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The Effect of Gamified Robotic Activities on Gifted Student

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Abstract

This study aims to explore how gamified robotics activities affect the cognitive and affective skills of gifted students. Using a mixed-methods design, it employed a straightforward experimental setup with a single group, measuring before and after the intervention. The research examined cognitive flexibility, computational thinking, motivation, and satisfaction throughout the process. The sample included 24 gifted middle school students. Data collection involved the player type determination scale, the middle school computational thinking scale, the cognitive flexibility scale, written opinion, and observational forms during activities. The activities, based on design principles, were carried out using LEGO EV3 educational robot kits. Results showed no significant change in cognitive competencies from pre- to post-test. However, students were actively engaged, and gamification elements boosted their motivation and satisfaction. Fun content positively influenced students, though challenges such as competition, coding difficulties, and intra-group conflicts were also noted.

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Introduction

Please use in today's information age, individuals need to possess both cognitive and affective skills (Geisinger, 2016). In this context, information processing, thinking, and cognitive flexibility skills are identified as two distinct competencies in the cognitive domain (Schäfer et al., 2024). Information processing thinking skills are defined as systematic thinking skills employed in resolving complex problems and analyzing data, grounded in the fundamental principles of computer science (Wing, 2006). Seymour Papert, on the other hand, expressed the concept of computational thinking in his 1980 book Mindstorms, emphasising the need to use this skill not only in programming or computer use but also in solving problems encountered in daily life (Papert, 1980). Today, this skill is recognized as a reflection of the combined use of skills such as tinkering, creating, debugging, persevering, and collaborating (Sırakaya, 2019). In the literature, different approaches are followed in teaching individuals this skill. Technology-focused approaches (computer programming, STEM, FeTeMM activities) and robotics (educational robots) are frequently preferred in education aimed at developing computational thinking skills, while non-computer-based approaches using tools such as pen and paper may also be preferred depending on the characteristics of the relevant environment and the cognitive levels of individuals (Selçuk, 2023). Today, due to changes in business processes and daily life, research in the scientific world has focused on computational thinking skills (Arslanhan & Artun, 2021). Nowadays, the proficiency in computational thinking skills is considered an important indicator among 21st-century skills in solving complex problems (Kaya et al., 2025; Tadeu et al., 2025).

Cognitive flexibility is defined as an individual's ability to generate alternative solutions in a problem situation, adapt to changing conditions, and discard old thought models when necessary (Güner & Gökçe, 2021). Cognitive flexibility is considered a critical skill that begins to develop at an early age and is refined through learning from mistakes (Güner & Gökçe, 2021). In summary, computational thinking skills are the ability to develop systematic solutions to problems and draw logical conclusions, while cognitive flexibility is the ability to generate different solutions under varying conditions (Kalelioglu et al., 2016; Karababa, 2025). These skills are among the most important competencies individuals will need to develop solutions to the problems they will encounter throughout their lives (Schäfer et al., 2024).

Gifted individuals demonstrate superiority over their peers in one or more areas, learn quickly, are creative, and have leadership tendencies (Demirçelik et al., 2017). These students, who are cognitively more advanced than their peers, can demonstrate higher-order thinking skills, such as problem-solving, critical thinking, creativity, and information processing, at an early age (Bebek, 2021). These individuals require education beyond the standard curriculum due to their high proficiency in cognitive, social, or artistic areas (Ateşgöz, 2024). This need requires that educational programs and environments be differentiated and organized in a way that maximizes the potential of these individuals (Ministry of National Education [MoNE], 2021). In educational processes designed for exceptional students, grouping students with similar abilities (Bebek, 2021), acceleration that enables the curriculum to be covered more quickly (Civelek, 2019), enrichment with in-depth content that attracts the student's interest (Avcu, 2019), and mentoring aimed at revealing potential through guidance (Öztürk, 2019). Additionally, STEM and engineering design-based education stand out as practical

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approaches that support these students' problem-solving, creative thinking, and collaboration skills (Jamali, 2019). In education programs designed for gifted students, it is essential to consider the individual differences of students and provide content that is tailored to their learning speeds, interests, and abilities (Avcu, 2019). While these individuals are open to group work and collaborative learning processes, content that is prepared in a meaningful and engaging manner is more motivating for them (Kulegel & Topsakal, 2021). On the other hand, it is necessary to support not only the cognitive but also the social and emotional development of these students (Arnstein et al., 2023). The educational activities to be prepared should be structured to include real-life problems in order to contribute to the development of their thinking and problem-solving skills (Dailey, 2017), and functional teaching environments and processes should be created where students can realise their potential, with careful consideration given to time and resource planning (Bebek, 2021).

Differentiation, a teaching approach used in activities designed for gifted individuals, aims to meet the individual needs of students (Yalçın, 2024). There is a need for teaching programmes that develop problem-solving skills, support creativity, and take into account individual differences, especially for gifted students (Kaya & Mertol, 2022). In this context, content, processes, and related materials must be prepared in a way that takes into account students' interests, needs, and learning styles. Although studies on gifted individuals have increased in recent years, there are limited studies examining the effectiveness of differentiated teaching models with international inclusivity (Yalçın, 2024). When examining the Science and Art Center (BİLSEM) guidelines (MoNE, 2021), which provide education to gifted students in cognitive and social areas, the emphasis on the necessity of differentiating the curriculum for gifted students is noteworthy (Yalçın, 2024). The high cognitive abilities, creativity, and scientific curiosity of gifted students increase the need for flexible and enriched learning environments (Tekcan, 2024). Therefore, it is of great importance that teaching activities appropriate to students' interests and potential are offered in suitable teaching environments (MoNE, 2021). Research indicates that activities conducted outside the classroom (Ateş, 2020) and differentiated learning environments have positive effects on student motivation and attitudes toward the course (Kaya et al., 2022). Based on the fact that gifted students tend to struggle in areas they are not interested in (Davis et al., 2011), it is recommended that differentiation strategies be employed in teaching activities (Tekcan, 2024).

Taking individual differences into account in education is of great importance (Pratama et al., 2022). In this context, the inclusion of gamification techniques in the teaching process in recent years has emerged as one of the approaches used to enhance student participation (Martínez-Hita et al., 2021) and motivation (Fotaris et al., 2016). However, it is stated that gifted individuals are inclined to solve complex problems (Çağlar, 2019) and therefore teaching activities should be structured accordingly (Renzulli, 1999). Considering the activities carried out, it has been observed that digital tools such as Kahoot, Quizizz, and Duolingo are frequently used to support competition and motivation during this process (Sercanoğlu et al., 2021). However, elements such as points, badges, and leaderboards used in the gamification process without appropriate user analysis and theoretical basis can lead to loss of motivation and negative outcomes in learning outcomes among students (Berber, 2018). Therefore, it is crucial to consider individual student differences in the gamification process and to identify player types through the necessary analyses (Kocadere & Çağlar, 2018). When considering the literature on the determination of player types, it is seen that individuals are categorised into different player types (Bartle, 1996). The most commonly used player type categories in the literature are generally highlighted as achievers, explorers, socialisers, and killers. Developing gamified environments based on these player profiles can motivate students and meet their learning needs (Manzano-León et al., 2021). Gamification, which is considered an engaging and motivating strategy for students who are moving away from traditional teaching methods (Peconio et al., 2021), can support the active participation and cognitive processes of gifted students in their learning processes, particularly in terms of the need for differentiated teaching practices (Alali & Wardat, 2024). Motivating and sustaining motivation in gifted students requires more effort than in other students (Peconio et al., 2021). This situation necessitates the creation of high-quality learning environments that support gifted students in reaching their full potential. In this regard, identifying player types is considered crucial in supporting student participation in activities, sustaining their motivation, completing tasks, and creating appropriate levels of difficulty (Peconio et al., 2021). These cases demonstrate the importance of utilising a range of tools and techniques in enriched and differentiated learning environments for gifted individuals. In this context, computer-based applications can be used as an effective method for individualising the education of these individuals (Sur, 2022).

