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The Effect of Gamified Adaptive Intelligent Tutoring System Artibos on Problem-Solving Skills

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This study aims to examine the contribution of ArtiBos, which is designed as a Gamified Adaptive Intelligent Tutoring System for students' problem-solving skills. In the study, first of all, the system's design features to improve problem-solving skills were examined, and then the effect of the system on problem-solving skills was evaluated. The study was carried out with 12 students studying in the ninth class of a High School in Türkiye and 6 mathematics teachers with different experiences working in the same school. A case study, one of the qualitative research methods were applied in this study through which ArtiBos system logs, student interviews, and teacher interviews were evaluated. Data pertaining to the number of solved problems, the number

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of problems created, the number of problems solved correctly, the duration of being online in the system, the rate of correct problem-solving, and the average solving time were examined to evaluate system logs. Interview questions have been prepared so that the contribution of system features to problem-solving skills can be evaluated. The data from the interview were analyzed and some codes for problem-solving skills were created. And then, sub-themes were created by combining the codes. The results show that ArtiBos affects students' problem-solving skills positively.

Introduction

It is not possible to teach the solution method of all types of problems through educational activities. Therefore, it is necessary not to teach problem-solving, but to teach problem-solving skills and to enable them to apply these skills in different areas (Eppe et al., 2022; Sun et al., 2022). Problem-solving skill, which has always been important from the past to the present, is one of the most important skills among the 21st-century skills. Problem-solving is the most essential skill required in all areas of our lives, increasing in importance and necessary for people to solve their problems effectively (Hollenstein et al., 2022; Melawati et al., 2022). The inclusion of problem-solving skills in the teaching process and gaining for individuals is an issue that is also emphasized by educators (Argelagos et al., 2022; Fatmawati et al., 2021; Rosen, Wolf, & Stoeffler, 2020; Sorby et al., 2022; Sun et al., 2020). Studies show that students experience some difficulties due to conceptual confusion in the problem-solving process (Andrews-Todd, & Foryth, 2020; García et al., 2019). In order to overcome this difficulty, researchers have considered problem-solving as a step-by-step process and stated that this process basically consists of the steps of understanding the problem, determining the strategy, applying the strategy, and evaluating the solution (Ibrokhimovich, 2022; Polya, 1957; Simamora, Sidabutar, & Surya, 2017).

Problem-solving skill is also significant in mathematics education (Baumanns & Rott, 2019; OECD, 2019; WEF, 2020). Studies show that before teaching students to solve mathematical problems, the relationship between mathematical problems and concepts in daily life should be taught. Thus, it will be easier for students to understand concepts and perform more accurate arithmetic operations by thinking about the content of the problem (García et al., 2019; Ibrokhimovich, 2022; Phonapichat et al., 2014; Sorby et al., 2022).

Using computer technologies in the problem-solving process is important for students to see where they made mistakes and receive appropriate feedback (Aidoo et al., 2022). For this reason, studies on the development of problem-solving skills emphasize the importance of using ICTs in the curriculum (Erol & Cirak, 2022; Lai & Bower, 2019; Li et al., 2022). The widespread use of ICTs in education has brought many innovations in the teaching process. Many new educational technologies, such as distance education technologies for ubiquitous learning (Minamatov, 2022); digital gamified teaching by providing permanent and practical learning (Cai et al., 2022); individualized environments and Intelligent Tutoring Systems (ITS) by providing personalized education (Taub & Azevedo, 2019), have also affected the teaching tools. Among these technologies, ITSs, which have become popular recently, are teaching systems in which artificial intelligence technologies are used, offering advantages such as guiding to students by imitating the instructors in the learning process, giving immediate feedback, helping decision-making, and guiding (Almasri et al., 2019; Bakeer & Abu-Naser, 2019). These systems support the learning process by imitating real teachers (Castro-Schez et al., 2021; Yüce, Abubakar, & İlkan, 2019). Studies on ITSs show that the step-by-step solving method prepared using artificial intelligence technologies improves students' problem-solving skills and increases their learning performance (Aleven et al., 2019; Jeremic et al., 2012; Nabiyev et al., 2013).

Problem-Solving Skill

Problem-solving skill is not only about solving mathematical problems but also about the ability to find solutions to real-life problems (Burkholder, 2021). Therefore, a person should have problem-solving skills against all unusual situations that he may encounter (Aslan, 2021; Baumanns & Rott, 2019).

In the problem-solving process, there are skills such as understanding the given problem, establishing a relationship between the data in the problem content, creative thinking, analysis and synthesis skills, and critical thinking (Hämäläinen et al., 2019; Shute et al., 2016; Wechsler et al., 2018). Numerous studies show that students have difficulties in using these skills in the problem-solving process (García et al., 2019; Phonapichat et al., 2014; Ramdani et al., 2021). This process can be passed through more effectively and efficiently for individuals with good problem-solving skills (Shute et al., 2016; Wechsler et al., 2018).

Problem-creating activities are also critical in developing problem-solving skills. Studies show that there is a strong connection between students' problem-creating and problem-solving skills (Aktaş, 2021; Celik & Arslan, 2022; Taufik et al., 2019). Many influential mathematics educators studied the effects of problem-creating activity on problem-solving skills (Brown & Walter, 2005; English, 1997; Kilpatrick, 1987; Silver, 1994). Paul Halmos, one of the important names in mathematics, stated in his book "The Heart of Mathematics" that problems are the basis of mathematics and that students should be trained as good problem creators and solvers (Halmos, 1980). Despite its contributions to problem-solving skills, problem-creating is not given much attention in mathematics education research (Cai, Hwang, Jiang, & Silber, 2015). Also, problem-creating does not have a clearly defined structure (Singer, Ellerton, & Cai, 2013). Therefore, it is important to evaluate the problem-creating activities in this study.

The Purpose of Research

In the studies on the contribution of AITS to problem-solving skills, it has been concluded that the system contributes to permanent learning away from rote learning and reduces students' cognitive load in the learning process (Nabiyev et al., 2013; Wang et al., 2015). In addition, it is seen in the literature that digital games are frequently used in learning-teaching processes (Liao, Chen, & Shih, 2019; Perini et al. 2018; Yeh, Chang, & Chen, 2019). However, there are few game designs for developing skills such as problem-solving, algorithmic, and analytical thinking (Hsu & Wang, 2018; Ruggiero & Green, 2017). In addition, it is emphasized that there are few elements in the games designed to develop problem-solving skills, and there is a need for game designs to develop this skill (Lester et al., 2014; Melander Bowden, 2019). In addition, since mathematics is generally perceived as difficult by students (Balım, 2009; Simamora, Sidabutar, & Surya, 2017), the contributions of such systems are even more important.

In this context, this study examines the effect of ArtiBos, a gamified adaptive intelligent tutoring system, on students' problem-solving skills. The research question of this study is identified as follows:

(1) How is the effect of ArtiBos on students' problem-solving skills?

Method

Research Method

This study is a qualitative case study. A case study is a research method that studies a current phenomenon in its real-life context. In this method, the researcher examines an event in depth (Yin, 2009, p. 24). Creswell (2007, p. 73) defines this method as “a qualitative research approach in which the researcher examines one or more situations in depth over time with data collection tools containing multiple sources (observations, interviews, audio-visuals, documents, reports) and defines the situations”. According to Patton (2002), the case study establishes a specific method for collecting, organizing, analyzing, and interpreting data, and therefore, it represents a process of analysis and interpretation. In this study, as in the definitions, a situation was examined in depth with various data collection tools.

Participants

The study group consists of 12 ninth-grade students studying at an Anatolian High School. The group was determined by using the purposive sampling method to analyze the prepared system's effect on students with different success levels. The purposive sampling is a qualitative sampling method in which the researcher reveals his preference for the individuals and the researcher chooses the individuals most suitable for the research (Yıldırım & Şimşek, 2011, pp.107-115). For this reason, the purposive sampling is a preferred method in qualitative research, as it allows for an in-depth study of situations that are thought to have rich information (Islamoglu, 2009, p.183). Based on this definition, 12 participants in this study were selected according to some criteria that would be suitable for the purpose of the study. First of all, the level of success of all students who used the designed system for six weeks was examined in detail. The achievement levels of the students were categorized into five different levels. Equal proportions of students were selected from each category. In addition, the students were selected from an equal number of genders. The distribution of students interviewed according to their gender and mathematics achievement scores are as in Table 1.

Table 1. Distribution of students by gender and math achievement scores

	n=33	%
Gender		
Female	6	50
Male	6	50
Mathematics Score		
0-30	3	25
31-50	2	16,66
51-70	2	16,66
71-85	3	25
85-100	2	16,66

In Table 1, it is seen that the interview group students are equal in gender distribution and approximately equal in score distribution.

The experts contributing to the study consist of 6 secondary school mathematics teachers working in the same school. Information regarding teachers' age, gender, professional experience, and educational status is given in Table 2.

