifted students' academic achievement in science and problem-solving skills. The descriptive results showed that the 5EECD increased students' academic achievement and problem-solving skills more with respect to the existing framework program. Likewise, the inferential statistics supported the descriptive findings. Namely, MANCOVA results showed that the 5EECD increased collective dependent variables of the students' academic achievement and problem-solving skills significantly when their pre-achievement and pre-problem-solving skills are controlled. Subsequent ANCOVA results also revealed that each of the academic achievement and problem-solving skills of the students in the experimental group increased significantly with respect to those of the students in the control group.

One of the significant findings of the current research is that the 5EECD was effective for increasing gifted students' academic achievement in the subject of force and motion. This result is consistent with those of previous research which integrated the 5E with coding activities (Büyükkarci & Taşlidere, 2024; Guven et al., 2022). Drawing students' attention to the force and motion subject in the engagement phases increased participants' desire and motivation to learn in the lessons. As Desouza (2017) states this stage motivated the participants towards learning by triggering their active participation in learning process. Then, use of structured coding activities enabled students discover information and situations related to the concepts in the exploration phases. As previous research (Ching et al., 2019; Hayes & Games, 2008; Yonyubon et al., 2022) noted, concreated coding experiences contributed to the students' learning by doing. In the explanation stages, the students' first explanation of the situations which they have previously discovered as a result of coding allowed the detection of deficiencies or mistakes. Then satisfactory explanations made by teacher recovered the missing or erroneous parts in the concepts. Likewise, in the elaboration phases, students had opportunities to apply their learning into practice by designing games; they were asked to dream and design their own games related to the subjects. As previous researches (Kapp, 2012; Puttick et al., 2024; Wang et al., 2022) stated, game design activities have been promising contexts for supporting gifted learners. Consistent with the idea of the Puttick et al. (2024), learning through building game in constructivist environment led students choose their pathways through learning experiences. They created environments, where the ideas about the content is formed, specified the purpose of the game, determined the potential problems and tried to solve them as presented by Kirriemuir and McFarlane (2004). The environments created by students accelerated the acquisition of knowledge and provided them with senses of achievements as noted by previous researches (Ke et al., 2019; Kirriemuir & McFarlane, 2004). It is thought that students actively constructed their understanding through engagement with the proposed daily-life problems. Finally, the evaluation phases offered opportunities to both students and teachers to evaluate learning outcomes. Detected deficiencies or errors were tried to be compensated. To sum up, the gifted students enjoyed and engaged in activities that appealed to their curiosity throughout the 5EECD. As previous research underlined (Taşlıdere, 2015; Beauchamp, 2004; Joswick & Hulings, 2023; Phillips & Jeffey, 2016) using technology with contemporary approach in science teaching made the lessons more interesting and successful. It is thought that all applications and activities of the 5EECD supported the academic success of the experimental group.

Other significant finding of the current study is that the 5EECD significantly affected gifted students' problem-solving skills. This outcome can be attributed due to the developed model which used coding and game design activities with 5E model in a compatible manner as suggested by Joswick and Hulings (2023). The finding is consistent with the previous research which noted that coding is important for the development of students' high-level skills at early age (Lye & Koh, 2018) and learning coding provides the basics of thinking and planning (Arfé et al., 2020; Siegle, 2017). In the current study, after taking students' attention towards force and motion concepts via engagement stages, the learners have found themselves in coding activities through Coding Activity Sheets to discover the objectives of the lessons. As Siegle (2017) presents they gained independence as troubleshooting the coding errors and overcoming challenges. Then, students explained their understanding based on the coding, and gained scientific information. Upon them, they conducted game design activities in the elaboration stages. Game design activities encouraged learners think more deeply about their game designs as stated by previous studies (Ruggiero & Green, 2017; Siegle, 2017). According to Jonassen (1997) problem-solving process involves representing, planning, execution and evaluating. In the whole study, total four Game Design Sheets were used as reported before. Each presented a real-life problem situation. Learners individually read and understood the scope of the problem. According to Ruggiero and Green (2017), understanding the scope of the problem corresponds to representing phase of problem-solving process. Then, each student specified the name, purpose, characters and rules of the game consequently. By doing so, the student first broke the problem into small pieces, then put back together in a logical step by step sequence and finally come up with a solution (Siegle, 2017). These activities correspond to planning phase of problem-solving process (Ruggiero & Green, 2017). After that s(he) acted on plan and conducted coding for the game. Finally, the student checked whether the execution helped them to solve the problem or not? Acting on plan, conducting coding for the game and checking whether the game works or not correspond to executing and evaluating phases of the problem-solving processes (Ruggiero & Green, 2017). Hence, all of the representing, planning, executing, evaluating and overcoming challenges in the process of creating game might have triggered the development of participants' problem-solving skills as previous researches (Jonassen, 1997; Laakso et al., 2021; Resnick, 2013; Ruggiero & Green, 2017; Siegle, 2017; Smith et al., 2020) claimed.