In contrast, it has been observed that design-oriented activities are incorporated to facilitate the transformation of gifted students' potential into observable performance (İnan, 2023). The design-oriented approach is characterized by its student-centered nature, to create creative and meaningful learning environments that foster empathy, creative thinking, collaboration, and trial-based learning (Razzouk & Shute, 2012). The most frequently cited model in the extant literature consists of five stages: the establishment of empathy, the definition of the problem, the generation of solution ideas, the testability of the selected ideas, and the testing of these ideas (Plattner et al., 2009). This cyclical process has a structure that supports continuous learning and improvement (Lüka, 2020). Design-oriented thinking processes, developed with these considerations in mind, have been shown to contribute to both the differentiation of teaching activities and the development of students' skills, such as computational thinking and cognitive flexibility (Kaba, 2024).

In summary, teaching environments planned according to the interests and needs of gifted students can be effective in bringing out their potential. It is anticipated that gamified design-oriented robotics activities can support the development of cognitive skills, such as information processing and cognitive flexibility, by enabling students to utilize their cognitive capacities, and that the learning process will be more participatory and satisfying for them. Although both skills are frequently studied in various student groups (Zhang & Gary, 2023), it is acknowledged that research on gifted student groups is limited (Avcu & Ayverdi, 2020). In this context, the study aims to evaluate the effect of gamified design-oriented learning activities on the cognitive flexibility and information processing thinking skills of gifted middle school students, as well as their experiences related to the process. Within this framework, the study aimed to address the following research questions.

1. What is the effect of gamified design-oriented robotics activities on the cognitive flexibility of gifted middle school students?
2. What is the effect of gamified design-oriented robotics activities on the computational thinking skills of gifted middle school students?
3. What are the opinions of gifted students regarding gamified design-oriented robotics activities?

Method

Research Design

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This study was conducted using a sequential explanatory design within the mixed-methods research framework. In this design, qualitative data are collected and analyzed to explain and examine in detail the primarily emphasized quantitative data. In brief, this research design is particularly important when significant and unexpected findings emerge from the analysis of quantitative data and require in-depth explanation (Creswell & Clark, 2018). In this study, the player types scale was employed for the initial categorisation of gifted students. Quantitative data on students' computational thinking skills and cognitive flexibility were collected using pre-tests administered prior to the implementation of the applications and post-tests administered thereafter. The qualitative data obtained from written opinion form and observation forms conducted during and after the application process were used both to support the quantitative data and to evaluate students' experiences regarding the implemented application.

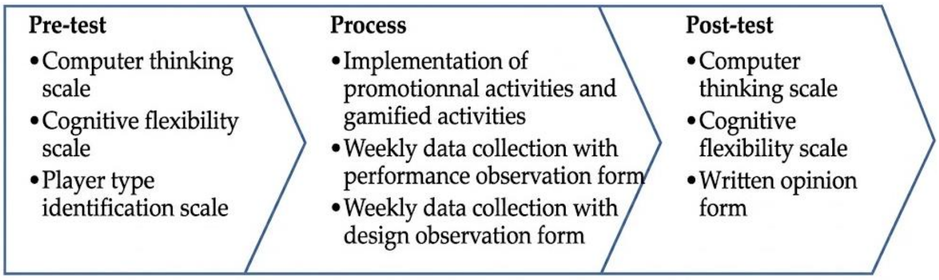

Figure 1. Application and data collection process

Sample Group

The study was conducted in *** province at a coding centre affiliated with the Ministry of National Education, with a single group of 24 gifted middle school students in grades 5-6 and 7. The students who participated in the activities were accepted into the coding centre based on a test measuring cognitive skills conducted throughout the province. The students included in the study were selected from among the volunteer students who continued to attend the coding centre in the second semester. All participating students were male, and parental consent was secured as part of the ethical approval process. Students in the research group are enrolled in a four-semester course program over two years. In the first semester, they take courses in Information Technology, Algorithm Design, and 3D Modeling; in the second semester, they take courses in Visual Coding, Basic Electronics, and Basic Robotics Applications; in the third semester, they take courses in Basic Robotics Applications, Mobile Application Development, and Text-Based Programming in C, and in the fourth semester, Mobile Application Development, Graphic Design and Animation, and Online Multimedia Development.

Among the students, some are preparing for project competitions organised by Tübitak, Teknofest, and MoNE. Students who take Information Technology classes at their schools continue their education at the coding centre on weekends. The activities within the scope of this research were carried out as extracurricular activities following the classes attended by the students on weekends.

Application Process

The gamified design-oriented robotics activities implemented during the research process were prepared in line with the D6 design framework (Werbach & Hunter, 2012) in the context of gamification. The D6 design framework encompasses theoretical aspects related to potential environments where gamification can be applied, as well as the design process. The framework consists of six steps, beginning with D. Table 1 presents the steps of the D6 gamification design framework.

Table 1. D6 gamification design framework

Steps of D6	Scope
Defining business objectives	This is the first step and consists of determining the goals that the gamification system must achieve.
Identification of target behaviours	These are supportive of the gains and express the behaviours that are expected to be performed.
Identifying player types	It refers to understanding players' behaviour and preferences, as well as identifying situations that will affect their motivation.
Planning event cycles	It refers to cyclical situations such as players competing in a competitive environment, evaluating themselves and their group after the competition to prepare for the next competition, advancing to the next level by demonstrating success, and winning. The actions taken by players provide feedback to the player through elements such as leaderboards, scoring, levels, and success status, enabling a motivating environment.
Addition of entertainment elements	The gamification environment must have a flexible structure that encompasses all players in terms of entertainment type. Although it is not easy to determine the entertainment situation, defining the characteristics of the group to be applied in advance will help the implementer.
Use of appropriate vehicles	It refers to the integration of gamification elements deemed appropriate in line with the defined player types and characteristics. When using these elements, attention should be paid to the characteristics of the tools and equipment. It is recommended that the materials used are consistent with the objectives and cover students of different levels and characteristics.

In the study, the learning outcomes associated with the first activity to be carried out within the context of the D6 gamification design framework were determined. When determining the learning outcomes, the learning outcomes included in the Block-Based Robotics and Coding Course Programme prepared by the Ministry of National Education's Directorate General of Lifelong Learning were taken into consideration. The selection of learning outcomes was determined by aligning the programme's objectives with both the needs of the students and the goals of the activities being conducted. In this regard, the selected programme includes modules that contain outcomes consistent with our objectives, such as individuals acquiring basic knowledge about problem solving and algorithms, gaining knowledge and skills about the mechanical, electromechanical, and electronic components of educational robots, and being able to produce solutions to problems they may encounter using block-based programming environments. Sample outcomes are provided in Table 2.

Table 2. Example job gains

Gains
Possess basic knowledge of problem solving and algorithms.
You will acquire knowledge and skills related to mechanical, electromechanical, and electronic components in educational robots.
Effectively uses block-based robot programming software and environments.
It produces solutions to problems that may arise in everyday life.

