Journal of Theoretical Educational Sciences, 18(3), 584-610, July 2025
Kuramsal Eğitimbilim Dergisi, 18(3), 584-610, Temmuz 2025
[Online]: http://dergipark.org.tr/akukeg
DOI number: http://doi.org/10.30831/akukeg.1637333

Do Intelligence Games Improve Problem Posing Skill?

Zekâ Oyunları Problem Kurma Becerisini Geliştirir Mi?

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Received: 11 February 2025 **Research Article** **Accepted:** 15 June 2025

ABSTRACT: The aim of this study was to examine the potential effect of intelligence games on the problem-posing skills of mathematics teachers. The research, in which case study, one of the qualitative research methods, was preferred, was conducted with two mathematics teachers enrolled in the Mathematics Education Master's Program with Thesis at a state university. Criterion sampling method was used to determine the participants. The criterion was that the teachers did not have any interventions for intelligence games and problem posing. A problem posing test consisting of four tasks was used as a data collection tool. In the test, a visual of each task was included and teachers were asked to pose a problem of each degree of difficulty by giving easy, moderately difficult and difficult prompts for each visual before and after the application. The cognitive complexity analysis framework proposed by Kwek (2015) was used to analyze the mathematical complexity of the problems constructed by the teachers. In the study, it was found that the prompt given in problem posing tasks contributed to the construction of more complex problems. However, high level complex problems were generally posed in the final determination. It was determined that the problems posed by the teachers, especially after the intervention for intelligence games, were high level complex and they associated them with intelligence games. Therefore, in this study, it was concluded that intelligence games cause the problems to be more complex and intelligence games improve problem posing skills.

Keywords: Intelligence games, problem posing, problem posing prompts.

ÖZ: Bu araştırmada, zekâ oyunlarının matematik öğretmenlerinin problem kurma becerileri üzerindeki potansiyel etkisini ortaya koymak amaçlanmıştır. Nitel araştırma yönteminden biri olan durum çalışmasının tercih edildiği araştırma, bir devlet üniversitesinin Matematik Eğitimi Tezli Yüksek Lisans programına kayıtlı iki matematik öğretmeni ile gerçekleştirilmiştir. Katılımcılarının belirlenmesinde ölçüt örnekleme yöntemi kullanılmıştır. Ölçüt olarak öğretmenlerin zekâ oyunları ve problem kurmaya yönelik müdahalelerinin olmamasıdır. Veri toplama aracı olarak dört görevden oluşan problem kurma testi kullanılmıştır. Testte her bir göreve ait bir görsele yer verilmiş ve öğretmenlerden uygulama öncesi ve sonrası her bir görsele ilişkin kolay, orta ve zor derecede birer problem kurmaları istenmiştir. Öğretmenlerin kurdukları problemlerin matematiksel karmaşıklığını analiz etmek için Kwek (2015) tarafından önerilen bilişsel karmaşıklık analiz çerçevesi kullanılmıştır. Araştırmada problem kurma görevlerinde verilen talimatın daha karmaşık problemlerin kurulmasına katkı sağladığı tespit edilmiştir. Ancak yüksek seviyede karmaşık problemler genellikle son tespit aşamasında kurulmuştur. Öğretmenlerin özellikle zekâ oyunlarına yönelik müdahaleden sonra kurdukları problemlerin yüksek seviyede karmaşık olduğu ve zekâ oyunları ile ilişkilendirdikleri belirlenmiştir. Dolayısıyla bu çalışmada zekâ oyunlarının kurulan problemlerin daha karmaşık olmasına neden olduğu ve zekâ oyunlarının problem kurma becerisini geliştirdiği sonucuna varılmıştır.

Anahtar kelimeler: Zekâ oyunları, problem kurma, problem kurma talimatları.

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Citation Information
Dokumacı Sütçü, N., & Örnek, T. (2025). Do intelligence games improve problem posing skill? *Kuramsal Eğitimbilim Dergisi [Journal of Theoretical Educational Sciences], 18*(3), 584-610.

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e-ISSN: 1308-1659

Games are important tools for learning and behavior change (Burgers et al., 2015). Games play a crucial role in children's brain development and are an effective teaching strategy used both in and out of school (Goldstein, 2003). It has been used as a learning tool in educational settings for centuries. It helps students to focus on the subject matter and significantly enhances their learning experience (Dahalan et al., 2024). Almost everything a child needs to learn is developed through play, including concrete skills such as motor coordination, counting, and speaking, and abstract skills such as imagination, problem solving, planning, and learning to learn (Goldstein, 2003). Games support the development of a wide range of skills such as problem solving, sequencing, deductive reasoning, which are necessary for autonomous learners. In this case, games can be used in educational settings to help create an environment in which children can increase their cognitive maturity levels (McFarlane et al., 2002).

Games have been the subject of research in various fields such as education, physics, psychology, computer science, media and cultural studies. Therefore, there are various game classifications in the literature (Kirriemuir & McFarlane, 2004). Intelligence games, which are one of the game types, can also be called mind games or puzzles (Bottino et al., 2010; Kirriemuir & McFarlane, 2004). An intelligence games is a problem designed for fun (Moursund, 2006). It is a gamified version of all kinds of problems, including real problems (Ministry of National Education [MoNE], 2013). Intelligence games should not depend on a single problem solving domain. They should be easy to express and remember. It should initially frustrate the problem solver, but promise a solution. It should be fun and engaging (Michalewicz et al., 2011). The aim of these games is to solve a specific mentally challenging problem or accomplish a specific task (Moursund, 2006).

Intelligence games develop imagination, combination, memory, logic and strategic judgment, relaxation and development, original and constructive, creative thinking. They also strengthen thinking about possibilities, determination and patience (Příhonská, 2008). According to Alessi and Trollip (2001), intelligence games teach general problem solving skills such as formulating solutions, gathering information careful observation, and testing them. Kiili (2007) stated that games are an appropriate strategy for developing students' problem solving skills. According to Michalewicz et al. (2011), teaching with intelligence games can be used to teach problem solving skills.