Table 2. Teacher Information

	n =6	%
Gender		
Female	3	50
Male	3	50
Age		
25-35	3	50
35-50	2	33,33
50-65	1	16,66
Professional Experience		
0-5 year	2	33,33
5-10 year	2	33,33
10+ year	2	33,33
Education Status		
Postgraduate	2	33,33
Graduate	4	66,66

According to Table 2, it is seen that half of the six teachers participating in the study are male, half are female, four teachers are university graduates, and two teachers are postgraduates. They have different professional experiences with different age groups.

Data Collection Tools

Quantitative data from system logs and qualitative data from semi-structured interviews were evaluated in order to examine ArtiBos' contribution to problem-solving skills. Interview questions have been prepared in such a way that the researcher can evaluate the contribution of system features to problem-solving skills.

In summary, the data collected from the students are as follows:

- System Data
    - The number of solved problems
    - The number of problems created
    - The time to be online in the system

System data were collected at two different times: during the lesson and extracurricular time.

- Detailed System Data
    - The number of solved problems
    - The average solution time of a problem
    - Number of problems solved correctly
    - Correct solving rate of problems
- Semi-structured interviews

  Also, the data collected from the teachers is as follows:
- Semi-structured interviews

ArtiBos as a Gamified Adaptive Intelligent Tutoring System

ArtiBos is a gamified adaptive intelligent tutoring system. It has been prepared with the contribution of The Scientific and Technological Research Council of Türkiye (TÜBİTAK) fund numbered 215K029. The researchers in the project consist of experts in Mathematics Education (1 Associate Professor and 5 Experts), Education Technologies (1 Professor and 2 Associate Professors), Web Designer (1 Expert), Computer Engineering (1 Professor) and Software Engineering (2 Experts). The system content was prepared in accordance with the current curriculum with the help of experts in the field of Mathematics. The system aims to increase individual teaching by enabling students to create mathematical problems through visual and animated elements, to identify and resolve problems in problem-solving during problem-creating experiences, and to enable students to construct their knowledge for algorithmic thinking and problem-solving skills.

There are seven modules that users can access when logged into the ArtiBos main screen with their username and password. These modules are Subject Lecture Module, Problem Creation Module, Problem-Solving Module, Problem Asking Module, User Accounts Module, Problem Level Module, and Adaptation Module. The ArtiBos homepage with these modules is shown in Figure 1.

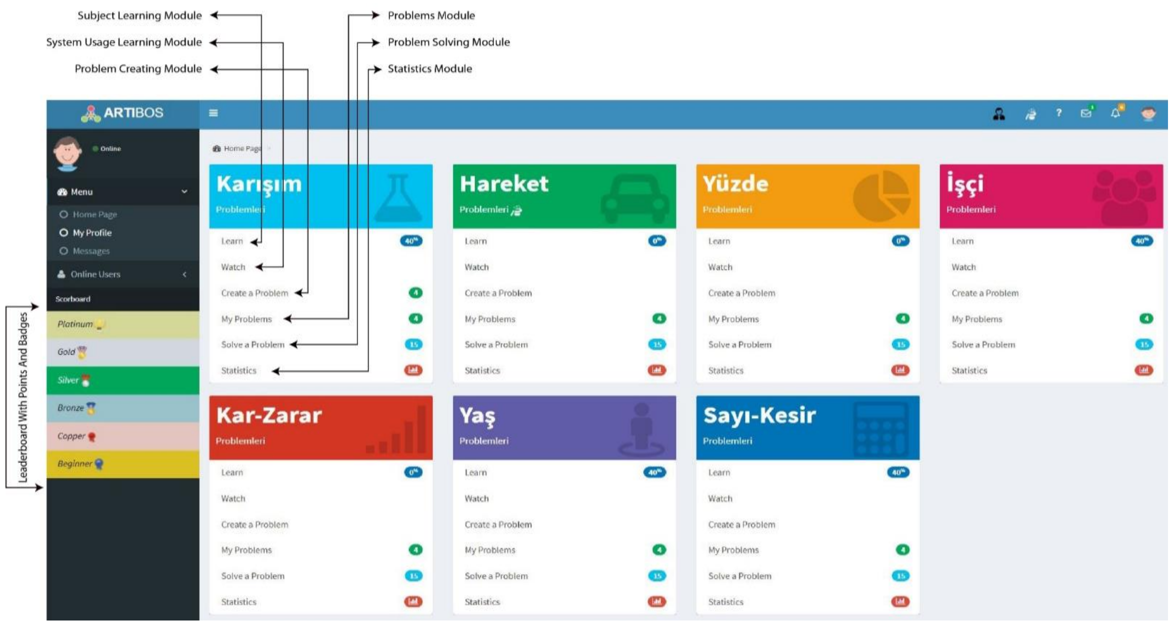

Figure 1. ArtiBos home page

The Subject Lecture Module, Problem Creation Module and Problem-Solving Module in this Figure have been prepared to improve students' subject matter knowledge and problem-solving skills. In this study, the findings of these modules were used.

Problem-Creating Design of ArtiBos

Users must complete the lecture module in order to practice problem activities. The sample image of the lecture module is shown in Figure 2.

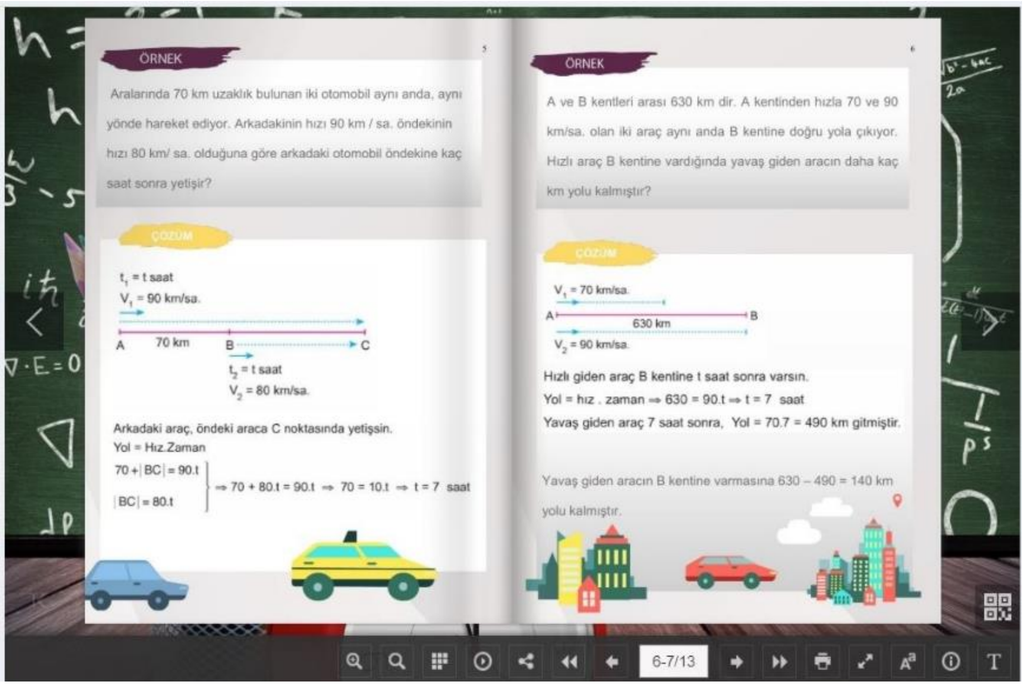

Figure 2. ArtiBos subject lecture module

In the scene shown in Figure 2, students acquire basic information on the subject consisting of animated content and colorful visuals, and then move on to problem-creating and solving activities.

Students can carry out problem-creating activities after they are informed about the subject. Figures 3, 4 and 5 show the problem-creating scenes of motion problems.

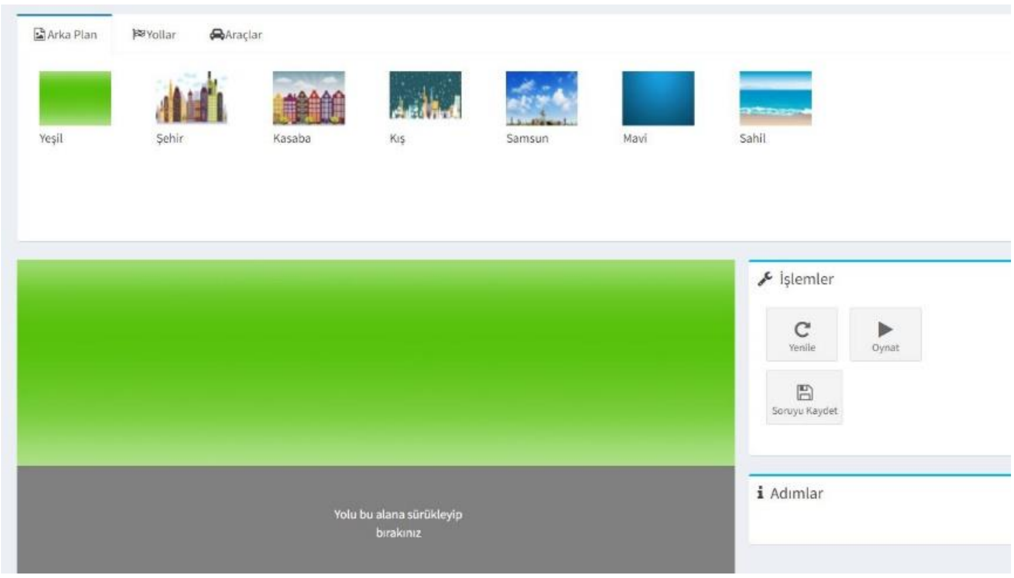

Figure 3. ArtiBos problem-creation module 1

In the problem creation menu, students can easily select the desired objects by dragging them and giving them the desired values. In Figure 3, the student first chooses the background and applies the chosen background by dragging it onto the stage.