The results also showed that the academic achievement and problem-solving skills of the control group students remained at a lower level compared to those of experimental group. Of course, this result was a predicted outcome, because the experimental group students exposed to enriched teaching activities with the 5EECD. On the other hand, the control group students received lecturing and completing worksheets. The teaching provided for this group was far from constructivist approach. The followings would be the possible reasons for the control group students' low levels of academic achievement and problem-solving skills. First of all, the lessons were studied according to the plans developed based on the existing framework program in modular structure. The teacher explained the concept via lecturing and the students took notes on their notebooks. After those, the worksheets including questions were distributed and the students solved them. Then necessary explanations and corrections were made according to the questions received from the learners. No additional support was provided outside the planned process. Students were not active as in the experimental group.

The findings of the current research revealed that the 5E model should be enriched with technological approaches and used for the gifted learner's science education. This outcome is consistent with those of previous research (Büyükkarci & Taşlidere, 2024; Joswick & Hulings, 2023; Yoon et al., 2020). The enriched contents and learning environments with the 5EECD became a promising context and learning environment supporting gifted individuals' learning and problem-solving skills and they increased students' enthusiasm, imagination, academic achievement and problem-solving skills as noted by previous research (Sak, 2014; Yoon et al., 2020). Hence, although each of the 5E model (Sak, 2014; Ürek, 2017), coding and game design activities (Balouktsis & Kekkeris, 2016; Resnick, 2013; Robertson & Howell, 2008) are presented to be effective for academic achievement and problem-solving skills in the related literature, the increases in the concerning depending variables are attributed to the 5EECD for the current research. Successful application of the 5EECD provided a synergy and encouraged learners to participate lessons both mentally and physically, and in turn, their active enrollment into the learning environment supported success and problem-solving skills as previous research claimed (Aksit & Wiebe, 2019; Chen, 2021; Puttick et al., 2024).

It would be useful to mention some issues regarding the validity of the current study. Namely, according to Fraenkel et al. (2012), there may be some threats in quasi-experimental designs that may affect the validity of the research. It is claimed that all threats to validity of the study were tried to be avoided and controlled. Mortality was not a problem, because there was no loss of data or any subjects, which could threaten internal validity. Students participated in the study from beginning to the end of the implementation. Before the research, the students and parents were informed about the research and all necessary precautions were taken. During the implementation process, Hawthorne effect was not observed, because no problems or negative events happened that could demotivate the students and affect them negatively. Also, the applications of the measuring tools were conducted in standard manners; they were administered simultaneously by the researcher and the data were collected in their own classrooms that the students were familiar with. So, instrumentation and testing were no problems for the internal validity of the study. The implementations of the treatments in both groups were conducted in line with the lesson plans to satisfy the treatment verification. In addition, for the external validity, it can be stated that this study was conducted with 3rd grade 80 gifted students studying in one of the four SACs in one province. These 80 gifted participants constituted approximately 54% of the accessible population. Hence, this value could be accepted as the evidence for the satisfaction of the population validity of the study. Also, the physical conditions of the classrooms, laboratories and technical equipment in the SAC where the research was conducted are almost similar to other SACs in Türkiye. This also supports the ecological validity of the study.