When the literature was examined, it was seen that there were studies (Bayramin, 2020; Chen et al., 2021; Çağan, 2022; Kurbal, 2015; Lin et al., 2011; Reiter et al., 2014; Şanlıdağ & Aykaç, 2021; Şişman, 2022; Yıldırım, 2023; Terzi, 2024; Zengin-Kılavuz, 2024) that revealed the positive effect of intelligence games on the development of students' problem solving skills. For example, in the study conducted by Terzi (2024), it was shown that intelligence games-based teaching practices were effective on the non-routine problem solving skills of 4th grade students. In a study conducted by Yıldırım (2023) with 7th grade students, it was revealed that intelligence games positively changed students' skills towards mathematics problem solving. In a study conducted by Bayramin (2020), it was revealed that 6th grade students used Polya's problem solving strategies while solving problems included in intelligence games and that intelligence games improved problem solving skills. In a study conducted by Kurbal (2015) with 6th grade middle school students, it was found that students who played intelligence games were successful in a problem solving test involving open-ended real life problems. Lin et al. (2011) designed a collaborative Chinese Tangram activity that incorporated problem-solving learning strategies to promote peer interactions and encourage students' higher-order thinking and creativity in geometric problem solving. The study revealed that 6th grade students' proficiency in rotation and area of shapes increased, and the score gap between lower and higher achievers narrowed.

Problem posing is a fundamental step in the problem solving process and directly affects the entire solution process. There are also studies in the literature (Kopparla et al., 2019; Örnek & Soylu, 2021) indicating that problem posing skills positively affect problem solving skills. Because problem posing is an integral part of problem solving (Kilpatrick, 1987; Leung, 2016). Problem posing has an important place in mathematics education because it can be used as a learning, teaching, and assessment tool in mathematics classrooms (Baumanss & Rott, 2024; Chen & Cai, 2020; Kinach, 2002; Lowrie, 1999; Silver, 1994). Despite the importance of problem posing, studies have shown that teachers' and pre-service teachers' problem posing skills are not at an adequate level (Crespo & Sinclair, 2008; Doğan-Coşkun, 2019; Ellerton, 2013; Kar, 2014; Tichá & Hošpesová, 2009); even if teachers and pre-service teachers can pose problems, they lack problem posing skills (Cai et al., 2020; Çomarlı, 2018; Leavy & Hourigan, 2019; Leung & Silver, 1997). At the same time, most of these studies were conducted with pre-service teachers. In this context, there is a limited number of studies examining teachers' problem posing skills in the literature. However, the deficiencies seen in the problems posed by teachers negatively affect the quality of teaching and thus student achievement (Kar, 2014; Kar & Işık, 2015). Therefore, it can be said that it is important to improve teachers' problem posing skills.

In the literature, there are various approaches to improve problem posing skills. One of these approaches is to examine the effect of a variable on problem posing. Studies (Abu-Elwan, 1999; Grundmeier, 2003; Kopparla et al., 2019; Örnek & Soylu, 2021) generally examined the effect of problem posing and problem solving intervention on problem posing. However, Kalmpourtzis (2019) conducted an experimental study with children aged 5-6 years and found that game design activities had a positive effect on the development of students' problem posing skills. Candiasa, Santiyadnya and Sunu (2018) used puzzles as a tool to increase problem posing skills in mathematics education. The problem posing learning model supported by puzzles significantly increased middle school students' interest in problem posing and improved their ability to construct meaningful mathematical problems. However, there is no research in the literature on whether the variable of intelligence games improves teachers' problem posing skills. However, it is very important for teachers to develop problem posing skills in order to provide an effective and meaningful learning environment by guiding students to develop different perspectives, produce creative solutions and develop learning processes related to real life. Therefore, in this study, it was aimed to determine whether intelligence games improve mathematics teachers' problem posing skills with a qualitative approach. It is thought that this study will make a significant contribution to the literature in terms of giving an idea about whether intelligence games can be preferred as a potential tool for developing problem posing skills.

In the literature, it is seen that there are different approaches to develop problem posing skills. These approaches include direct teaching methods as well as experience-based practices that encourage students' active participation and cognitive processes. In this context, studies examining the effects of certain variables on problem posing skills draw attention. In the studies conducted in the literature (Abu-Elwan, 1999; Grundmeier, 2003; Kopparla et al., 2019; Örnek & Soylu, 2021), the effects of problem solving and problem posing intervention on problem posing were generally examined. These studies show that the interventions applied to the participants provide a significant improvement in problem posing skills. However, there are findings that play-based approaches can also be effective on the development of problem-posing skills. For example, Kalmpourtzis (2019), in his experimental study conducted with children aged 5-6 years, revealed that game design activities had positive effects on students' problem-posing skills. Similarly, Candiasa, Santiyadnya, and Sunu (2018), in their research with secondary school students, developed a learning model that includes the use of puzzles in mathematics teaching and reported that this model increased students' interest in problem posing and improved their ability to construct more meaningful mathematical problems. Such studies are important in that game-based approaches support cognitive development and creative thinking. However, when the literature was analysed, no study was found to examine the effect of intelligence games on teachers' problem posing skills. However, teachers' problem posing skills play a critical role not only in terms of their own professional competences but also in supporting the development of students' higher order thinking skills. Problem posing provides an effective learning process for students to develop different perspectives, generate creative solutions and explore mathematical situations related to real life. Therefore, teachers' ability to develop these skills contributes to their ability to create richer and more meaningful learning environments in their classroom practices.

In this context, the main purpose of the present study is to reveal the potential effect of intelligence games on mathematics teachers' problem posing skills. The study aims to examine how such games contribute to teachers' problem posing process and how they affect the cognitive level of the problems. In this context, the research question of the study was: 'What is the potential effect of intelligence games on problem posing skills?'. It is thought that the findings obtained from the study will provide information about the usability of intelligence games as a potential tool in teacher education processes; therefore, it will contribute to the pedagogical and cognitive development of teachers. In addition, this study will make an important contribution in terms of filling the gap in the literature on the use of game-based applications in the development of teachers' problem posing skills.