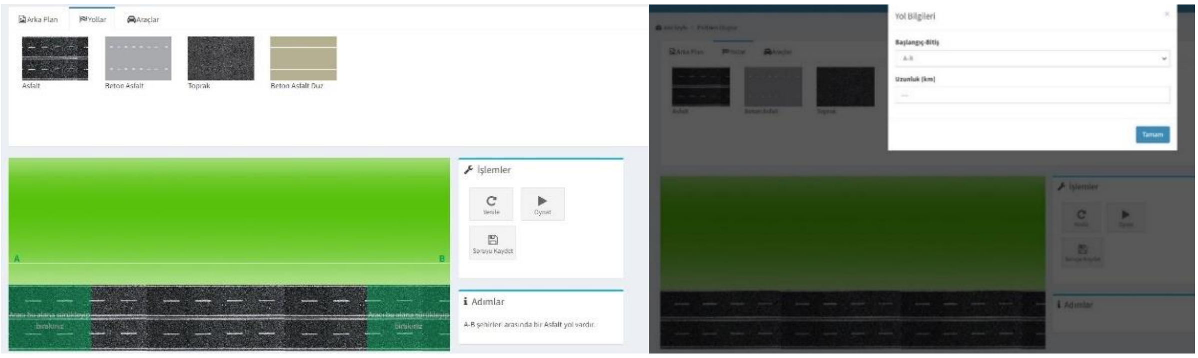

Figure 4. ArtiBos problem creation module 2

In Figure 4, the road is selected and applied to the scene. When the road is selected, numerical information about the road can be chosen from the menu on the screen.

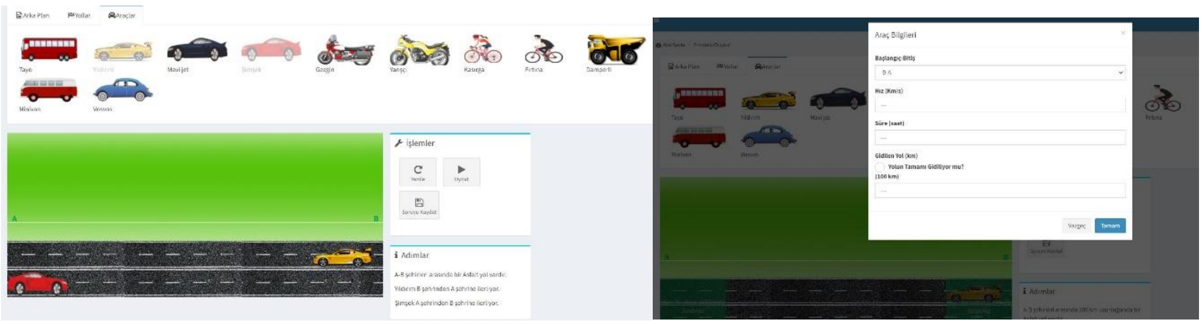

Figure 5. ArtiBos problem creation module 3

After the road is selected, vehicles are selected as in Figure 5. After the vehicle selection, the information regarding speed, distance and time of the vehicle can be chosen from the menu on the screen. After these processes are completed, the question text is completed by choosing the appropriate question among the possible question words. The Natural Language Processing Module automatically creates the problem based on the objects added to the scene and the values written for these objects. According to the written values, the Graf model working in the background of ArtiBos determines the nodes that can be asked in the problem and prepares the appropriate suggestions for the question word. The problem is created when the student chooses the question word for the problem sentence created by Natural Language Processing Module.

Problem-Solving Design of ArtiBos

Problem-solving activities are carried out after the subject is enhanced with problem-creating activities. The problem-solving activity is based on Polya's problem-solving steps. The first step, understanding the problem, is shown in Figure 6.

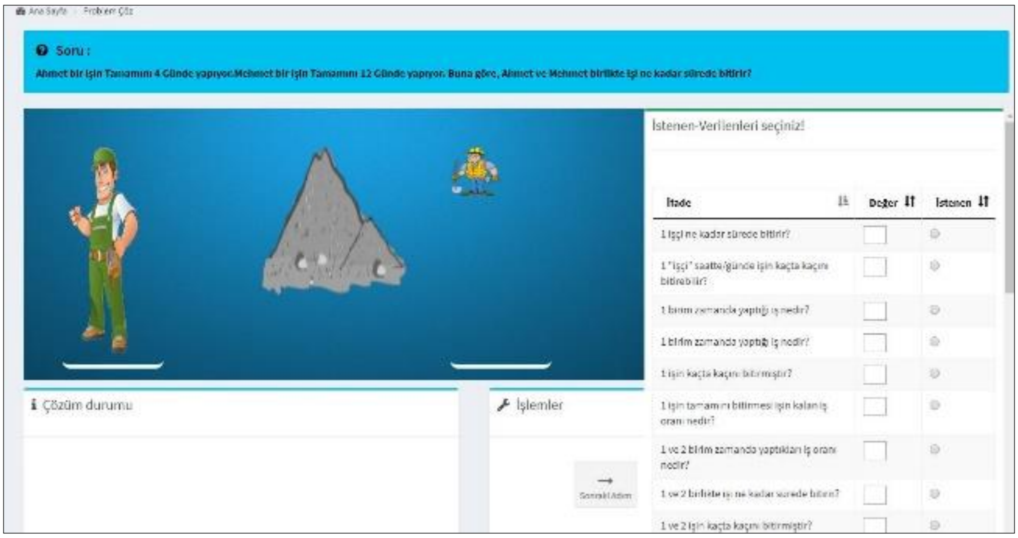

Figure 6. ArtiBos problem-solving module - the step of understanding the problem

At the stage of understanding the problem, the student examines the question text with its visuals, writes the values in the table and marks the desired value. The student completing the first step, proceeds to the steps of Choosing the Strategy for the Solution and Implementing the Strategy. Strategy creation and the appropriate mathematical operations are applied on the same screen. The students first select the appropriate step for the solution strategy they have determined and then create the necessary mathematical equation to do this operation. The step of choosing the strategy and implementing the strategy is shown in Figure 7.

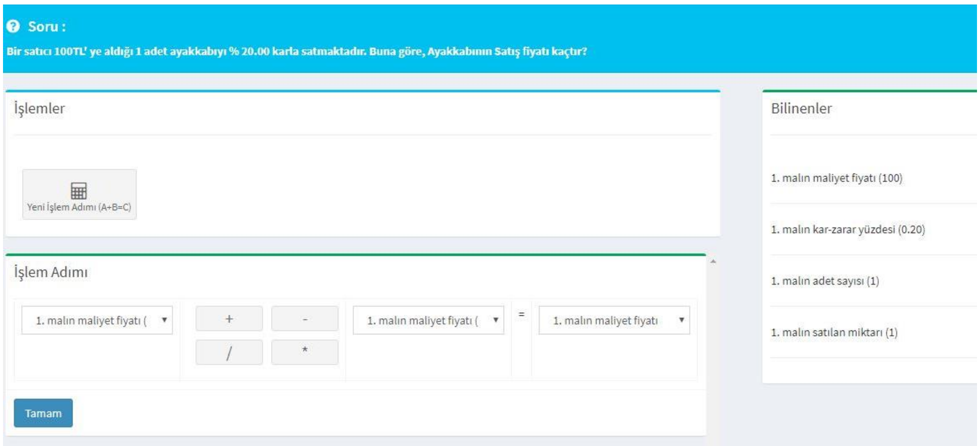

Figure 7. ArtiBos problem-solving module - the step of selecting the strategy and implementing the strategy

In the last step, evaluating the solution, there are four options: seeing different solutions, seeing the process steps, creating a similar question, and resolving the question. The options are shown in Figure 8.