In the second step, target behaviours were determined. Examples of indicators describing target behaviours include students' ability to connect with the robot by learning the properties of mechanical parts in activities and their ability to use task-oriented sensors correctly. The activities carried out during the weeks when the application was implemented, the tasks that students were required to perform, the robotic components used, and the related learning outcomes are presented in Table 3.

Table 3. Relationship between activity, task, gain, and robotic component

Weeks	**Event Held**	**Task**	**Gain**	**Robot components used**
Week 1	Introduction week	Implementation of a mechanical design	Identifies mechanical and electromechanical components in educational robots.	Mechanical components
Week 2	Stop If You Can: The	Robot that stops closest to the wall wins.	Learn the basic structure and operating principles of block-based software. Establish a connection between the computer and the robot being developed.	Large motor, buttons, and mechanical components
Week 3	Wheel or Idea?	The team that comes closest to the finish line with their design, created without using wheels, wins the race.	Learn the basic structure and operating principles of block-based software. Establish a connection between the computer and the robot being developed.	Large motor, medium motor, buttons, and mechanical components
Week 4	Win by Spinning	The robot that touches the obstacle near the wall and returns to the starting line wins the game.	Uses structures appropriate for movement, appearance, sound, data, and events. Uses structures appropriate for perception, processing, and robotics.	Ultrasonic sensor, large motor, buttons, mechanical components

Week 5	A meteorite may fall.	The team that reaches the finish line without hitting obstacles randomly placed by the opponent along a predetermined route wins.	Uses structures appropriate for movement, appearance, sound, data, and events. Uses perception, processing, and robot-specific structures appropriately. Uses control structures appropriately.	Ultrasonic sensor, large motor, buttons, mechanical components
Week 6	Traffic Cards	Robots that follow the rules indicated by green, yellow, and red lines on a predetermined route win the race.	Uses structures appropriate for movement, appearance, sound, data, and events. Uses perception, processing, and robot-specific structures appropriately. Uses control structures appropriately.	Colour sensor, ultrasonic sensor, large motor, buttons, mechanical components
Week 7	Robopark	The winner is the one who parks their robot in the specially marked coloured area.	Uses structures appropriate for movement, appearance, sound, data, and events. Uses perception, processing, and robot-specific structures appropriately. Uses control structures appropriately.	Colour sensor, ultrasonic sensor, large motor, buttons, mechanical components
Week 8	Escape from the Maze	The player who completes the maze in the shortest time wins.	Uses structures appropriate for movement, appearance, sound, data, and events. Uses perception, processing, and robot-specific structures appropriately. Uses control structures appropriately.	Colour sensor, ultrasonic sensor, large motor, buttons, mechanical components

In the third stage, the participant students were classified according to their player types using the player type determination scale developed by Fiş Erümit et al. (2021). The player types identified for the students as a result of the evaluation are presented in Table 4.

Table 4. Distribution of students' weighted player types

Player Types		**Number of Students**	**Player Type Distribution**								
Explorers	Socialisers	9	S9	S17	S18	S19	S21	S11	S14	S6	S22
Explorers	Killers	8	S3	S12	S16	S23	S7	S8	S2	S4	
Explorers	Achievers	3	S13	S15	S5						
Achievers	Socialisers	3	S1	S10	S24						
Killers	Socialisers	1	S20								
Achievers	Killers	0									
	Overall	24									

S:Student

Adjustments were made to the activities based on the findings of the player type identification scale. In this context, tasks and gamification elements appropriate for the activities were added. In each activity, gamification elements that appeal to all player types have been included; activity designs that focus on only one player type have been avoided. Although there were no students in some player types at the beginning, it was anticipated that participants could exhibit behaviours specific to different player types during the activity process. In line with this possibility, gamification elements targeting player types that are not represented in terms of numbers have been integrated into all activities, just as they are for

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other player types. Thus, the inclusivity of the activities has been increased, and a balanced learning environment that appeals to the motivational sources of each student has been created. The tasks and gamification elements added to the activities, according to the defined player types, are listed in Table 5.

Table 5. Integration of gamification elements into activities according to player types

				Added Gamification Elements			
Player Type	**Number of Players**	**Player Characteristics**	**Added Task Features**	**Teams Collaboration Transactions Queue Avatar**	**Level Progress Tasks Resource gathering Accessing content**	**Competition Winning situation Challenge Fighting**	**Scoring Leaderboard Awards**
Explorer-Socialiser	9	They enjoy exploring and social interaction. They are open to learning new things through teamwork.	Exploration and collaboration tasks, social learning	✓	✓		
Explorer-Killer	8	They love to explore and are also competitive by nature.	Competitive exploration missions		✓	✓	
Explorer-Achiever	3	They love to explore and are motivated to achieve their goals.	Exploration missions, innovative solutions, and success criteria		✓	✓	✓
Achiever-Socialiser	3	They enjoy social interaction and aim to succeed by working with others.	Teamwork tasks, social interaction, common goals, and success criteria	✓		✓	✓
Killer-Socialiser	1	They enjoy competing and social interaction, and they also value teamwork in order to achieve success.	Competitive group tasks	✓		✓	

Achiever-Killer	0	They focus on success and enjoy competing. They have a desire to outperform other players.	Competitive tasks, success criteria		✓	✓

In the fourth step, the cycle of activities created was prepared in line with design-oriented thinking, enabling students to empathize, define, design, create prototypes, and evaluate through testing during the process. The completion of tasks created during these cycles and the acquisition of new tasks as a result serve as an example of a level system, while also aiming to strengthen the connection between motivation, feedback, and actions, thereby supporting competition and collaboration.

In the fifth step, situations in which students could have fun were identified, and elements of fun were added to the activities using data obtained from the scale. However, Lazzaro (2009) stated in his study that players could enjoy different types of fun contrary to what was determined. For example, a player who wants to compete or complete tasks may have come to the activity area that day simply to spend time with friends and relieve stress. Therefore, the activity included tasks and elements aimed at the general group as much as possible, and efforts were made to minimize differences among players.

In the sixth and final step, activities were conducted using the LEGO EV3 educational robot, taking into account the characteristics of the students, teachers, environment, and available tools. In particular, it can be said that it contributed to the process because there were no compatibility issues between the parts, it had add-ons that helped gamification, it was an inclusive tool for students of different levels, it was durable and valuable, it supported collaborative activities, and it laid the groundwork for achieving the goals. The aim was to create an environment conducive to group work by providing spacious tables and fostering a competitive and collaborative atmosphere through themed activities.

Introduction and basic setup week: Students were given pre-tests on computational thinking and cognitive flexibility scales. Students were informed about the purpose and process of the application. Lego EV3 parts and equipment were introduced, and students were asked to design simple vehicles. Then, information was provided about the LEGO EV3 coding environment interface, block structures, and features.

Figure 2. Recognizing lego EV3 parts (left), plugin and block introduction (right)

First Activity (Stop If You Can): Students were asked to stop their robots at specific points using distance measurement-based tasks. The tasks were performed using non-standard measurements made with Lego pieces and motor blocks. The teams' success in the task was made tangible by adding Lego pieces to the evaluation towers in each round.