Finally, the related literature showed that the number of studies using coding with the 5E model in science education is quite limited (Büyükkarci & Taşlidere, 2024; Guven et al., 2022), and although much research focused on learning through game playing, very limited research has focused on learning through designing digital game by coding (Dishon & Kafai, 2020; Puttick et al., 2024; Ruggiero & Green, 2017) in science education. Especially, there was no study which integrated coding and digital game design activities into the 5E model in teaching force and motion subject and investigating the effectiveness of treatment on 3rd grade gifted students' achievement in and problem-solving skills. The current research attempted to fill the gap in the related literature. Hence, it is hoped that the findings of the current study would contribute to the gifted learners' science education literature.

6 Conclusion

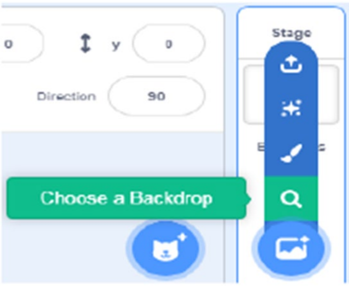
The current study aimed to develop an enriched learning environment via the 5EECD and investigate its' effectiveness on 3rd grade gifted students' science achievement and problem-solving skills. The findings showed that successful application of the 5EECD increased students' both academic achievement in force and motion concept and problem-solving skills more with respect to those of the students instructed with existing framework program. The coding and digital game design activities completed in accordance with the stages of the 5E contributed greatly to the development of students' academic achievement and problem-solving skills. These findings imply that integrating coding and digital game design activities with 5E model would be used for 3rd grade gifted students' science education to enhance their science achievement and problem-solving skills.

There are some limitations in the current research. First, the study was limited to 3rd grade gifted primary school students studying in the SAC in one province of Türkiye. For this reason, the effect of the 5EECD on achievement and problem-solving skills can be investigated with the participation of more 3rd grade gifted students in other provinces. Second, the current research developed the 5EECD and investigated the effect of it on gifted students' achievement in science and problem-solving skills. The results showed that the 5EECD was affective for gifted students' achievement and problem-solving skills. Investigating which of the coding, digital game design and 5E model triggered students' achievement and problem-solving skills more was not the scope of the current research. But further studies would be conducted to search the relative effects of coding, digital game design and 5E model on gifted learners' science achievement and problem-solving skills. Third, this research used quasi-experimental design of quantitative research methods and hence the results depend on only the quantitative data obtained from measuring instruments. A similar study would be conducted by using mixed-methods research and the results would be analyzed considering both quantitative and qualitative data. Finally, the future studies would investigate the effect of the 5EECD on 3rd grade gifted students' other variables such as attitude towards science, motivation and creativity as well as achievement and problem-solving skills, and their results can be compared with those of the current study.

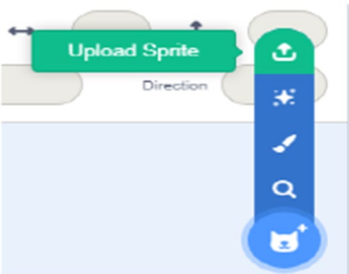
Appendix 1

Please read and follow the directions given below carefully. Observe what you will have at the end of coding.

To select a scene, click the "Choose a Backdrop" command in the "Stage" section. In the menu that appears, select the ’Bench with View’ scene by clicking the ’Outdoors’ title.

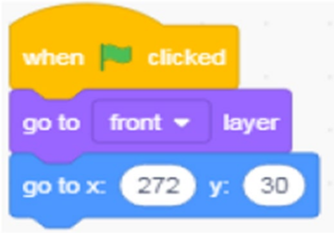


To change the character, click on the "Upload Sprite" command in the "Sprite" section. Select the sprites "Avery Walking, baby stroller, pull and push" from the "force and motion" folder on the computer.