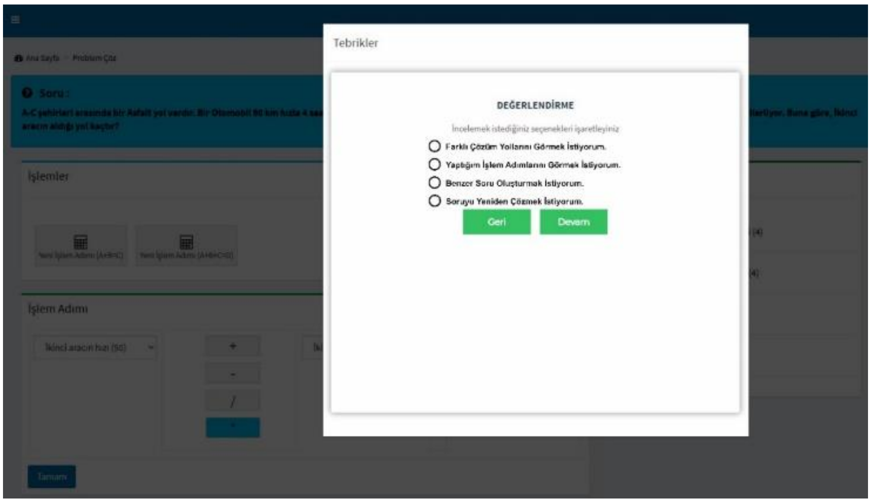

Figure 8. ArtiBos problem-solving module - the step of evaluation of the solution

The sample statistics screen with information on the number of problem creations in ArtiBos is shown in Figure 9 and Figure 10.

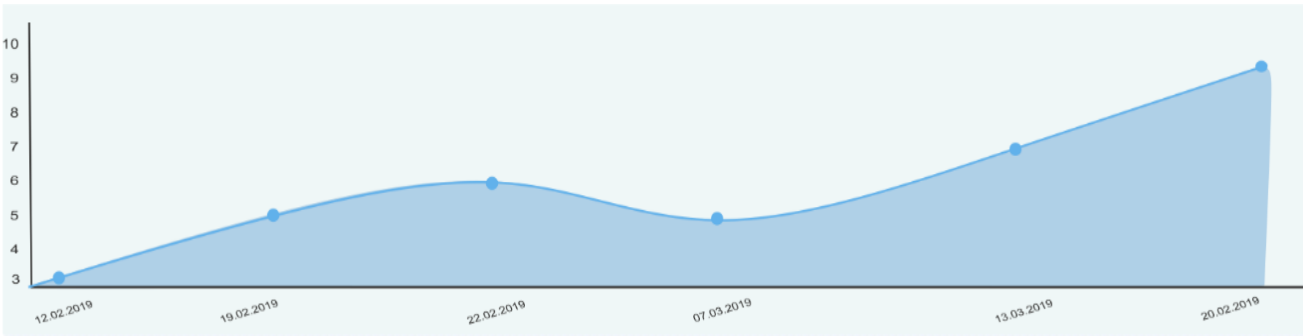

Figure 9. Statistics menu I

ru Metni	1. Aşama Çözüm Süresi	1. Aşama hata Sayısı	2. Aşama Çözüm Süresi	2. Aşama hata Sayısı	Toplam Hata Sayısı	Toplam Süre	Kazanılan/Kaybedilen Puan	Durum
3 şehirleri arasında bir Asfalt yol vardır. Bir Tayo 111 km hızla 11 saat boyunca B şehrinden A şehrine ilerliyor. Bir Gezgin 222 km hızla 22 at boyunca A şehrinden B şehrine ilerliyor.Gezgin aldığı yol kaçtır?	00:0:13	1	00:2:19	--	1	00:02:32	2,288844	Başarılı
3 şehirleri arasında bir Asfalt yol vardır. Bir Tayo 111 km hızla 11 saat boyunca B şehrinden A şehrine ilerliyor. Bir Gezgin 222 km hızla 22 at boyunca A şehrinden B şehrine ilerliyor.Gezgin aldığı yol kaçtır?	00:0:44	1	00:0:33	--	1	00:01:17	4,536012	Başarılı
3 şehirleri arasında bir Beton Asfalt yol vardır. Tayo 60 km hızla 5 saat boyunca A şehrinden B şehrine ilerliyor.Otobus aldığı yol kaçtır?	00:0:12	1	00:0:53	2	3	00:01:50	-0,259047	Başarısız
3 şehirleri arasında 450 km uzunluğunda bir Beton Asfalt yol vardır. Bir Tayo 90 km hızla 450km gidiyor. A şehrinden B şehrine liyor.Otobus hareket süresi kaçtır?	00:0:25	1	00:0:52	--	1	00:01:17	2,576076	Başarılı
3 şehirleri arasında 450 km uzunluğunda bir Beton Asfalt yol vardır. Bir Tayo 90 km hızla 450km gidiyor. A şehrinden B şehrine liyor.Otobus hareket süresi kaçtır?	00:0:13	1	00:0:22	--	1	00:00:35	3,543372	Başarılı

Figure 10. Statistics menu II

The numbers and rate of students creating and solving problems, problem creation and solving times, the number of errors made while solving problems, and numerical data on error steps are shown in the statistics menu based on the dates.

Results

System Logs

In order to evaluate the effect of ArtiBos on students' problem-solving skills, 12 students selected from different levels of success were included in the system. The number of solved problems, the number of problems created, the time spent on the system, the rate of correctly solved problems, and the average time spent on solving the problems were examined. In addition, the mistakes made, and the time spent at each step during problem-solving were examined in detail. Problem-creating and solving activities were applied on six different dates and sessions. Moreover, students did problem-creating and solving activities individually during extracurricular times. ArtiBos system data are shown in Table 3. System data about problem-solving are shown in Table 4.

Table 3. ArtiBos system data

NO	1. Session (15.02.2019)			Extracurricular (2 Days)			2. Session (18.02.2019)			Extracurricular (2 Days)			3. Session (21.02.2019)			Extracurricular (3 Days)			4. Session (25.02.2019)			Extracurricular (3 Days)			5. Session (01.03.2019)			Extracurricular (3 Days)			6. Session (05.03.2019)		
	Number of Solved Problems	Number of Created Problems	Time to be online (min)	Number of Solved Problems	Number of Created Problems	Time to be online (min)	Number of Solved Problems	Number of Created Problems	Time to be online (min)	Number of Solved Problems	Number of Created Problems	Time to be online (min)	Number of Solved Problems	Number of Created Problems	Time to be online (min)	Number of Solved Problems	Number of Created Problems	Time to be online (min)	Number of Solved Problems	Number of Created Problems	Time to be online (min)	Number of Solved Problems	Number of Created Problems	Time to be online (min)	Number of Solved Problems	Number of Created Problems	Time to be online (min)	Number of Solved Problems	Number of Created Problems	Time to be online (min)	Number of Solved Problems	Number of Created Problems	Time to be online (min)
s1	4	7	90	0	0	0	5	8	87	0	0	0	5	10	101	0	6	57	8	9	105	1	7	65	9	12	110	3	6	71	10	11	105
s2	3	5	95	0	0	0	4	6	85	1	3	45	5	6	98	0	5	40	7	11	104	0	5	41	7	13	112	1	7	68	8	13	112
s3	3	6	87	0	0	0	6	6	84	0	0	0	6	8	97	1	7	75	6	10	105	1	6	68	7	10	100	1	6	63	10	15	105
s4	2	5	88	0	0	0	5	5	86	0	0	0	4	6	105	1	4	42	4	8	106	1	5	49	5	13	106	2	7	79	7	10	106
s5	3	5	85	0	0	0	4	7	86	0	0	13	6	6	110	2	5	49	5	9	109	1	10	77	6	10	107	2	6	58	7	9	111
s6	2	8	90	0	0	15	6	7	89	0	3	39	6	7	108	0	3	36	4	13	110	1	4	51	5	15	106	1	8	62	6	13	100
s7	3	5	94	0	0	0	5	7	88	0	0	16	5	6	99	2	2	51	6	11	99	1	5	53	6	14	104	1	11	76	7	12	99
s8	5	4	98	1	2	37	5	8	87	2	2	42	4	9	95	0	0	0	5	12	106	1	9	57	6	11	113	0	12	78	6	11	103
s9	3	3	96	0	0	0	4	9	87	0	0	0	3	12	106	1	0	18	4	11	104	0	5	44	5	12	112	1	4	49	7	11	108
s10	4	3	84	0	1	21	3	10	90	0	0	0	7	9	109	0	1	20	7	10	102	0	4	29	7	9	110	2	7	63	8	13	108
s11	4	6	93	1	1	35	5	9	81	2	3	54	6	11	110	1	3	41	5	12	109	0	8	62	5	14	105	1	5	58	6	16	114
s12	3	3	82	0	0	0	5	8	84	1	1	25	6	8	100	0	0	6	6	9	111	1	4	47	6	11	101	1	9	67	7	14	112
Avr			90			9			86			19			103			36			105			53			107			66			106
Sum	39	60		2	4		57	90		6	12		63	98		8	36		67	125		8	72		74	144		16	88		89	148	

The data in Table 3 are visualized in Figure 10 and Figure 11.