Method

Research Design

This study adopted a qualitative research method, which involves collecting data through techniques such as observation, interviews, and document analysis to explore perceptions and events in their natural contexts in a comprehensive and realistic way (Yıldırım & Şimşek, 2018). In this study, a case study, which is one of the qualitative research methods, was preferred because it allows for a detailed examination and comparison of the problems that the participants posed in the predetermination and final determination. As it is known, the aim of this type of studies is to draw conclusions about a specific situation.

Participants

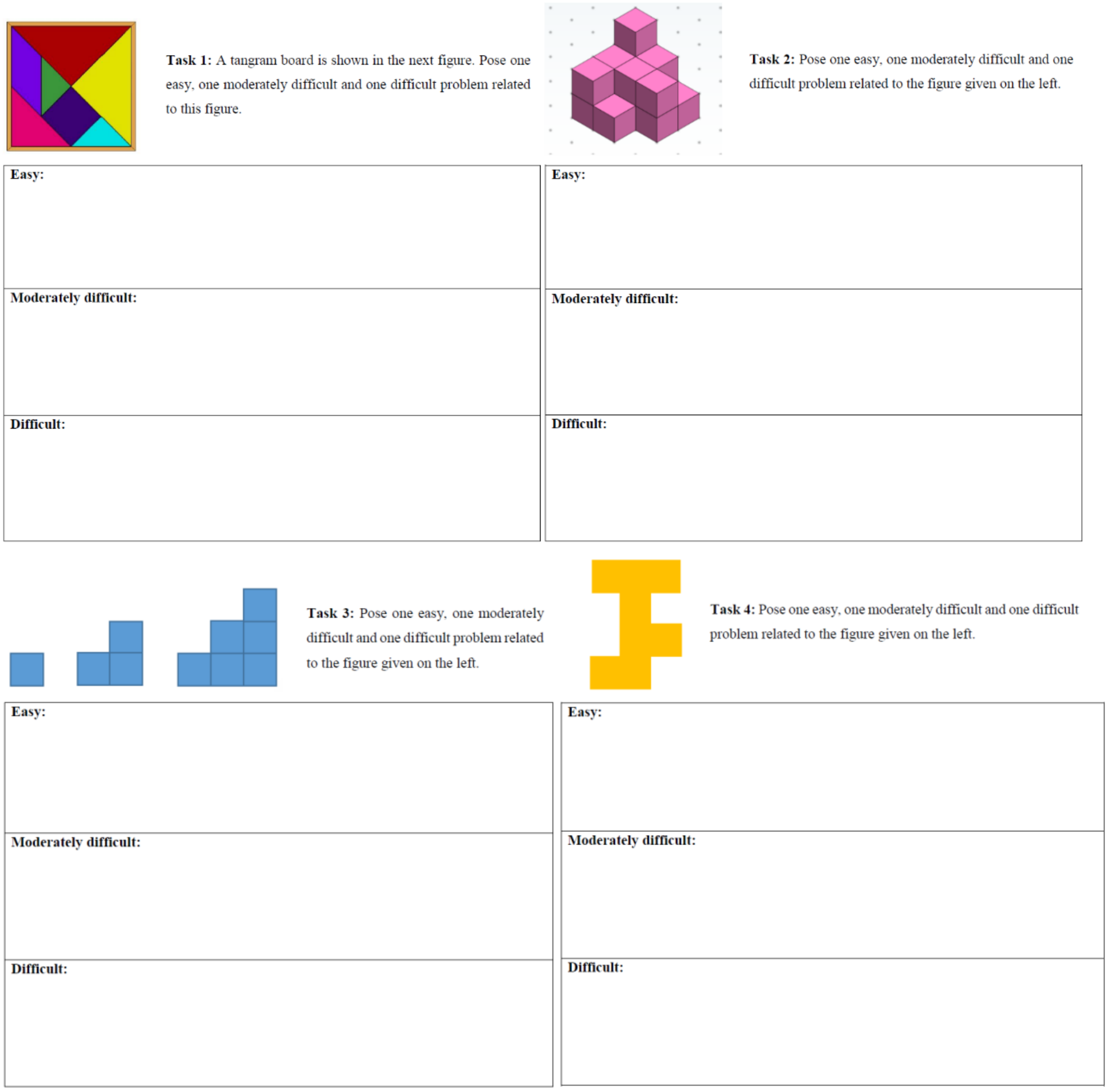
The participants of this study were two secondary school mathematics teachers enrolled in a state university's Mathematics Education Master's Program with Thesis who took the course of Intelligence Games in Mathematics Education. The participants were selected using the criterion sampling method, which is a type of purposeful sampling technique. In the criterion sampling method, all situations where predetermined criteria or criteria are met are studied (Creswell & Poth, 2018; Yıldırım & Şimşek, 2018). In this study, the criterion was the absence of teachers' interventions for intelligence games and problem posing. Initially, five teachers participated voluntarily in the study and one teacher left the study without giving a reason after the fifth week. The study was completed with four teachers. Due to the intensive findings of the study, two teachers were randomly selected among the four teachers and their findings were presented. Therefore, the findings of this study are based on the data of two teachers. The randomly selected teachers were given the pseudonyms Ela and Aysun.

Data Collection Tool

The "Problem Posing Test" prepared by the researchers was used as a data collection tool in the study. Initially, six tasks were included in the problem posing test. After receiving two expert opinions, two tasks were removed from the test on the grounds that they were not suitable for the purpose of the study. In the final test, which consisted of four tasks, a visual was included for each task and teachers were asked to construct a problem for each visual in easy, moderately difficult and difficult degrees before and after the application. The tasks of the problem posing test are given in Figure 1.