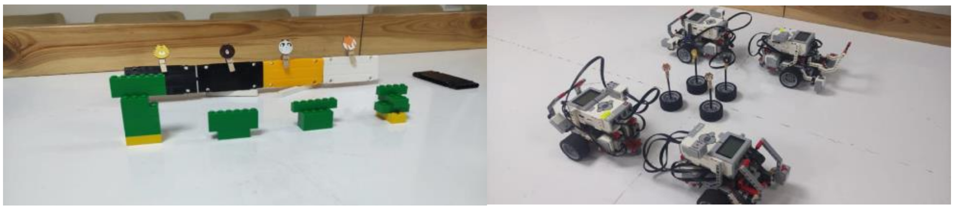

Figure 3. Evaluation towers and team avatars (left), table layout (right)

Second Activity (Wheel or Idea): Students were asked to develop alternative movement mechanisms that do not rely on wheels. They were asked to brainstorm within their groups to create original designs and test the performance of their robots in the competition area. Depending on the distance to the target area, additions were made to the evaluation towers in each round. At the end of the activity, a success ranking was determined based on the height reached by the towers next to the teams' avatars.

Third Activity (Win with a Tour): Students were trained in the use of sensors and robot guidance. Students were asked to turn their robots around using ultrasonic sensors and large motors, then return them to their designated starting position. Groups were ranked based on their performance in completing the task.

Fourth Activity (Meteorite Fall): Students were asked to guide their robots to designated points without being affected by meteorite obstacles. Students were asked to use ultrasonic sensors and large motors to avoid obstacles and move within the designated area. Guidance was provided to students on properly connecting sensors and conducting technical checks. Groups were ranked based on scoring related to task success.

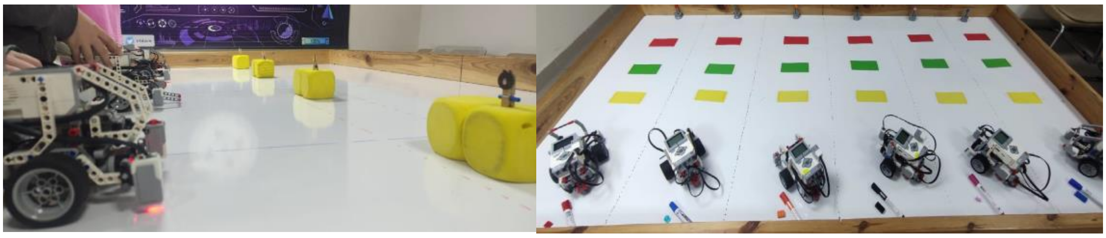

Figure 4. Competition area and obstacles (left), sample theme tools (right)

Fifth Activity (Traffic Cards): Students were asked to stop their robots on the correct color cards while performing color recognition tasks. Group avatars and scores were associated with colors to support visual learning. After all rounds, the teams were ranked, starting with the team that scored the highest.

Sixth Activity (Robopark): Students were asked to direct their robots to designated parking areas and were paid symbolic "Lego units" based on their success in parking. The group that spent the fewest Lego units was deemed successful. Depending on their success, groups were given hints as rewards that they could use in subsequent tasks.

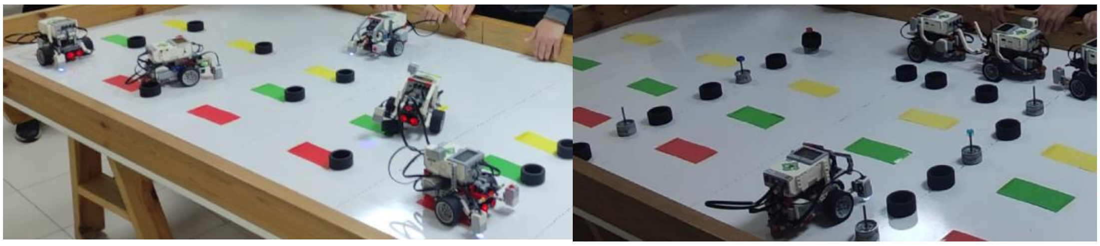

Figure 5. Parking spaces (left), Competition area reference points (right)

Seventh Activity (Escape from the Maze): Students were asked to guide their robots out of a maze. Groups were awarded Lego units based on their exit times. The group that accumulated the most Lego units was deemed successful. At the end of the activity, computational thinking and cognitive flexibility scales were administered as post-tests.

Data Collection and Analysis

The following tools were used to collect data during the research process: Player Type Determination Scale, Cognitive Flexibility Scale, Computerised Thinking Scale (for secondary schools), Written Opinion Form, Performance Observation Form, and Design Observation Form.

Player Type Determination Scale: The scale created by Fiş Erümit et al. (2021) builds on Bartle's player types and includes 32 items divided into six factors, with each item offering two response options. Its design is based on the idea that most players do not have a single dominant type; instead, they may show traits of multiple types. Therefore, the scale features six separate categories representing paired player types. Cronbach's alpha reliability scores for these types range from 0.663 to 0.772, suggesting a normal distribution. This scale was administered as an online form before the study to assess the player-type traits of participating students.

Computational Thinking Scale (For Middle School Level): Developed by Korkmaz, Çakır, and Özden (2015), this scale aims to assess middle school students' computational thinking skills. It features 22 items organized into five factors, designed as a 5-point Likert scale. The overall reliability, indicated by Cronbach's alpha, is .809. This online scale was administered both before and after the intervention to measure students' computational thinking abilities.

Cognitive Flexibility Scale: Çelikkaleli (2014) performed an adaptation and reliability analysis of the Cognitive Flexibility Scale, originally created by Martin and Rubin (1995). After adaptation, the Turkish version of the scale was finalized with 11 items, down from the initial 12. It uses a 6-point Likert scale, with "Strongly disagree" at 1 and "Strongly agree" at 6. The scale's split-half reliability is .77. This survey was conducted online, both before and after the intervention, to assess students' cognitive flexibility.

Written Opinion Form: The written opinion form was distributed to students online after the study was carried out. Before use, it was prepared based on a review of relevant literature, aligned with the study's theoretical framework and sub-problems, and considering the implementation process. The form was then revised based on feedback from instructional technology experts. After linguistic and semantic review by Turkish language specialists, it was finally administered online to the participating students.

Performance Observation Form: Developed in the form of a graded scoring key to evaluate the performance of student groups during the research process. The form, developed through a design-oriented thinking process (Plattner et al., 2009), comprises interconnected stages, including empathy, definition, idea generation, prototyping, and testing. The form consists of 5 categories and positive rating criteria ranging from 1 to 3.

Design Observation Form: Developed in the form of a graded scoring key to evaluate products developed by design groups. The form consists of seven categories: task status, mobility, code blocks, durability, appearance, accessibility, and innovation, with positive scoring criteria ranging from 1 to 3. The performance observation form was used to evaluate the products created by design groups at the end of the activity process.

The performance and design observation forms were developed with consideration of the study's theoretical structure, purpose, and the target outcomes of the activities. Both forms were presented to field experts with academic studies in coding, robotics, and computational thinking skills during the draft stage to obtain feedback and suggestions. Following the feedback and suggestions, the revisions were implemented, and the text was then reviewed by experts trained in Turkish education to spot any linguistic and semantic inconsistencies.