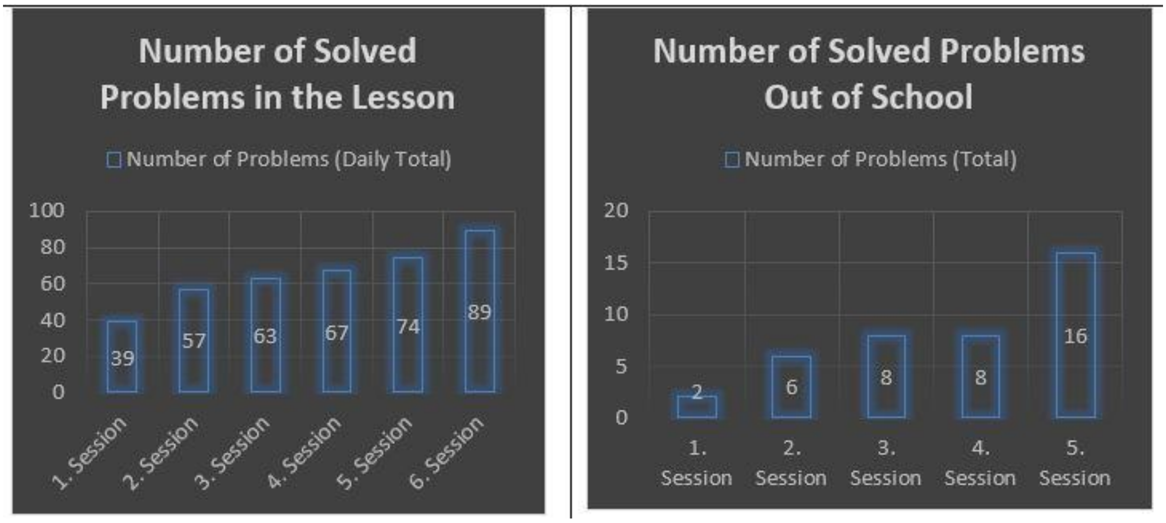

Figure 11. Total number of problems solved by students in lessons and out of school

According to Figure 11.a, the number of problems that students solve in two lesson hours in each session gradually increases. According to Figure 11.b, students solved problems five times outside the school. While the first two activities lasted two days, the remaining three activities lasted three days. Therefore, it is necessary to evaluate the problem-solving numbers in the Figure by dividing them by time. Considering Figure 11.b together with these data, we can say that the number of problems solved by the students increased in the second activity, decreased in the third activity, did not change in the fourth activity, and increased in the fifth activity.

Figure 12. Total number of problems created by students in lessons and out of school
According to Figure 12, it is seen that the number of problems created by students in class and out of class activities is increasing.

In addition to the system data, detailed system data related to the problem-solving process were also analyzed. Problem-solving system data is given in Table 4.

Table 4. Problem-solving process system data

NO	1. Session				2. Session				3. Session				4. Session				5. Session				6. Session			
	Number of Solved Problems	Average Solution Time of a Problem (sec)	Number of Problems Solved Correctly	Correct Solving Rate of Problems	Number of Solved Problems	Average Solution Time of a Problem (sec)	Number of Problems Solved Correctly	Correct Solving Rate of Problems	Number of Solved Problems	Average Solution Time of a Problem (sec)	Number of Problems Solved Correctly	Correct Solving Rate of Problems	Number of Solved Problems	Average Solution Time of a Problem (sec)	Number of Problems Solved Correctly	Correct Solving Rate of Problems	Number of Solved Problems	Average Solution Time of a Problem (sec)	Number of Problems Solved Correctly	Correct Solving Rate of Problems	Number of Solved Problems	Average Solution Time of a Problem (sec)	Number of Problems Solved Correctly	Correct Solving Rate of Problems
s1	4	343	1	25	5	242	3	60	5	180	4	80	8	165	7	87,5	9	138	7	77,78	10	115	9	90
s2	3	508	2	66,66	4	468	3	75	5	198	2	40	7	129	6	85,71	7	139	5	71,43	8	119	8	100
s3	3	746	0	0	6	366	3	50	6	240	2	33,33	6	186	5	83,33	7	172	5	71,43	10	145	7	70
s4	2	519	1	50	5	336	2	40	4	247	3	75	4	206	4	100	5	153	4	80	7	138	5	71,43
s5	3	654	1	33,33	4	334	2	50	6	231	5	83,33	5	149	5	100	6	155	5	83,33	7	140	5	71,43
s6	2	642	0	0	6	373	3	50	6	296	4	66,66	4	256	4	100	5	184	5	100	6	158	6	100
s7	3	625	1	33,33	5	273	2	40	5	324	3	60	6	166	5	83,33	6	140	5	83,33	7	125	6	85,71
s8	5	273	4	80	5	171	4	80	4	175	4	100	5	147	5	100	6	140	5	83,33	6	125	5	83,33
s9	3	633	1	33,33	4	288	1	25	3	171	2	66,66	4	176	3	75	5	176	3	60	7	144	5	71,43
s10	4	715	0	0	3	301	3	100	7	308	5	71,42	7	187	5	71,42	7	158	5	71,43	8	142	7	87,50
s11	4	488	2	50	5	258	2	40	6	284	5	83,33	5	180	5	100	5	161	4	80	6	151	5	83,33
s12	3	631	1	33,33	5	429	1	20	6	258	4	66,66	6	198	5	83,33	6	156	5	83,33	7	131	6	85,71
Avr		567		33,74		326		52,5		253		68,86		177		89,13		157		78,78		137		83,32
Sum	39		14		57		29		63		43		67		59		74		58		89		74	

Each of the problem-solving activities in Table 4 was carried out in 2 lesson hours. In the same lessons, students also carried out other activities in ArtiBos, such as problem-creating. According to Table 4, it is seen that while the rate of correctly solved problems gradually increases, and the amount of time spent for problem-solving decreases. This result shows that the students get used to the step-by-step solving method in the system over time, which reduces the rate of making mistakes and increases their speed. The change in problem-solving time and the rate of correctly solved problems are more clearly displayed in Figure 13 and Figure 14.

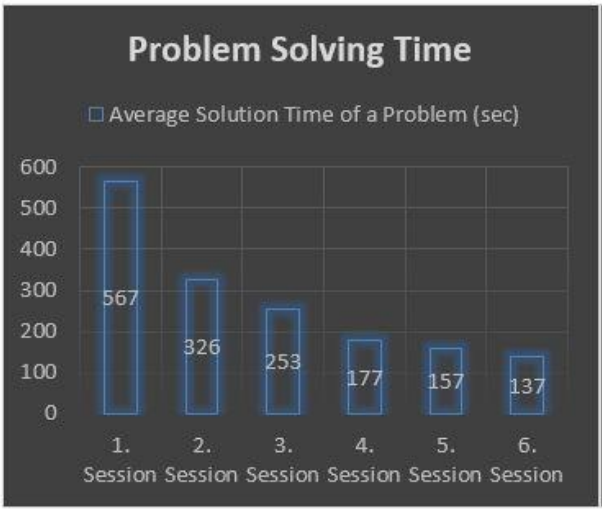

Figure 13. Problem-solving time

Figure 14. Correct solving rate of problems

According to Figure 13, it is stated that the time spent on problem-solving is gradually decreasing. On the other hand, in Figure 14, it is noteworthy that while the rate of correctly solved problems increased gradually, it decreased in the fifth session. In the fifth session, problems about profit and loss problems were carried out and it was observed that the students had difficulty in using the interface for this kind of problem.

Student Opinions about Improving Problem-Solving Skills of ArtiBos

In order to evaluate the contribution of the system to students' problem-solving skills, semi-structured interviews were applied to 12 students. In the interview, questions about the effects of the system on students' attitudes toward mathematics and their perspectives on mathematics problems were asked. The data from the interview were analyzed and some codes for problem-solving skills were created. And then, sub-themes were created by combining the codes. The themes created were combined under the main themes of *positive* and *negative attitudes*. The sub-themes of positive attitudes stated by the students regarding the problem-solving skills on the system are shown in Figure 15, and the sub-themes of the negative attitudes are shown in Figure 16.

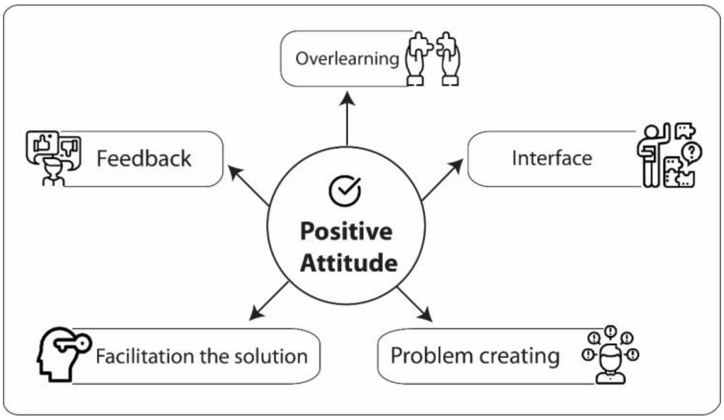

Figure 15. Student opinions on problem-solving skills - positive attitude theme

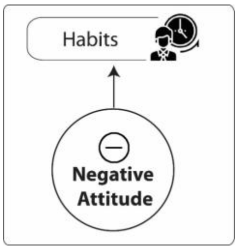

Figure 16. Student opinions on problem-solving skills - negative attitude theme

According to Figure 15, students' opinions on problem-solving skills were sub-themes of overlearning, interface, problem-creating, facilitating the solution, and feedback and the sub-themes formed the theme of positive attitudes. These sub-themes were formed by combining ten codes. On the other hand, in Figure 16, it is seen that there is a habit sub-theme under the negative attitude theme. This sub-theme was formed by combining two codes. In Table 5, the theme, sub-themes, and codes are indicated with their frequency and percentage distributions.