Figure 1

Tasks of the Problem Posing Test

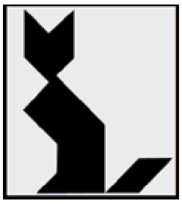
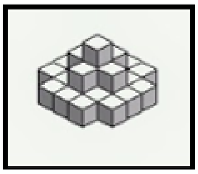


Implementation Process

The implementation, conducted by the first author of this study, lasted for a total of eight weeks, two hours per week. Before the implementation, teachers were given a problem posing test for two class hours. In the first week of the implementation, a presentation was given on what intelligence games are, their benefits, categories of intelligence games, sample games for each category and the basic rules of these games. In the following weeks, Katamino, Tangram, Q.bitz Extreme, Soma Cube, Architecto, Perspecto and Swish games were practiced in two class hours for each game. The tasks in the games were presented to the teachers at beginner, intermediate, and advanced levels. The beginner level involves understanding the rules of the games, developing fundamental knowledge and skills, and participating in beginner-level gameplay. The intermediate level involves making logical inferences, starting from the correct point, and playing intermediate-level games. The advanced level emphasizes mastering advanced-level knowledge and skills while engaging in complex and challenging gameplay (MoNE, 2013). After the implementation, the problem posing test was administered to the teachers during two class hours. Table 1 shows the visuals of the games played during the implementation process.

Table 1

Visuals of the Games Played During the Implementation Process

Katamino			
Tangram			
Qbitz Extreme			
Soma Cube			
Architecto			
Perspecto			
Swish			

Data Analysis

In this study, the mathematical complexity of the problems posed by teachers was evaluated. The cognitive complexity analysis framework proposed by Kwek (2015) was used to analyze the complexity of teachers' problems. According to this framework, cognitive complexity is analyzed at three levels: low, moderate and high. Problems with low cognitive complexity are usually solved in one or a few steps by remembering mathematical rules and knowledge. Problems with moderate cognitive complexity go one click beyond recall and require more thought and decision-making processes. Problems with high cognitive complexity require the use of metacognitive skills such as reasoning, analyzing and generalizing. Since cognitive complexity refers to the cognitive effort required to solve a problem (Ulusoy, 2024), the features required to solve the problem were listed to determine which level the problems in the current study corresponded to. Sample coding for each level is presented in Table 2. In addition, the problems posed by the teachers were also analyzed in terms of their subjects and their relationship with intelligence games.

Table 2

Sample Coding for Each Level

Task number/ Degree of difficulty	The posed problem	Features required to solve the problem	Cognitive load	Explanation
First task/ Easy	If the perimeter of the large square shape is 24 cm and the red and yellow triangles are right triangles, what is the perimeter of the red triangle?	*Tangram board (large square) perimeter *Length of side of large square/hypotenuse of red triangle *Red triangle side lengths *Perimeter of red triangle	Low	This problem, posed by teacher Aysun in the predetermination, was evaluated as a problem with low cognitive complexity because it required remembering the perimeter formula and the properties of the Pythagorean relation.
Third task/ Moderately difficult	The first three steps of a pattern consisting of unit squares are given above. What is the perimeter of the shape in the sixth step?	*Creating step 6 of the pattern *Each square's side length *Calculating the perimeter of the shape in step 6 of the pattern	Moderate	This problem, posed by teacher Ela in the final determination, was evaluated as a problem with moderate cognitive complexity because it required the pattern to be expanded to the 6th step.
Fourth task/ Difficult	The top view of a shape made up of unit cubes is as in the figure above. The numbers written on the shape show how many unit cubes are on top of each other. Draw the side view of this shape given from the top.	*Top view of the shape made of unit cubes *Creating a three-dimensional shape based on the numbers on the shape *Drawing a side view of the created shape	High	This problem, posed by teacher Ela in the final determination, was evaluated as a problem with high cognitive complexity because it required thinking of a two-dimensional shape as three-dimensional, that is, it carried out a process with multiple decision points.

Validity and Reliability

In this study, various strategies were utilised to ensure the validity and reliability of qualitative data. Validity and reliability measures for the qualitative process of the study were structured in line with the recommendations of Yıldırım and Şimşek (2018).

Within the scope of internal validity (credibility), the first author of the current study had a continuous and intensive interaction with the teachers during the eight-week implementation process. The stages of data analysis and interpretation of the findings were carried out with the cooperation of two authors in order to minimise subjective biases in the interpretation of the data. In addition, the problem posing test used as a data collection tool was presented to the opinions of two experts and necessary arrangements were made. In terms of external validity (transferability), the whole process of the research was described in detail; contextual adequacy was ensured by explaining the necessary features of the solutions of the problems. Criterion sampling method, one of the purposeful sampling methods, was preferred in determining the participants. This supports the transferability of the findings to similar contexts. Within the scope of internal reliability (consistency), the data analysis process was carried out in line with a pre-structured and detailed conceptual framework. This approach made it possible to analyse the data in a systematic and holistic manner. In terms of external reliability (confirmability), the data collection tool, the data obtained and the coding made during the analysis process were archived by the researchers. This practice ensures that the study can be examined and verified by other researchers when necessary.

Ethics Statements

All procedures performed in studies involving human participants were in accordance with the ethical standards. The ethical committee approval for this study was obtained from the Social Sciences Ethics Committee at Dicle University. (Registration Number is E-14679147-663.05-730577).

Findings

In this section, the findings obtained from the research are presented for teacher Ela and teacher Aysun respectively.

Findings for Teacher Ela

The analysis of the problems Ela teacher posed for the first task in the predetermination and final determination is given in Table 3.