In the study, the cognitive flexibility scale developed by Martin and Rubbin (1995) and adapted into Turkish by Çelikkaleli (2014) was administered as a pre-test at the beginning of the study and as a post-test at the end of the study to assess students' levels of cognitive flexibility in the context of the first sub-problem. To determine whether the data met the conditions for parametric tests, the Shapiro-Wilk normality test, as well as kurtosis and skewness values, were analyzed, along with outlier detection. For the pre-test, the Shapiro-Wilk normality test yielded a p-value of .146 ($p > .05$); the kurtosis value was 0.029, the skewness value was -1.329, and no outliers were detected. For the final test, the Shapiro-Wilk normality test result was $p = 0.318$ ($p > 0.05$), the kurtosis value was 0.542, the skewness value was -0.294, and again, no outliers were found. Since all values were within the accepted range (-1.5 to +1.5) and the normality test results were not significant, it was assumed that the pre-test and post-test data were normally distributed. In the reliability analysis conducted on the data obtained from the scale, Cronbach's alpha coefficients were found to be 0.625 for the pre-test and 0.593 for the post-test. Since the coefficients were close to the acceptable limit, the measurements were considered reliable. Following these checks, the pre-test and post-test results were analyzed using the paired samples t-test.

In the study, the Computational Thinking Scale, developed by Korkmaz and colleagues (2015), was used to assess students' computational thinking skills about the second sub-problem. In parallel with the data analysis process applied to the cognitive flexibility scale, the parametric test assumptions were also examined for this scale. For the pre-test, the Shapiro-Wilk normality test yielded a p-value of 0.765 ($p > 0.05$); the kurtosis value was calculated as -0.190, and the skewness value was -0.499. No outliers were identified. For the final test, the Shapiro-Wilk normality test yielded a p-value of 0.208 ($p > 0.05$); the kurtosis value was 0.509, the skewness value was -0.748, and again, no outliers were detected. Since all values were within the accepted range (-1.5 to +1.5) and the normality test results were not significant, it was assumed that the pre-test and post-test data were normally distributed. In the reliability analysis conducted on the data obtained from the scale, Cronbach's alpha coefficients were found to be 0.861 for the pre-test and 0.831 for the post-test; these values fall within the excellent range (0.80–0.90), indicating that the measurements are reliable. After all controls were performed, the pre-test and post-test results were analyzed using a paired samples t-test.

In the context of the study's third sub-problem and considering the distribution of dominant player types in the participant group (see Table 4), opinions on the implementation process were gathered through a written interview form from six students randomly chosen from each category. The analysis revealed that student opinions were grouped under three main themes: motivation, satisfaction, and suggestions for the process. The motivation theme was classified into two subheadings: supportive elements and challenging elements. The findings were presented in pairs of themes and codes, supported by examples of student statements.

Findings

In this study, the impact of gamified design-oriented learning activities was analyzed in terms of cognitive flexibility, information processing skills, and student opinions, and the data obtained was converted into findings.

The findings obtained from the analyses conducted on the effect of the implemented application process on students' cognitive flexibility showed that there was no significant difference between students' cognitive flexibility after the study and their cognitive flexibility before the study ($t=-,083$, $p>.05$). The average cognitive flexibility score of the students before the implementation was $\bar{X}=4.88$, while the average final test score after the implementation was $\bar{X}=4.87$. The results obtained are presented in Table 6.

Table 6. t-test findings regarding pre-test and post-test scores on the cognitive flexibility scale

Measurement	N	$\bar{X}$	S	sd	t	p
Pre-test	24	4.88	.512	23	-.083	.934
Post-test	24	4.87	.498			

The distribution of results related to students' cognitive flexibility averages before and after the study is presented in Figure 6.

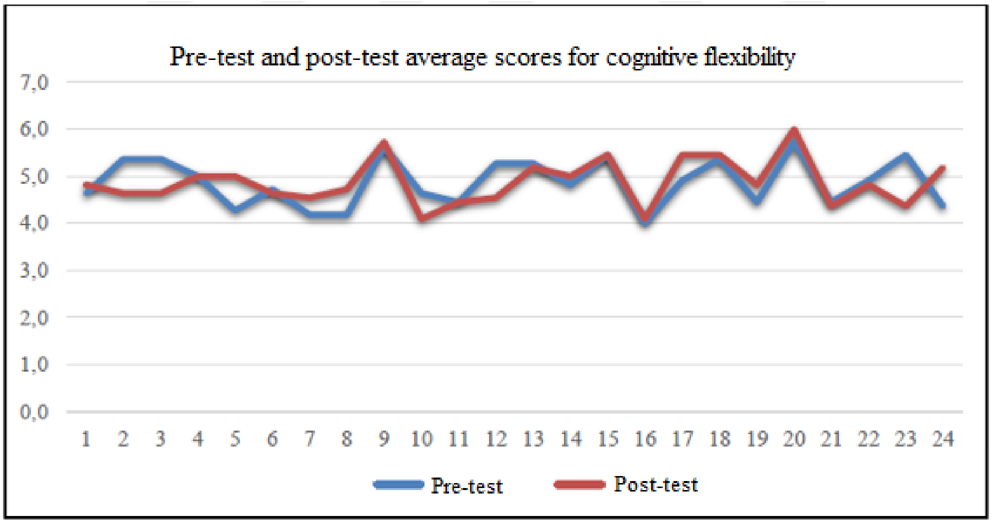

Figure 6. Students' average cognitive flexibility scores before and after the study

When examining the averages shown in Figure 6, although variations were observed in the students' averages on the cognitive flexibility scale before and after the study, these variations did not reveal any significant differences. In summary, this study suggests that the application process based on gamified design-oriented activities within a robotic framework did not have a significant effect on the cognitive flexibility of gifted students.

As a result of the analyses, it was determined that there was no significant difference between the pre-test and post-test scores of students' computational thinking skills ($t=.390$, $p>.05$). The mean pre-test score of students' computational thinking skills before the application was $\bar{X}=4.06$, while the mean post-test score was $\bar{X}= 4.03$. The results obtained are presented in Table 7.

Table 7. t-test findings regarding pre-test and post-test scores on the computational thinking scale

Measurement	N	$\bar{X}$	S	sd	t	p
Pre-test	24	4.06	.487	23	.390	.700
Post-test	24	4.03	.477			

The distribution of results regarding students' average scores on the computational thinking scale before and after the study is presented in Figure 7.

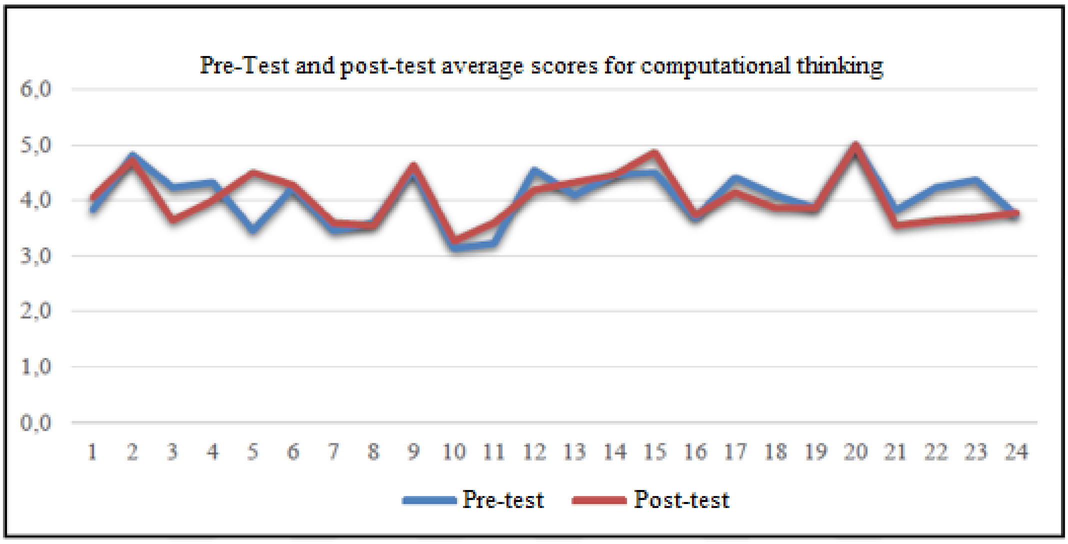

Figure 7. Average scores on the computational thinking scale before and after the study

The analyses revealed no significant change between the measurements taken before and after the implementation process. Furthermore, when the averages were examined, it was observed that the pre-test and post-test averages were almost identical. In summary, the implementation process based on gamified design-oriented activities within the framework of robotics did not have a significant effect on students' computational thinking skills.