Table 5. Student opinions on problem-solving skills of ArtiBos

Themes	Sub-themes	Codes	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12	f	%
Positive Attitude	Overlearning	Sample questions					√				√				2	17
		Mini exams		√			√				√				3	25
	Interface	Animated display	√		√	√	√		√	√	√		√	√	9	75
		Colored interface		√		√	√			√		√		√	6	50
	Problem creating	Learning by creating		√					√	√					3	25
		Automatic question text		√	√		√	√		√		√	√		7	58
	Facilitation the solution	Step by step solving	√			√			√				√		4	33
		Given-asked table				√			√	√			√		4	33
	Feedback	Solution time	√		√			√				√			4	33

		Incorrect steps			√			√			2	17
Negative Attitude	Habits	Lack of pen and paper	√		√	√		√	√	√	6	50
		Digital calculator	√	√	√	√	√	√	√		7	58

The sub-themes and codes of the positive attitudes are in Figure 17; the sub-themes and codes of the negative attitudes are presented visually in Figure 18.

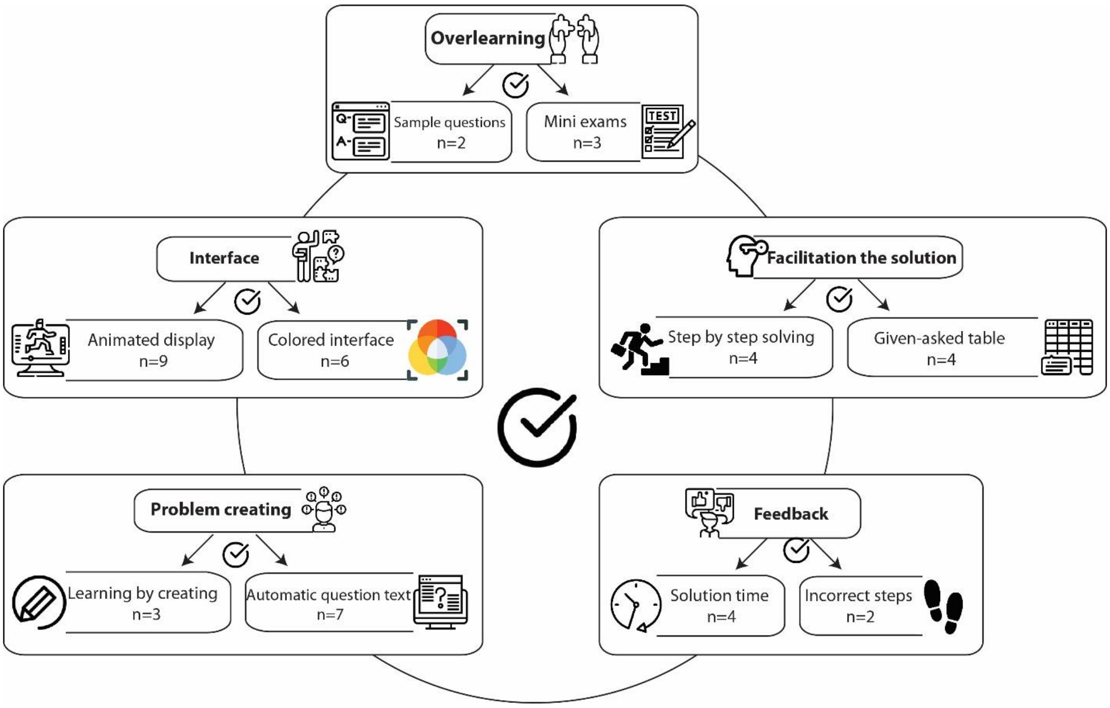

Figure 17. Student opinions on problem-solving skills – positive attitude sub-themes and codes

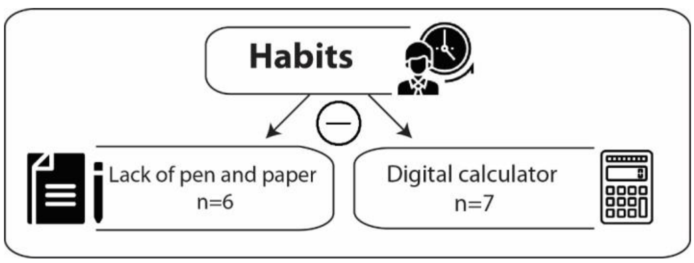

Figure 18. Student opinions on problem-solving skills – negative attitude sub-themes and codes

According to the positive attitude theme in Table 5, Figure 17 and Figure 18, the overlearning sub-theme consists of sample questions and mini-exams codes; the interface sub-theme consists of animated display and colored interface codes; the problem-creating sub-theme consists of learning by creating and automatic question text codes; the facilitating the solution sub-theme consists of step-by-step solving and given-asked table codes; the feedback sub-theme consists of solution time and incorrect steps codes. The sub-theme of habits in the negative attitudes consists of the lack of pen and paper, and digital calculator codes.

According to the frequency table, the highest rate in the positive attitude theme is the animated display code (75%). An example quotation of this code is as follows.

*"Cars, in sample problems, was like watching a video. I had so much fun. The *** website at our school has only text and no pictures. So, that site is so boring."* S5

According to the findings, the automatic question text code also has a high rate (58%). An example quotation of this code is as follows.

"I've never created a problem before. It's nice to enter numbers here and get automatic questions. I was able to choose the question I wanted and create a problem. We also learned what different questions could be asked." S8

Half of the students emphasized the colorful interface of the system. An example quotation of this code is as follows.

"…For example, I added the photo of my mother, father and brother for age problems. I wrote their name and I chose the background and colors. I created a colorful problem with my family." S4

These codes are followed by step-by-step solving, given-asked table and solution time codes (33%) with equal percentages. The quotations are as follows.

"…Yes, because it would be better to solve the problems step by step and avoid confusion." S11

"If I get confused while solving a problem, I stop solving it. Then, I start solving it from the beginning, but I spend a lot of time and I still can't solve it. It is really important to solve it at once without making mistakes. The table in ArtiBos is really good for solving this problem, teacher." S7

Mini-exams and learning by creating codes under the theme of positive attitudes were found out in the interview data of 25% of the students. The quotation from students are as follows.

"…Subject Lecture Module was short and fun. After each lecture, sample questions were also good. After the subject was studied, we took an exam and I got 100 points." S9

"It was good to create a problem, teacher. At first I felt like I was just playing games but then it helped me solve problems better." S2

Other codes under the theme of positive attitudes are sample questions and incorrect steps codes, which have the lowest rate (17%). An example is as follows.

"…It was very helpful to have sample questions at the end of each lecture…" S9

The digital calculator code (58%) has the highest rate under the negative attitude themes. This result shows that more than half of the students think the calculator negatively affects their problem-solving skills. Half of the students think that their problem-solving skills have decreased due to the lack of paper and pencil. These two codes show that problem-solving on a platform students are not used to can negatively affect their problem-solving-skills. The quotations from students about these codes are as follows.

"…The system is fun, but we'd better calculate it ourselves using pen and paper. I also couldn't use the calculator at first. It made me a little tired. Then, my score decreased because I made a mistake." S1

"…I think the calculation screen is not good, dear teacher. I can solve math problems more easily on paper. It would be nice if there was a touch paper next to the computer screen." S8

According to the students' opinions, it can be said that the problem-creating menu on the system has a positive effect on students' perspectives on mathematical problems. The students stated that they liked the system features for several reasons, such as the variety of items on the problem-creation menu and the availability of automatic question text. Moreover, the students evaluate the traditional educational system as inefficient since it lacks these features. In addition, the students stated that the step-by-step problem-solving method prevents confusion and the feedback in the system is important not to repeat the same mistakes. However, negative opinions about the insufficiency of the calculator for problem-solving and the lack of paper and pencil were also stated. This shows that it is difficult for students to change their problem-solving habits.

Teacher Opinions about Improving Problem-Solving Skills of ArtiBos

In order to evaluate the contribution of the system to problem-solving skills, semi-structured interviews were applied to six teachers. In the interview, questions about how the problem-solving steps in the system and the content of the problem could affect the problem-solving skills of the students were asked. The data from the interview were analyzed and some codes for problem-solving skills were generated. And then, sub-themes were created by combining the codes. The themes created were combined under the main theme of positive attitudes and negative attitudes. The sub-themes under positive attitudes stated by the teachers regarding the problem-solving skills of the system are shown in Figure 19, and the sub-themes under negative attitudes are shown in Figure 20.