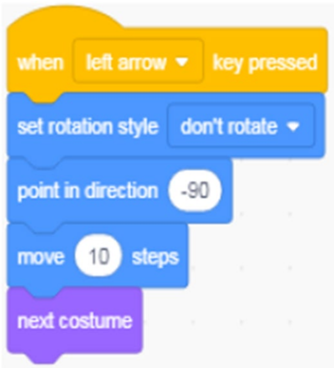


The codes for the character "Avery Walking" are as follows.

1. Select the "when green flag clicked" block from the "Events" menu and drag it to the coding area.
2. Select the "go to front layer" block from the "Looks" menu and drag it under the "when green flag clicked" block.
3. Select the "go to x: y: " block from the "Motion" menu and drag it under the "go to front layer" block. Set the value as in the picture.

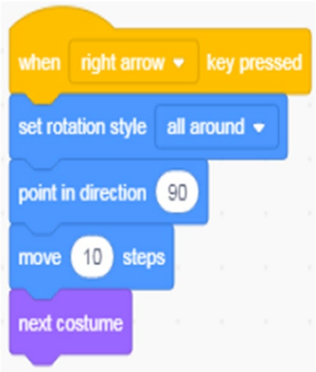


1. Select the "when left arrow key pressed" block from the "Events" menu and drag it to the coding area.
2. Select the "set rotate style don't rotate" block from the "Motion" menu and drag it under the "when left arrow key pressed" block.
3. Select the "point in direction -90" block from the "Motion" menu and drag it under the "set rotate style don't rotate" block.
4. Select the "move 10 steps" block from the "Motion" menu and drag it under the " point in direction -90" block.
5. Select the "next costume" block from the "Looks" menu and drag it under the "move 10 steps" block.



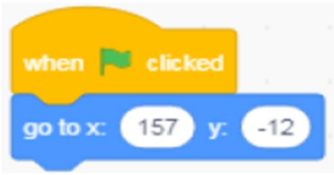
1. Select the "when right arrow key pressed" block from the "Events" menu and drag it to the coding area.
2. Select the "set rotation style all around" block from the "Motion" menu and drag it under the " when right arrow key pressed " block.
3. Select the "point in direction 90" block from the "Motion" menu and drag it under the "set rotation style all around" block.
4. Select the "move 10 steps" block from the "Motion" menu and drag it under the " point in direction 90" block.

5. Select the "next costume" block from the "Looks" menu and drag it under the "move 10 steps" block.

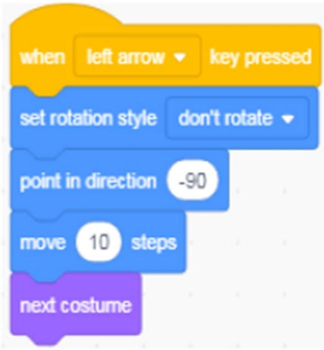


The codes for the character " baby stroller" are as follows.

1. Select the "when green flag clicked" block from the "Events" menu and drag it to the coding area.
2. Select the "go to x: y: " block from the "Motion" menu and drag it under the "when green flag clicked" block. Set the values as in the picture.



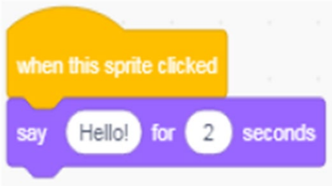
1. Select the "when left arrow key pressed" block from the "Events" menu and drag it to the coding area.
2. Select the "set rotate style don't rotate" block from the "Motion" menu and drag it under the "when left arrow key pressed" block.
3. Select the "point in direction -90" block from the "Motion" menu and drag it under the "set rotate style don't rotate" block.
4. Select the "move 10 steps" block from the "Motion" menu and drag it under the " point in direction -90" block.
5. Select the "next costume" block from the "Looks" menu and drag it under the "move 10 steps" block.