As a result of the content analysis conducted on the data obtained through the written opinion form, student opinions were grouped under three main themes: motivation, satisfaction, and suggestions for the process. The motivation theme was organized under two subheadings: supportive factors and challenging factors that affect motivation. Figure 8 below shows the factors that support students' motivation during the implementation process.

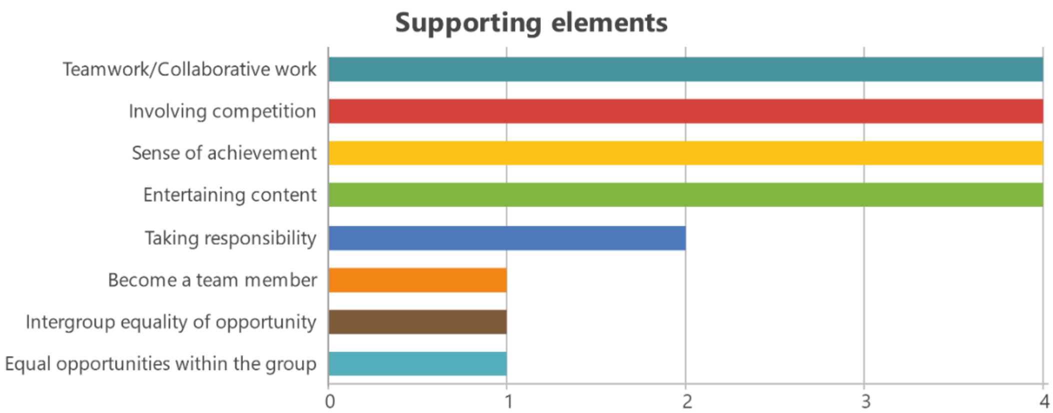

Figure 8. Factors supporting student motivation (n=6)

According to Figure 8, the elements that most support student motivation during the application process are cooperation, competition, and the feeling of winning. These are followed by activities that are both fun and instill responsibility, teamwork, and provide equal

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opportunities. These findings indicate that the activities are perceived as fun, motivating, and participatory by students. Below are examples of student statements regarding this issue.

S6: "Working with my friend motivated me."

S3: "We found the activities easy since my friends and I completed them together."

S20: "We showcased improved teamwork."

The game's level and progression features effectively motivated players and encouraged ambition.

S24: "Taking turns allowed the groups to perform measurements in a calm and orderly fashion."

S1: "The activity scoring system motivated us to concentrate on earning points."

The elements identified as challenging to student motivation during the implementation process are presented in Figure 9 below.

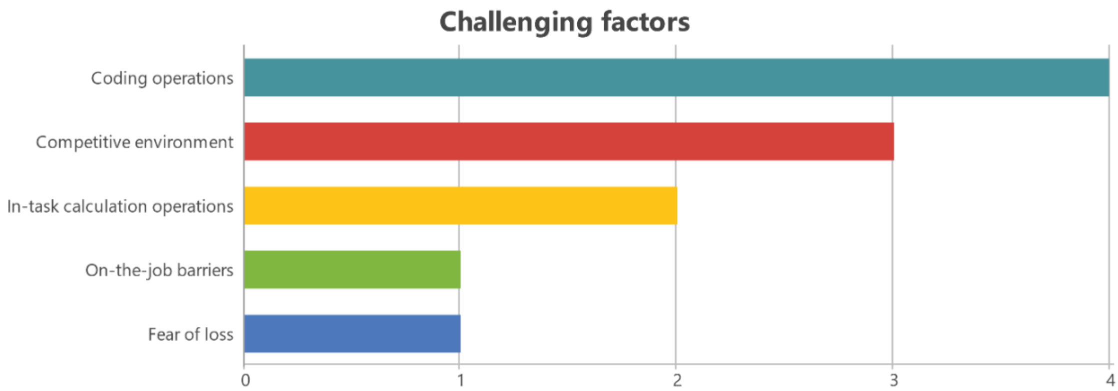

Figure 9. Factors that hinder motivation during the implementation process in the context of student opinions (n=6)

According to Figure 9, coding tasks, competitive environment, computational requirements, obstacles in the task, and fear of failure are among the factors that challenge students' motivation. The competitive environment is perceived as both a supportive and challenging factor, suggesting that students respond differently to competition based on their player types. These findings indicate that motivational factors can vary depending on the type of player. Among the challenging factors, coding tasks were the most frequently mentioned, with students stating that they had difficulty remembering and using the codes correctly. Additionally, some students mentioned that losing repeatedly in a competitive environment had a negative impact on their motivation. Below are examples of student statements regarding this issue.

S6: "It was challenging because the codes weren't in Turkish."

S1: "It was challenging to remember the purpose of each code."

S13: "The competitive environment was quite uncomfortable because the other teams appeared to dislike us."

S13: "The measurement and calculation procedures needed for the activities were quite challenging."

S20: "Going through multiple losses in a row during the activities fostered a feeling of hopelessness."

Student opinions regarding satisfaction are organized under two separate subheadings: positive and negative. In this context, the codes identified for positive situations that support satisfaction are presented in Figure 10.

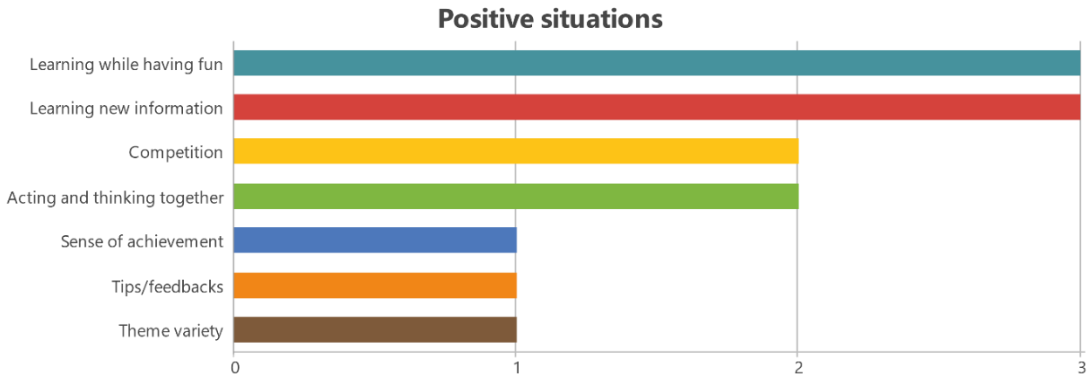

Figure 10. Situations perceived positively in terms of satisfaction (n=6)

According to Figure 10, the factors that increase student satisfaction the most are learning through fun and collaborative teamwork. Competition and the desire to win have supported both motivation and satisfaction. Additionally, the variety of activity topics and the hints provided when students struggle with tasks are also factors that contribute to satisfaction. It is observed that competition improves coding skills, while group work strengthens mutual understanding. Below are examples of student statements regarding this issue.