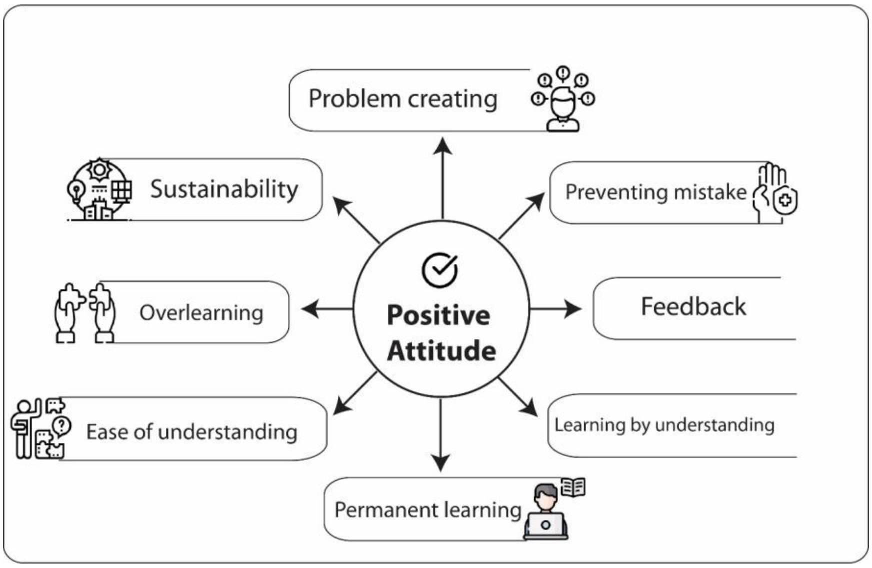

Figure 19. Teacher opinions on problem-solving skills - positive attitude theme

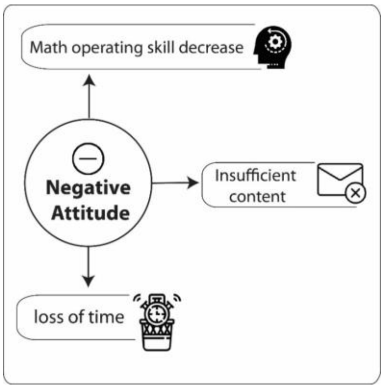

Figure 20. Teacher opinions on problem-solving skills - negative attitude theme

According to Figure 19, the opinions of teachers on problem-solving skills consist of sub-themes of problem-creating, preventing mistakes, feedback, learning by understanding, permanent learning, ease of understanding, overlearning and sustainability, and these sub-themes formed the theme of positive attitudes. These sub-themes were formed by combining 18 codes. On the other hand, in Figure 20, it is seen that math operating skill decrease, insufficient content and loss of time sub-themes form negative attitudes. These sub-themes were formed by combining three codes. In Table 6, the theme, sub-themes, and codes are indicated with their frequency and percentage distributions.

Table 6. Teacher opinions on problem-solving skills of ArtiBos

Themes	Sub-themes	Codes	t1	t2	t3	t4	t5	t6	f	%
Positive Attitude	Problem creating	Learning by creating	√	√	√		√	√	5	83
	Preventing mistake	Step by step solving	√	√	√	√	√	√	6	100
		Given-asked table		√			√	√	3	50
	Feedback	Solution time	√		√	√	√	√	5	83
		Incorrect steps	√		√	√	√	√	5	83
	Learning by understanding	Step by step solving	√	√	√	√	√	√	6	100
		Given-asked table		√			√	√	3	50
	Permanent learning	Animated display	√	√		√	√		4	67
		Colored interface	√	√		√	√		4	67
		Concrete objects	√	√		√	√		4	67
		Step by step solving	√	√	√	√	√	√	6	100
		Given-asked table		√			√	√	3	50
	Ease of understanding	Animated display	√	√		√	√		4	67
	Overlearning	Possible question types	√	√			√	√	4	67
		Sample questions				√			1	17

		Mini exams			√				1	17
	Sustainability	Transfer to paper	√				√		2	33
Negative Attitude	Math operating skill decrease	Digital calculator	√	√		√		√	4	67
	Insufficient content	Lack of advanced question			√		√		2	33
	loss of time	Adaptation period			√				1	17

The sub-themes and codes of the positive attitudes theme are in Figure 21; the sub-themes and codes of the negative attitudes theme are presented visually in Figure 22**.**

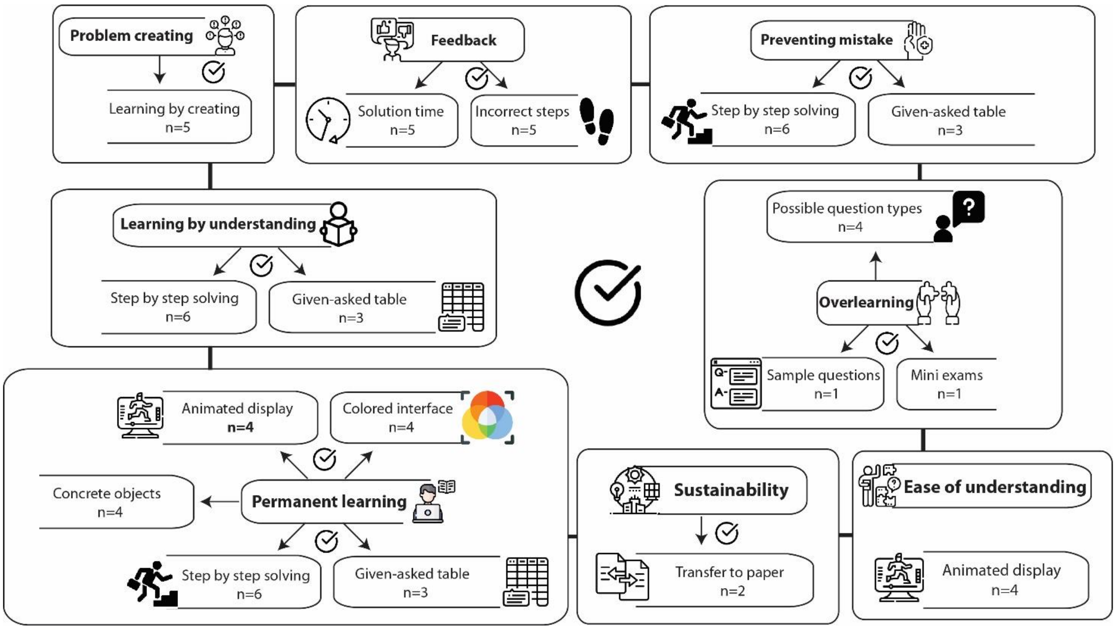

Figure 21. Teacher opinions on problem-solving skills – positive attitude sub-themes and codes

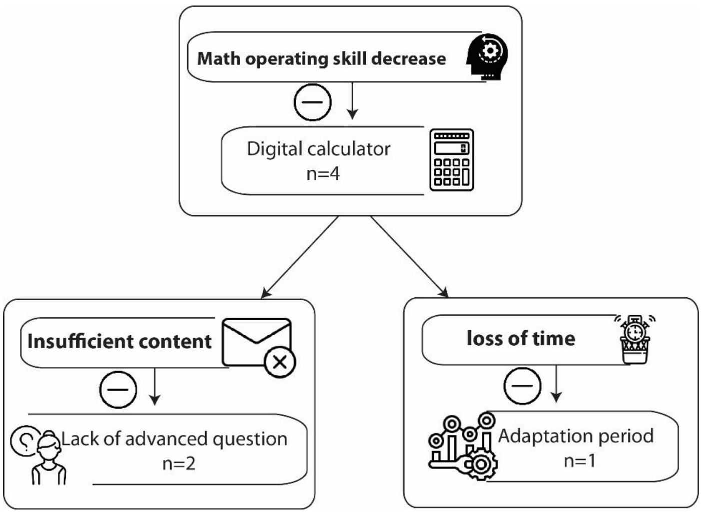

Figure 22. Teacher opinions on problem-solving skills – negative attitude sub-themes and codes

According to the positive attitude theme in Table 6, Figure 21 and Figure 22, the problem-creating sub-theme consists of learning by creating code; the preventing mistake sub-theme consists of step by step solving and given-asked table codes; the feedback sub-theme consists of solution time and incorrect steps codes; the learning by understanding sub-theme consists of step-by-step solving and given-asked table codes; the permanent learning sub-theme consists of animated display, colored interface, concrete objects, step by step solving and given-asked table codes; the ease of understanding sub-theme consists of animated display code; the overlearning sub-theme consists of possible question types, sample questions and mini exams code; the sustainability sub-theme consists of transfer to paper code. According to the negative attitude theme, the Math operating skill decrease sub-theme consists of digital calculator code, the insufficient content sub-theme consists of lack of advanced questions code, and the loss of time sub-theme consists of adaptation period code.
According to the frequency table, the highest rate is the step-by-step solving code (100%). In addition, it is noteworthy that this code is included in the sub-themes of preventing mistakes, learning by understanding, and permanent learning. This result shows that all of the teachers argue that the step-by-step solving method in the system will contribute to problem-solving skills. An example quotation of this code is as follows.