Table 3

Analysis of Ela Teacher's Posed Problems for the First Task in the Predetermination and Final Determination

	Predetermination				Final determination			
Degree of difficulty	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load
Easy	*Diagonal length of the tangram board (large square) *Side length of the large square *Area of the red and yellow triangles / half of the area of the large square	Area	Not related	Low	*Hypotenuse of the red triangle *Side lengths of the yellow triangle *Area of the yellow triangle	Area	Not related	Low
Moderately Difficult	*Hypotenuse of the yellow triangle *Side lengths of the yellow triangle *Side length of the purple square *Area of the trapezoid formed by the purple square and the blue triangle	Area	Not related	Low	*Side lengths of the pink triangle *Length of the short side of the parallelogram *Length of the long side of the parallelogram / hypotenuse of the green triangle *Side lengths of the green triangle *Perimeter of the trapezoid formed by the green triangle and the parallelogram	Perimeter	Not related	Low
Difficult	The data is inconsistent (The data in the problem statement is inconsistent because the properties of the tangram are not correctly known).	Perimeter	Not related	None	*Perimeter of the tangram board *Side length of the tangram board *Tangram pieces start 1 cm inside each edge *Hypotenuse of the yellow triangle *Side lengths of the yellow triangle *Side length of the purple square *Side lengths of the green triangle *Hypotenuse of the green triangle *Perimeter of the yellow triangle, purple square, and green triangle	Perimeter	Related	Moderate

When Table 3 is analyzed, it is seen that teacher Ela posed easy and moderately difficult problems requiring area calculation and difficult problems requiring perimeter calculation in the predetermination for the first task. In the final determination, the problem posed by teacher Ela at the easy degree required area calculation, while the problems posed by teacher Ela at the moderately difficult and difficult degrees required perimeter calculation. In the predetermination and final determination, problems with easy and moderately difficult degrees are at a low level in terms of cognitive load. In the predetermination, in the problem posed for the difficult degree, since the properties of the tangram were not known correctly, the data were inconsistent and there was no solution to the problem. Therefore, the cognitive load could not be determined. In the final determination, the problem posed for the difficult degree was at the moderate level in terms of cognitive load. Accordingly, only in the final determination, the problem posed for the difficult degree was at the moderate level in terms of cognitive load, and this finding can be interpreted as that the given prompt directed Ela teacher to pose a more cognitively complex problem. At the same time, the problem that teacher Ela posed for the difficult degree only in the final determination was related to intelligence games. The fact that this problem, which teacher Ela posed by associating it with intelligence games, was cognitively more complex than the other problems, can be said that intelligence games contribute to the posing of more complex problems. The analysis of the problems Ela teacher posed for the second task in the predetermination and final determination is given in Table 4.

Table 4

Analysis of Ela Teacher's Posed Problems for the Second Task in the Predetermination and Final Determination

	Predetermination				Final determination			
Degree of difficulty	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load
Easy	*Unit cubes to consider when looking at the figure from top *Number of unit cubes in top view	Appearance	Related	Moderate	*Number of unit cubes in the figure *Number of unit cubes used for new cubes that can be created	Decomposition Combination	Related	High
Moderately Difficult	*Considering all of the unit cubes in the figure *Number of unit cubes in the figüre	Counting	Not related	Moderate	*Coloring the outer surfaces of unit cubes *Identifying colored unit cubes *Number of painted exterior surfaces	Exterior surface painting	Related	High
Difficult	*One side length of unit cubes *Completing the shape into the smallest possible volume cube *Volume of the newly formed cube	Shape completion Volume	Not related	High	*Coloring the outer surfaces of unit cubes *Identify painted and unpainted unit cubes *Number of painted outer surfaces of painted cubes and number of unpainted unit cubes	Exterior surface painting	Related	High

According to Table 5, for the third task, teacher Ela posed problems requiring easy and moderately difficult degrees pattern extension, difficult degree pattern extension and generalization in the predetermination. In the final determination, she posed problems requiring easy degree combination, moderately difficult degree pattern extension and perimeter calculation, and difficult degree pattern extension, generalization, combination and distance calculation. Teacher Ela posed problems at a moderate level in terms of cognitive load for moderately difficult degree and at a high level in terms of cognitive load for difficult degree. In other words, for the third task, the cognitive complexity of the problems posed by teacher Ela in the predetermination and final determination for moderately difficult and difficult degrees did not change. However, while teacher Ela posed a moderate level problem in terms of cognitive load for easy degree in the predetermination, she posed a high level problem in terms of cognitive load in the final determination. The fact that the problem posed by teacher Ela for easy degree in the final determination was cognitively more complex than the problem in the predetermination can be said that intelligence games contribute to the posing of more complex problems. The analysis of the problems Ela teacher posed for the fourth task in the predetermination and final determination is given in Table 6.

Table 5

Analysis of Ela Teacher's Posed Problems for the Third Task in the Predetermination and Final Determination

	Predetermination				Final determination			
Degree of difficulty	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load
Easy	*Creating the 4th step of the pattern *Calculating the number of squares in the 4th step of the pattern	Pattern extension	Not related	Moderate	*Choosing two different shapes that can form squares *Creating the square with the smallest area	Combination	Not related	High
Moderately Difficult	*Pattern rule /Creating the 4th, 5th, and 6th steps of the pattern *Calculating the number of squares in the 4th, 5th, and 6th steps of the pattern	Pattern extension	Not related	Moderate	*Creating the 6th step of the pattern *The side length of each square *Calculating the perimeter of the shape in the 6th step of the pattern	Pattern extension Perimeter	Not related	Moderate
Difficult	*Discovering the relationship between the steps of the pattern *Finding a general rule for this relationship *Using the general rule to calculate the number of squares in the 10th step	Pattern extension Generaliziation	Not related	High	*Creating a square region by combining two consecutive steps in the first 10 steps *Arranging the square regions from largest to smallest side by side *Creating a right triangle assuming the distance between two points as the hypotenuse *Calculating the hypotenuse based on the lengths of the perpendicular sides of a right triangle	Pattern extension Generalization Combination Distance	Not related	High

Table 6

Analysis of Ela Teacher's Posed Problems for the Fourth Task in the Predetermination and Final Determination