S24: "Participating in robotics activities and competing with other teams is very enjoyable."

S1: "Working together as a team strengthens the feeling of achieving a shared understanding."

S3: "The robotics activities were fun because they took place in a competitive setting."

S6: "The activities are easier when the teacher provides assistance."

S24: "Because the groups compete, more effective codes develop."

Although there are some negative opinions regarding satisfaction, no significant negative situation is expressed intensely by students when examining the frequencies. Therefore, negative opinions are limited and are presented in Figure 11.

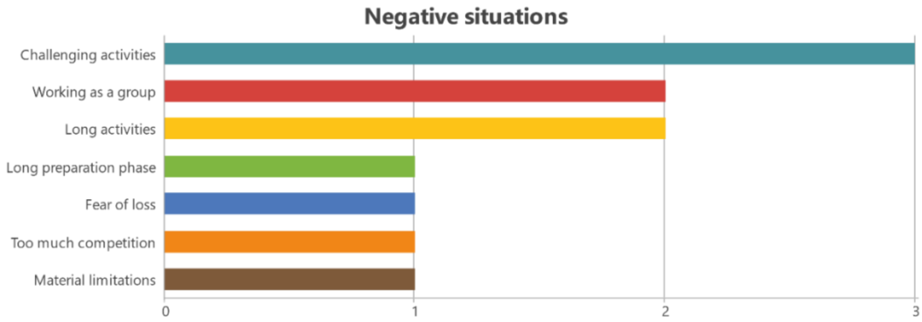

Figure 11. Situations perceived negatively in terms of satisfaction

According to the data in Figure 11, some students negatively evaluated the difficulty of the activities (S13: "The codes were difficult"), the complexity of the tasks (S24: "The tasks were difficult"), and the incomprehensibility of the activities (S1: "I could not fully understand the activities"). Additionally, the student coded as S1 mentioned that there were occasional disagreements during group work (S1: "We sometimes could not agree as a group") and S3 mentioned that the activities sometimes took too long (S3: "The activities sometimes took too long"). Another negative situation was related to the inadequacy of materials needed for some tasks (S24: "The materials were not enough for everyone"). These negative views are limited in number and are not generalizable.

Consistent with the first two research questions, it appears that the activities did not lead to substantial improvements in students' computational thinking and cognitive flexibility. Nonetheless, students rated the activities positively regarding satisfaction and motivation. The results suggest that incorporating gamification elements into design-focused tasks, alongside team-based activities, enhanced students' motivation and satisfaction. In fact, data from student performance assessments and activity design forms during implementation reinforce this conclusion. Based on the performance and design observation forms, students generally took active roles in the tasks during the activities. Tables 8 and 9 show the average scores for the performances of the working groups during the implementation process and the designs they created.

Table 8. Average scores from the performance observation form (n=24)

App. Stages	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 7
Empathy	2,88	3,00	3,00	3,00	2,67	2,83	3,00
Definition	2,63	2,57	2,43	2,63	3,00	2,83	3,00
Idea Generation	2,75	2,71	2,43	2,63	2,83	2,83	3,00
Prototyping	2,75	2,43	2,29	2,63	2,67	2,50	3,00
Testing	3,00	2,86	2,57	3,00	3,00	3,00	3,00

Notably, they collaborated closely during empathy, idea generation, prototyping, and testing stages. In the initial empathy phase, some students hesitated to share their opinions. During the definition stage, while most students followed the rules, a few behaved outside the established guidelines. However, with the guidance provided during the activities, students showed improved ability to adapt and participate effectively. As activities advanced, students showed growth in intra-group collaboration, technical skills, and task completion. During the idea generation phase, solution-focused and broadly accepted ideas became more common within groups, although some dominant members occasionally ignored others' opinions. However, this issue lessened over time as the implementation continued, and all members' contributions increased. In the prototyping and testing stages, most students took active roles, and there were improvements in task sharing and technical abilities. The testing phase was particularly engaging, with students showing the highest interest, likely driven by the competitive element and scoring system that boosted motivation. Overall, as the tasks moved forward, students' success rates improved, demonstrating notable progress across all groups. In the final activity, students scored full or nearly full points at all stages. However, in the earlier activities, their average scores were somewhat lower.

Table 9. Average scores from the design observation form (n=24)

Indicators	**Activity 1**	**Activity 2**	**Activity 3**	**Activity 4**	**Activity 5**	**Activity 6**	**Activity 7**
Task Performance	2,88	1,86	2,43	2,63	2,67	2,50	3,00
Mobility	2,75	1,71	3,00	2,88	2,67	2,83	3,00
Code Blocks	2,88	2,14	2,43	2,75	2,50	2,50	3,00
Durability	2,88	3,00	3,00	3,00	2,83	2,83	3,00
Appearance	2,88	1,43	2,86	3,00	3,00	3,00	3,00
Accessibility	2,88	2,14	2,86	3,00	3,00	3,00	3,00
Innovation	2,13	2,00	2,00	2,00	2,33	3,00	2,00

In terms of the products that emerged after the activities, it was determined that a process parallel to student performance development emerged. For example, it was observed that students initially made mistakes in the robot design and coding process, assembling some parts incorrectly or misusing the required codes. Over time, these errors observed during the design process decreased, and students showed a more careful attitude. Initial assembly and coding errors gradually decreased. At the same time, when analyzing the average scores on the design observation form, this pattern was distinctly evident in the second activity. While the durability of the robots designed for these activities increased with the careful assembly of the parts, sensor failures and part dislocations negatively impacted the product's performance.

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As the process progressed, the errors observed in the products decreased due to the increase in students' attention levels. It was noticed that hardware problems (deteriorating sensors, easily detached parts) sometimes negatively affected students' interaction with the robot and the success of the activities. However, it was observed that students were able to intervene in these situations over time and started to act more consciously in the maintenance and repair processes of robots. In this context, it was observed that the average scores on the design observation form, similar to those on the performance observation form, neared full scores in the last two activities.

Discussion and Conclusion

Numerous studies on gamification and robotics emphasize that they support problem-solving and higher-order thinking skills, and their effectiveness in developing these skills (Buckley & Doyle, 2014). In this study of gifted students in informatics, there was no significant difference between pre-test and post-test scores for students' cognitive flexibility and computational thinking skills. This result reflected the fact that the study group consisted of gifted students who also attended various computer science courses concurrently. The students' high pre-test scores on both skills may have limited the intervention's observable effects. This situation is similar to studies that have found high pre-test performance can mask the effects of intervention studies (Liu et al., 2016). These studies suggest that when students begin intervention studies with a strong academic foundation, it is challenging to observe the expected improvements in their performance. On the other hand, the nature of cognitive flexibility may also influence the observed results. Considering that cognitive flexibility is the ability to adapt one is thinking to new and unexpected situations, it is stated that it would be quite challenging to prepare the training necessary for individuals with high cognitive flexibility skills to develop them further (Montrieux & Schellens, 2018). Schroer and Thomas (2020) draw attention to the teaching strategies employed during the implementation process and emphasize that problem-based and adaptive learning technologies should be utilized to challenge students' pre-existing thought patterns directly. Similarly, Koca (2023) and Gürbüz (2022) emphasize that cognitive flexibility can be enhanced through application-based activities. In this case, it is considered that the "ceiling effect" (Nalliah & Allareddy, 2014), which is expressed in the literature as the difficulty of statistically detecting any additional learning gains as students approach the upper limit of their abilities, directly affects the emergence of the result in this study. The stability of the high pre-test scores in the post-test supports this view.