1. Select the "when right arrow key pressed" block from the "Events" menu and drag it to the coding area.
2. Select the "point in direction 90" block from the "Motion" menu and drag it under the "when right arrow key pressed" block.
3. Select the "move 10 steps" block from the "Motion" menu and drag it under the " point in direction 90" block.
4. Select the "next costume" block from the "Looks" menu and drag it under the "move 10 steps" block.

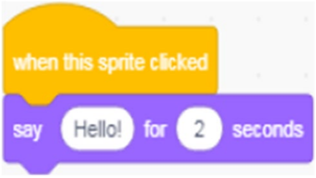
The codes for the "Pull" character are as follows.

1. Select the "when this sprite clicked" block from the "Events" menu and drag it to the coding area.
2. Select the "say Hello! for 2 s" block from the "Looks" menu and drag it under the "when this sprite clicked" block. Replace "Hello!" with "Use Right Arrow to Pull".



The codes for the character "Push" are as follows.

1. Select the "when this sprite clicked" block from the "Events" menu and drag it to the coding area.
2. Select the "say Hello! for 2 s" block from the "Looks" menu and drag it under the "when this sprite clicked" block. Replace "Hello!" with "Use Left Arrow to Push".



Appendix 2

Please write your name and read the problem situation given in the sheet. Design a game in accordance with the given problem situation by specifying the name, purpose, characters and rules of your game in the related blanks given below.

Name Surname:

Subject: Push and Pull Forces

Problem Situation: Buglem and Veli attended sports courses during the summer holidays. Buglem enrolled in the archery course and Veli enrolled in the football course. On the first day of the course, Buglem had problems in drawing the arrow with her fingers, while Veli had problems in sending the ball into the goal properly. Design a game to help Buglem and Veli solve the problems they had in the courses

Name of the Game:

Purpose of the Game:

Characters of the Game:

Rules of the Game:

Appendix 3

Please write what you have discovered at the end of your coding activity. Explain what you have learned with your own words briefly?

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What will we do?

1. Let's try to move the objects we see in our class by pushing or pulling.
2. Let's write the objects that we can/can't move by them by pushing and pulling in the table given below.

Objects that can be moved by pushing	Objects that can be moved by pulling
1	1
2	2
3	3
4	4
5	5

Think about the following question and write your explanation in blanks.

Were there any objects that you could not move by pushing or pulling? What are these objects? How do you think the objects that you cannot move by pushing or pulling can be moved?

…………………………………………………………………………………………

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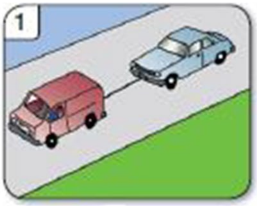
Appendix 4

Some situations were given in the left side below. Please read each situation and write what type of force (push or pull) is applied in the blank given right side.

Situations	Type of Force
1. Pressing the keyboard keys	....
2. Taking off a sweater	....
3. Climbing a mountain	....
4. Bowling ball being thrown forward .	....
5. A horse leads a sleigh	....
6. Two stubborn goats pushing each other	....
7. Tractor driving a trailer	....
8. The wind making a sailboat sail	....
9. Pressing the camera button	....
10. Closing the umbrella	....
11. The train moving the carriage forward	....
12. A child closing a drawer	....
13. Driving a nail into a wall	....
14. Opening the refrigerator door	....
15. Inserting the key into the door hole to open the door	....

Appendix 5

Some situations are given in the numbered pictures below. Let's examine the pictures and decide what force (push or pull) is applied to move the objects and write answer in the spaces provided under each picture.



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Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request and the full report of the project is available at the Council of Higher Education Thesis Center (https://tez.yok.gov.tr/UlusalTezMerkezi/giris.jsp).

Declarations

Conflicts of interests The authors declare that they have no competing interests.

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