"It is very useful to solving step-by-step and checking the solution, to see the errors." T2

As one of the important results of the study, the majority of the teachers (83%) argue that the students' problem-solving skills will improve with the problem-creating activities. Some of the teacher statements are shown as the following:

"Problem-creating is more useful than problem-solving though it is very difficult. However, creating problems in the system is easy and fun." T3

Solution time and incorrect steps codes under the theme of positive attitude were also included in the interview data of the majority of teachers (83%). According to this result, the teachers argue that the solution times, incorrect steps, and the feedback feature in the system will contribute to students' problem-solving skills. An example quotation of this code is as follows.

"It is very good to be able to control the solution. The teacher may not be able to do this in the classroom for every student because time is limited. Feedback to more students means more student improvement." T1

Animated display, colorful interface and concrete object codes were found in the interview data from most of the teachers (67%). Animated display code is included under the sub-theme of both permanent learning and ease of understanding; colored interface and concrete object codes are included under the permanent learning sub-theme. The teachers argued that the objects and interface design in the system will also provide permanent learning and contribute to problem-solving skills in this direction. An example quotation of this code is as follows.

"The use of animated materials in the problem-solving process can attract the attention of the students and improve their problem-solving skills." T2

The code of being able to see the question types was stated by most of the teachers (67%). An example quotation of this code is as follows.

"Developing problem-solving skills requires lots of practice. It's nice to have lots of questions here. More questions may be added." T6

It is noteworthy that given-asked table code is included in the sub-themes of preventing mistakes, learning by understanding and permanent learning. An example is as follows.

"…It is effective to write down the given values before solving the problem. This way also prevents forgetting and helps with complex questions." T2

Transfer to paper (33%) code is another code in the sustainability sub-theme obtained from teacher data. The teachers argued that if the students can transfer using the problem-solving steps acquired on the system into paper in real-life classroom settings, this habit will contribute to the problem-solving process. An example quotation of this code is as follows.

"If students learn the step-by-step solving process in the system well, they can solve problems with paper and pencil in the same way. They need to get used to it." T1

Sample questions and mini-test codes (17%) in the theme of positive attitudes have the lowest rate. An example quotation of this code is as follows.

"I teach on the blackboard, give exam papers and solve questions. However, using such a system and using technology is very important. I can solve a question faster." T4

The digital calculator code in the negative attitude theme has the highest percentage (67%). Teachers argue that the calculator in the system may blunt students' computing skills, which may negatively affect their problem-solving skills. An example quotation of this code is as follows.

"We always tell our students to solve problems step-by-step. After the numbers are written in your system, the calculation is done automatically. This limits the student's processing skills." T4

Other codes in the theme of negative attitude are lack of advanced questions (33%) and adaptation period (17%).

As a result, all teachers argue that the step-by-step solving feature of the system will improve students' problem-solving skills. The vast majority of teachers (83%) argue that problem-creating activities and seeing incorrect steps will contribute to problem-solving skills. In addition, half of the teachers think that the given-asked table (given asked anlaşılır degil) in the system will contribute to the problem-solving process. On the other hand, most teachers (67%) think that the digital calculators in the system will negatively affect the problem-solving process.

Discussion and Conclusion

This study examined the effects of ArtiBos, designed as a gamified adaptive intelligent tutoring system, on students' problem-solving skills. For this purpose, quantitative data from ArtiBos and qualitative data from student and teacher interviews were evaluated.

Students can do both problem-creating and problem-solving activities by ArtiBos. They can select the desired object, background, and add them to their scene by the drag-and-drop method. In addition, all activities are recorded, and the students are given frequent feedback.

The number of problems created by students using ArtiBos in both in-class and extracurricular activities has gradually increased. In addition, both student and teacher interview results showed that problem-creating activities would contribute to learning. Most of the students liked the automatic question text while creating problems. On the other hand, teachers argue that the learning process by creating problems will improve problem-solving skills. It has been proven that problem-creating positively affects critical and analytical thinking with a student-centered approach, which contributes to the problem-solving process (Arikan & Unal, 2015; Celik & Arslan, 2022; Taufik et al., 2019). In addition, according to studies, problem-creating activities in mathematics education contribute to problem-solving skills (Brown & Walter, 2005; English, 1997; Halmos, 1980, p. 524; Silver, 1994) and support students' complex problem-solving skills by helping them understand deeply (Cai, Hwang, Jiang, & Silber, 2015; Singer & Voica, 2015). Problem-solving in ArtiBos is designed according to Polya's problem-solving steps. First, the students complete *understanding the problem* step by writing the values given in the problem content into the table. Students who successfully pass this step move on to *Selecting the Strategy for the Solution* and *Implementing the Strategy*. In the *evaluation of the solution* step, the students can evaluate the solution processes with four different options. According to the system data from ArtiBos, the rate of correctly solved questions increases over time, while the solving time decreases. This result shows that the students get used to the step-by-step solving process in the system over time, and thus the rate of making mistakes decreases and the students increase their problem-solving speed. This shows that the system's problem-solving structure contributes to the students' problem-solving skills. Studies have shown that ITS and AITS improve critical thinking (Squire & Barab, 2004; Bourke, 2019), provide a better understanding of the content (Boyle et al., 2016; Tsay, Kofinasb, & Luo, 2018; Yeh, Chang, & Chen, 2019), helping them to use their control, planning and remembering skills more effectively (Boot et al., 2008) and improving their problem-solving skills (Aleven et al., 2019; Annetta, 2008; Liu, Cheng, & Huang, 2011; Wilson et al., 2009).

Problem-solving steps facilitate problem-solving (Altun & Arslan, 2006). In the literature, it is argued that the problem-solving process should be divided into steps (Baki, 2006; Dewey, 1933; Garofalo & Lester, 1985; Heller, Keith, & Anderson, 1992; Mayer, 1985; Simamora, Sidabutar, & Surya, 2017). In addition, many studies show that problem-solving activities applied according to Polya's problem-solving steps have positive effects on students' problem-solving skills (Erümit, 2014; Lee, 2016; Gopinath & Lertlit, 2017; Karataş & Baki, 2017; Maharani et al., 2019; Maulyda et al., 2019; Tohir, 2018; Pradika, Amin, & Khabibah, 2020). In the problem-solving process, there are skills of understanding the given problem, establishing a relationship between the data in the problem content, analysis and synthesis (Hämäläinen et al., 2019; Shute et al., 2016; Wechsler et al., 2018). Studies show that students have difficulties using these skills in the problem-solving process (García et al., 2019; Phonapichat et al., 2014; Tambychika & Meerah, 2010). People with good problem-solving skills can manage this process more effectively and efficiently (Shute et al., 2016; Wechsler et al., 2018).

According to the interview findings, all of the students found the problem-creating and solving activities in the system better than the traditional education environment and stated that features such as step-by-step solving and giving feedback contributed positively to the problem-solving process. Teachers emphasized that students will be able to think concretely and understand the questions better through the system's visual richness. In addition, teachers thought that step-by-step problem-solving process would reduce mistakes, and feedback is important for students to see where they make mistakes. As a result, both teachers and students think that the system will make a positive contribution. In similar studies conducted with AITS, there are findings showing that students' problem-solving skills increase. (Aleven et al., 2019; Eseryel et al., 2014; Hwang et al., 2012; Jeremic et al., 2012; Liu, Cheng, & Huang, 2011; Wilson et al., 2009).

Step-by-step problem-solving makes it easier for students to follow their actions throughout the solving process and to see their mistakes. For example, when the first step of Polya's steps, understanding the problem, cannot be completed effectively, the student may feel that the problem-solving process will be difficult (Tias & Wutsqa, 2015). Interview data show that students understand the problems more quickly, thanks to the system's colorful interface and animated display. Vilenius-Tuahimaa, Aunola, and Nurmi (2008) state that there is a proportional relationship between the level of understanding of the problem in the solution process of mathematical problems and the success of problem-solving. Ersoy and Güner (2014) emphasized the importance of choosing an appropriate problem-solving strategy. In ArtiBos, the rate of correctly solved problems gradually increases and the solving time decreases. This result shows that the students get used to the step-by-step solving method in the system over time, which reduces the rate of making mistakes, and they increase their problem-solving speed. In addition, the rate of applying the right strategy has also increased. Experiencing problems in the step of applying the strategy, which is the third step of Polya's steps, shows that the student has difficulty in applying mathematical operations, concepts and procedures to solve problems (Sari & Wijaya, 2017). These results show that the step-by-step problem-solving method contributes to students' problem-solving skills.

Recommendations

This study examines the effect of ArtiBos, designed as an adaptive intelligent tutoring system, on students' problem-solving skills. Some suggestions were offered for the research by considering the study's design, implementation, and evaluation processes.

- Data diversity can be made by expanding the sample and accessing students in different profiles.
- Studies can be carried out to apply the problem-solving steps taught in the system to any problem in daily life.
- Research can be carried out on how students with different mathematics achievements may benefit from the system differently.
- In the system's problem-solving steps, it can be examined whether student performances change according to the types of problems.
- The development of students' problem-solving skills can be examined according to variables such as the ways of solving problems and the quality of the problems they have created.

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