Interest and motivation play an important role in the development of cognitive abilities. For example, in their studies on the cognitive flexibility of middle school students, İşler (2023) found that student motivation is positively correlated with cognitive flexibility. In this study as well, students revealed that robotics activities incorporating gamification support competition, cooperation, and motivation. Competition is recognized as a powerful motivator in gamified learning environments. In a study by Hernández-Fernández et al. (2020), it is noted that classroom gamification increases student motivation and satisfaction through various competitive elements and can enhance the learning experience when managed effectively. Many studies emphasize that when coding skills activities are conducted in ways that require collaboration in competitive environments, this approach positively influences student engagement and performance (Qiao et al., 2022). These results support the idea that instructional environments that incorporate collaboration and competition can contribute positively to students' learning needs. Another situation that is reflected positively in student opinions is the evaluation of gamified robotics activities as fun. For example, Sanz-Martos et al. (2024) concluded that gamification increases student satisfaction and motivation by highlighting the enjoyment of fun experiences in educational environments. In this study, it was found that robotic activities that were considered fun by gifted students positively affected their satisfaction and participation in the process. This result is similar to the findings of Sarı and Altun's (2016) study on gamification, which was integrated into a computer course. In addition, the fact that students stated that competing with their friends increased their sense of competition and being fun increased their motivation is in line with Türkan's (2019) finding that competition increases the desire to win. Collaborative and competitive elements are essential in developing a rich teaching environment. Chen et al. (2020) emphasize that robotics education is an effective way to develop 21st-century competencies, especially when competitive elements are added. The literature suggests that robotics activities should incorporate healthy competition alongside collaborative principles to maximize student engagement and skill development. Moreover, it is emphasized that when students are given responsibilities in educational activities, this increases their intrinsic motivation and commitment to learning goals (Mohamed et al., 2024). As a result, the findings regarding cooperation, competition, and fun in supporting motivation in gamified design-oriented robotics activities are consistent with the existing literature, which states that these components enhance student engagement and learning outcomes.

The findings of this study indicated that some students were motivated by competition, while others were motivated by entertaining content. This finding aligns with the research of Aydogan and Aydogan (2020) on player types. It is understood that gamification strategies tailored to different player types create an engaging and motivating environment, especially for gifted students. However, the findings of this study also showed that gamified systems can cause stress, anxiety, and loss of motivation in some students. This finding aligns with the results obtained by Koç and Sütçü (2023) in their study on grammar lesson implementation, which revealed that failing to win creates negative feelings in some students. For example, unlike competitive students, others may be more participatory in collaborative work-based environments (Aksu & Durak, 2019). This finding suggests that the competition element should be used with caution. Similarly, in this study, some students viewed the competitive environment as a factor that supported motivation, while others saw it as negative. This can be interpreted as competitive environments do not yield positive results for all students. Similarly, Ziadat and Sakarneh (2021) concluded that although the competitive environment in gamification supports motivation and participation for gifted students, failures that may occur in overly competitive environments will negatively affect the process. However, the same scenarios have also been observed to evoke adverse emotions in response to failure or loss. This is especially salient in the context of competition, underscoring the need for practitioners to consider how different types of players respond to competitive stimuli.

Another prominent issue in the study is the difficulties students emphasized with the coding processes in the activities carried out. The most frequently mentioned difficulty among students was related to coding procedures. Students reported difficulties in remembering the code and using it correctly. These findings are similar to those of studies that highlight the challenges students encounter during the transition to complex coding concepts. For example, Hebda (2023), in his study on the development of coding skills with gifted students, emphasized that students become anxious when they encounter obstacles that negatively affect their progress in the process. Therefore, he emphasized that activities that require high-level thinking skills, such as coding, can be considered a challenging factor for gifted students (Hebda, 2023). Similarly, Meşe and Dursun (2019) state that mixed tasks may weaken the pedagogical aspect of activities that include gamification, which can reduce student participation. Another situation that was stated negatively during the implementation process was in-group cooperation. The existence of disagreements within the group work ("Sometimes we do not get along as a group") is similar to the study by Clegg et al. (2018), which examines cooperation in educational environments. Clegg et al. (2018) emphasize that conflicts may occur between participants when roles within the group are not clearly defined. Students' mention of activity durations illustrates another critical aspect of gamified tasks. Long activities can contribute to cognitive overload and negatively affect motivation. Araújo and Carvalho (2022) concluded that the allocation of time for task completion is closely related to students' engagement and overall satisfaction, and is a prerequisite for effective gamification. This finding highlights the importance of time planning for organized tasks. Therefore, it can be argued that shorter, well-structured tasks can facilitate more profound learning experiences without overwhelming students and contribute to all students having a similar level of satisfaction with the implementation process. Another noteworthy aspect of the research is the adequacy of the robotic materials. Among the findings from the written interview form, one student's statement that the robotic materials used were inadequate drew attention. Although expressed by only one student, this situation highlights the importance of planning and conducting robotics activities. In the context of resources for Gamified Robotics activities, Zainal (2023) notes that careful planning will enable the participation of all students. A similar emphasis is also noted in Dindar et al.'s (2020) study on English vocabulary learning in a collaborative and competitive environment. Researchers highlight the adequacy of resources for achieving the desired learning outcomes in gamified activities. The gamified, design-oriented robotics activities, the subject of this study, were conducted in an institutional coding center that is structured and actively utilized in robotics and coding. All the robotic elements necessary for each organized group to perform their assigned tasks were available at the center. The researcher checked the robot kits and auxiliary materials to be used before each application and kept them ready for use. However, during the application, it was observed that the sensors in some LEGO robotic sets, albeit limited, could malfunction, or some parts could come loose from their intended positions. It was reported that these negativities, albeit limited, caused students to experience some difficulty in maintaining and repairing the robot. However, unlike the initial activities, it was observed that the students were better able to cope with such problems in the later activities and were able to quickly replace the parts that caused issues in the robot's structural development. In summary, it is evaluated that students improved in areas such as technical skills, teamwork, attention, and problem-solving during the activities.

The findings of this study highlight the importance of critical elements, including fun learning, collaborative teamwork, competition, group dynamics, time management, resource allocation, and special support mechanisms, in gamified design-oriented robotics activities for gifted students. As can be understood from the literature, it is evident that educational activities should maintain a balanced level of difficulty to sustain motivation and engagement in students. When tasks are perceived as overwhelming or confusing, as indicated by the students' statement "the codes were difficult", it can detract from the intended benefits of gamified experiences and lead to a hostile learning atmosphere. In this context, it can be inferred that an effective combination of these factors is effective in increasing both student satisfaction and motivation. On the other hand, the challenges identified in gamified design-oriented robotics activities reflect the importance of cognitive demands, emotional responses to competition, and individual student differences. Educators should consider these factors when designing robotics activities to increase motivation among gifted students. A balanced approach that incorporates various competitive elements, provides adequate coding support, fosters a positive learning environment, and acknowledges individual differences can create a more motivating and practical educational experience for gifted students in the field of informatics. On the other hand, eliminating the difficulties reported in the study will contribute to the effectiveness of gamified design-oriented activities. The findings suggest that the success of gamified design-based robotics activities is closely related to creating environments that balance difficulty and comprehensibility, take into account student participation and satisfaction, and facilitate both collaboration and resource availability.

Author Contribution Statement

Özkan KOMAR: *Literature review, data analyses*

Alper ŞİMŞEK: *Conceptualization, methodology*

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