	Predetermination				Final determination			
Degree of difficulty	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load
Easy	*Dividing the shape into 8 unit squares *Each square having a side length of 1 unit *Calculating the perimeter of the shape	Perimeter	Not related	Low	*Dividing the shape into 8 unit squares *Dividing the shape into two parts, each consisting of 4 unit squares *Drawing the appearance of the two parts	Decomposition	Related	Low
Moderately Difficult	*Dividing the shape into 8 unit squares *Adding new unit squares to create the smallest area rectangle *Determining the number of added square	Completion	Not related	Moderate	*Drawing new parts consisting of no more than four unit squares *Determining the parts that can be used to create the shape	Combination	Related	High
Difficult	*Considering the given shape as Step 1 *Drawing Step 2 by rotating Step 1 90° clockwise once *Drawing Step 3 by rotating Step 2 90° clockwise once	Rotation	Related	Moderate	*Top view of the shape made of unit cubes *Creating the three-dimensional shape based on the numbers on the shape *Drawing the side view of the created shape	Appearance	Related	High

According to Table 6, in the predetermination for the fourth task, teacher Ela posed problems requiring easy degree of perimeter calculation, moderately difficult degree of completion, and difficult degree of rotation. In the final determination, she posed a problem requiring easy degree of decomposition, moderately difficult degree of combination, and difficult degree of appearence. Teacher Ela posed problems at a low level in terms of cognitive load for easy degree in the predetermination and final determination. In other words, the cognitive complexity of the problems that teacher Ela posed for easy degree in the predetermination and final determination did not change. The given easy prompt may be the reason why the cognitive complexity of the problems posed by teacher Ela did not change in the predetermination and final determination. While teacher Ela posed problems at a moderate level in terms of cognitive load for both moderately difficult and difficult degrees in the predetermination, she posed problems at a high level in terms of cognitive load for both degrees of difficulty in the final determination.

In other words, teacher Ela posed more complex problems for moderately difficult and difficult degree in the final determination. At the same time, in the predetermination, only the difficult degree problem was related to intelligence games, whereas in the final determination, all three degree problems were related to intelligence games. The fact that Ela generally posed problems at a higher level in terms of cognitive load in the final determination compared to the predetermination and that all three degree problems in the final determination were related to intelligence games can be interpreted as the fact that intelligence games improve problem posing skills.

Findings Related to Teacher Aysun

The analysis of the problems Aysun teacher posed for the first task in the predetermination and final determination is given in Table 7.

Table 7

Analysis of Aysun Teacher's Posed Problems for the First Task in the Predetermination and Final Determination

	Predetermination				Final determination			
Degree of difficulty	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load
Easy	*Perimeter of the tangram board (large square) *Side length of the large square / Hypotenuse of the red triangle *The lengths of the perpendicular sides of the red triangle *Perimeter of the red triangle	Perimeter	Not related	Low	*Selecting the shapes with the smallest area from the tangram board *Creating a rectangle with the selected shapes *Drawing the rectangle created	Decomposition Combination Area	Related	Moderate
Moderately Difficult	*Area of the large square *Side length of the large square *The length of the perpendicular sides of the pink triangle *Area of the pink triangle	Area	Not related	Low	*Selecting shapes from the tangram board * Creating at least three models with the same perimeter length using the selected shapes	Decomposition Combination Perimeter	Related	Moderate
Difficult	It is not clear and understandable.	Perimeter	Not related	None	*Selecting shapes from the tangram board *Creating square shapes with the selected shapes *Comparing the areas of the squares	Decomposition Combination Area	Related	Moderate

When Table 7 is analyzed, it is seen that teacher Aysun posed easy and difficult degrees problems requiring perimeter calculation and moderately difficult degree problems requiring area calculation in the predetermination for the first task. In the final determination, the easy and difficult degrees problems posed by Aysun require decomposition, combination and area calculation, while the moderately difficult degree problem requires decomposition, combination and perimeter calculation. In the predetermination, the problems with easy and moderately difficult degrees were at low level in terms of cognitive load, while in the final determination, the problems with easy and moderately difficult degrees were at moderate level in terms of cognitive load. In the predetermination, the cognitive load could not be determined because the problem posed for the difficult degree was not clear and understandable, while the problem posed for the difficult degree in the final determination was at the moderate level in terms of cognitive load. In addition, the problems for all three difficulty degrees in the final determination were related to intelligence games. In other words, teacher Aysun posed more complex problems in the final determination and associated the problems with intelligence games. The fact that the problems at all three degrees that teacher Aysun posed in the final determination by associating them with intelligence games were cognitively more complex than the problems posed in the predetermination can be said that intelligence games contributed to the posing of more complex problems. The analysis of the problems Aysun teacher posed for the second task in the predetermination and final determination is given in Table 8.

According to Table 8, in the predetermination for the second task, teacher Aysun posed problems requiring perimeter calculation at an easy degree, volume calculation at a moderately difficult degree, and proportioning at a difficult degree. In the final determination, she posed easy and moderate degrees problems related to appearance and perimeter calculation, and difficult degree problems related to appearance, combination and quantity. Since the perimeter of a three-dimensional shape could not be calculated in the problem posed at the easy degree in the predetermination, the data were illogical and the cognitive load of the problem could not be determined. At the same time, the cognitive load of the problem could not be determined because the problem posed for the difficult degree was not clear and understandable. In the final determination, the problem posed at the easy degree was moderate in terms of cognitive load, and the problem posed at the difficult degree was high in terms of cognitive load. The problem posed by teacher Aysun for the moderately difficult degree in the predetermination was at a low level in terms of cognitive load and at a moderate level in the final determination. In addition, the problems posed by teacher Aysun for all three difficulty degrees in the final determination were related to intelligence games. These findings can be interpreted as intelligence games improve problem posing skills. The analysis of the problems Aysun teacher posed for the third task in the predetermination and final determination is given in Table 9.

Table 8

Analysis of Aysun Teacher's Posed Problems for the Second Task in the Predetermination and Final Determination

	Predetermination				Final determination			
Degree of difficulty	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load
Easy	*Since the perimeter of a three-dimensional shape cannot be calculated, the data is illogical.	Permeter	Not related	None	*Edge length of the unit cubes in the shape *Drawing the right-side view of the shape *Perimeter of the right-side view	Appearance Permeter	Related	Moderate
Moderately Difficult	*Number of unit cubes in the shape *Calculating the volume of the shape	Volume	Not related	Low	*Volume of each cube in the shape *Edge length of each cube *Front and back views of the shape *Perimeter of the front and back views	Appearance Permeter	Related	Moderate
Difficult	It is not clear and understandable.	Ratio	Not related	None	*Back view of the shape *Creating models using soma cube pieces that match the back view of the shape *Calculating the total cost of the created model considering the cost of each soma cube piece used	Appearance Combination Quantity	Related	High

Table 9

Analysis of Aysun Teacher's Posed Problems for the Third Task in the Predetermination and Final Determination

	Predetermination				Final determination			
Degree of difficulty	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load
Easy	*Creating the 5th step of the pattern	Pattern extension	Not related	Moderate	*Creating the 4th, 5th, 6th, and 7th steps of the pattern *Calculating the number of squares in the 4th, 5th, 6th, and 7th steps of the pattern	Pattern extension	Not related	Moderate
Moderately Difficult	*The side length of each square *Creating the shapes in the 7th and 5th steps of the pattern *The difference in the perimeter lengths of the shapes in the 7th and 5th steps	Pattern extension Perimeter	Not related	Moderate	*Expanding the pattern up to the 5th step at most *The total area of the shapes up to the 5th step	Pattern extension Area	Not related	Moderate
Difficult	*Expanding the pattern up to the 7th step at most *Calculating how many steps can be progressed with 70 additional squares at most	Pattern extension Analysis	Not related	High	*Creating the 4th step of the pattern *Selecting the appropriate pieces from the Katamino game *Creating the image of the 4th step of the pattern with the selected shapes	Pattern extension Decomposition Combination	Related	High

According to Table 9, in the predetermination for the third task, teacher Aysun posed problems related to pattern extension for easy degree, pattern extension and perimeter calculation for moderately difficult degree, pattern extension and analysis for difficult degree. In the final determination, the problems posed by teacher Aysun require pattern extension at easy degree, pattern extension and area calculation at moderately difficult degree, pattern extension, decomposition and combination at difficult degree. In the predetermination and final determination, it is seen that the easy and moderately difficult degrees problems posed by teacher Aysun are at moderate level in terms of cognitive load, while the difficult degree problems are at high level. In other words, the cognitive complexity of the problems posed by teacher Aysun in the predetermination and final determination did not change for all three difficulty degrees. Nevertheless, the problem posed at the difficult degree in the final determination was related to intelligence games. This finding can be interpreted as the positive effect of intelligence games on problem posing skills. The fact that the problem-posing activity used in the third task evoked patterns may have caused this situation. The analysis of the problems Aysun teacher posed for the fourth task in the predetermination and final determination is given in Table 10.

Table 10

Analysis of Aysun Teacher's Posed Problems for the Fourth Task in the Predetermination and Final Determination

	Predetermination				Final determination			
Degree of difficulty	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load	Features required to solve the problem	Topic	Relationship with intelligence games	Cognitive load
Easy	*One side length of unit squares *Perimeter of the shape	Perimeter	Not related	Low	* Perimeter of the shape * The side length of each unit square in the shape * Completing the shape into a rectangle * The lengths of the short and long sides of the rectangle * Area of the rectangle	Perimeter Completion Area	Not related	Low
Moderately Difficult	*One side length of unit squares *Area of the shape	Area	Not related	Low	*Selecting the appropriate pieces from the soma cube game *Assembling the selected soma cube pieces to match the front view of the shape *Explaining the steps followed	Appearance Combunation	Related	High
Difficult	*Top view of the shape composed of unit cubes *Creating a three-dimensional shape based on the numbers on the shape *Edge length of each unit cube in the formed shape *Volume of the created shape	Appearance Volume	Related	High	*Top view of the shape composed of unit cubes *Creating a three-dimensional shape based on the numbers on the shape using soma cube pieces	Appearance Combunation	Related	High

According to Table 10, in the predetermination for the fourth task, teacher Aysun posed problems requiring perimeter calculation at an easy degree, area calculation at a moderately difficult degree, and appearance and volume calculation at a difficult degree. In the final determination, she posed easy degree problems related to perimeter, completion and area calculation, and moderately difficult and difficult degrees problems related to appearance and combunation. However, the problem that teacher Aysun posed at the easy degree in the predetermination and final determination was low level in terms of cognitive load, while the problems she posed at the difficult degree were high level complex. While the problem posed by teacher Aysun for moderately difficult degree in the predetermination was low level in terms of cognitive load, it was high level complex in the final determination. In addition, when the relationship between the posed problems and intelligence games is examined, the problem posed for moderately difficult degree in the final determination and the problems for difficult degree in the predetermination and final determinations have a relationship with intelligence games. The fact that the problem posed by teacher Aysun at the moderately difficult degree by associating it with the intelligence games was more cognitively complex in the final determination than the problem posed in the predetermination can be said that the intelligence games contributed to the posing of more complex problems.

When the problems posed by Ela teacher for four tasks are analyzed, it is seen that she posed problems with higher cognitive load and more associated with intelligence games, especially in the final determination, compared to the predetermination. In the first task, the problem posed at the difficult degree was transformed from a problem with no solution to a problem with a moderate cognitive load. In the second task, the cognitive load of the easy and moderately difficult degree problems increased, and the use of more features in the difficult degree problem drew attention. In the third task, while the cognitive complexity increased in the easy degree problem, the complexity was maintained in the moderately difficult and difficult degree problems. In the fourth task, the cognitive complexity of the moderately difficult and difficult degree problems increased, and the relationship with intelligence games spread to all degrees of difficulty. In general, it was concluded that teacher Ela posed problems requiring higher level thinking skills at the final determination and that this development was supported by the intelligence games-based process.

When the problems posed by teacher Aysun in the four tasks are analyzed, it is seen that she posed problems that were cognitively more complex and more associated with intelligence games in the final determination than in the predetermination. In the first task, while the cognitive load of the easy and moderately difficult degree problems increased, the difficult degree problem, which was not clear and understandable in the predetermination, gained a meaningful structure in the final determination and reached a moderate cognitive load. In the second task, while some of the problems in the predetermination were not valid and logical, in the final determination, valid and more complex problems were posed at all three degrees; cognitive load increased especially at the difficult degree. In the third task, although the cognitive load levels remained constant, it is noteworthy that the difficult degree problem in the final determination was associated with intelligence games. In the fourth task, cognitive complexity increased especially at the moderately difficult degree, while the relationship with intelligence games became evident at both the moderately difficult and difficult degrees. In general, it was concluded that teacher Aysun posed more structured, valid and complex problems at the final determination and that this development was supported by the intelligence games-based process.

Discussion and Conclusion

In this study, the complexity of the problems posed by both teachers generally increased as the degree of difficulty increased. Especially when teachers were asked to pose difficult problems, they generally posed more complex problems. Therefore, it can be said that the prompts given in the problem posing tasks contributed to the teachers to construct more complex problems. Similarly, Cai et al. (2023) found that when students were asked to pose difficult problems, the posed problems were much more complex linguistically and semantically and the solutions of the posed problems involved more relations or steps. The possible reason for this result from this study is that asking students to pose problems of varying difficulty prompts them to think more (Cai & Hwang, 2002; Cai et al., 2023). That is, since being prompted to pose a problem with more specific requirements leads to a tendency to think more about the solvability and complexity of problems (Cai et al. 2023; Silber & Cai, 2017), the teachers in this study generally posed more complex problems when asked to pose difficult problems. At the same time, this finding confirms the results of studies (e.g., Cai et al., 2023) that provide evidence that problem posing tasks can provide a better understanding of the mathematical thinking of problem posers if they require different levels of difficulty. On the other hand, this result contradicts the results presented by Baumanss and Rott (2024) who found that similar prompts did not significantly affect creative problem posing performance. The same contradiction is also present in the study conducted by Christou et al. (2024). The researchers found that the level of complexity did not affect teachers' performance in problem posing for the fraction part-whole concept. The results of such studies may vary depending on the type of problem posing activity used and the concept or topic to be problem posed.

The prompts given in the problem posing tasks contributed to the posing of cognitively more complex problems. However, highly complex problems were generally posed in the final determination. It was determined that the problems posed by the teachers, especially after the intervention for intelligence games, were highly complex and associated with intelligence games. Therefore, in this study, it was concluded that intelligence games cause the problems to be more complex and that intelligence games improve problem posing skills. This result is also supported by the topic preferences of the teachers in the problems they constructed. The problems posed by the teachers at low levels in terms of cognitive load are generally related to topics that require measurement such as perimeter and area. Topics such as decomposition, combination, and appearance, which are related to intelligence games, triggered teachers to pose high level complex problems. Therefore, the results of the current study show that learning environments based on intelligence games can be supported with problem posing activities.

The intelligence games used in this study can encourage teachers to think visually and spatially and to understand abstract and concrete relationships. Since these games involve the reconstruction of shapes, parts or spatial arrangements according to a problem or goal to be solved, they encourage the processes of problem identification and the development of creative solutions. Teachers who engage in these types of games can gain the ability to better convey the problem posing process to their students. For example, intelligence games such as three-dimensional puzzles, jigsaw puzzles, and various block structures can strengthen individuals' ability to analyze problem situations, think of solutions, and create and present their own problems to others. This can improve teachers' problem identification and construction skills as well as their problem solving skills, especially in areas such as mathematics and science. Candiasa, Santiyadnya and Sunu (2018) found that the problem posing learning model supported by puzzles improved middle school students' ability to construct meaningful mathematical problems. Kalmpourtzis (2019) found that game design activities had a positive effect on the development of problem-solving skills of students aged 5-6 years. On the other hand, there are studies (Bayramin, 2020; Chen et al., 2021; Çağan, 2022; Kurbal, 2015; Lin et al., 2011; Reiter et al., 2013; Şanlıdağ & Aykaç, 2021; Şişman, 2022; Yıldırım, 2023; Terzi, 2024; Zengin-Kılavuz, 2024) that reveal the positive effect of intelligence games on the development of students' problem solving skills. Considering that problem solving improves problem posing skills (Örnek & Soylu, 2021; Silver & Cai, 1996), it can be said that the fact that intelligence games improve problem posing skills confirms the results of this study.

One limitation of this study is that the findings are based on the written responses of two teachers. For this reason, in the current study, it was qualitatively determined that intelligence games caused the problems to be more complex and therefore intelligence games improved problem posing skills. In future studies, whether intelligence games improve problem posing skills can be examined experimentally.

Another limitation of this study is that the data were collected only with paper and pencil. Therefore, teachers' understanding of the cognitive processes and interpretations of the tasks could not be identified, even if the products of the problem posing tasks were available. Consequently, even if the authors of this study think that posing a difficult or complex problem is a superior outcome, they have no real understanding of how teachers interpret these prompts and how they relate them to intelligence games. More specifically, this study did not identify teachers' understanding of an easy problem, a moderately difficult problem, and a difficult problem. It also did not examine in detail how the intelligence games intervention was reflected in the complexity measures used in this study.

Acknowledgements

The authors would like to thank the teachers who participated in this study.

Statement of Responsibility

All authors contributed to the study. The first author was involved in conceptualization, literature review, design, data collection, writing, review, editing and supervision. The second author contributed to literature review, design, methodology, analysis, writing, review, editing, and supervision.

Conflicts of Interest

The authors declare no conflict interests.

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