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An examplary application of mathematics teaching based on formative assessment

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Abstract: Mathematics, by nature, has a spiral structure. The fact that the students fail to acquire an achievement in the mathematics course negatively affects other achievements. Therefore, students' mathematics failure continues exponentially. In this context, it is important to identify and eliminate students' weaknesses, if any, with the formative assessments in the learning process. The present study aimed to improve the success level of the students with the formative assessment-based teaching practice about circle and circular region in secondary school seventh-grade mathematics teaching and implement an exemplary application for formative assessment-based teaching.
Since the study sought to evaluate the learning process of the students and eliminate the weaknesses identified in the process, an action research design, one of the methods of qualitative research, was used. The study was carried out with 34 seventh-grade secondary school students. Data were collected and analyzed descriptively through observation, interview and various formative assessment tools used in the process. At the end of the three-week implementation period, substantial improvement was observed in the achievements of low and medium-achieving students, and the overall success of the students changed positively at the end of the process.

1. INTRODUCTION

The individuals who can manage and understand mathematics have the opportunity to use this knowledge in their business and daily lives in the future (Amankonah, 2013). Due to the unique spiral structure of mathematics, success in one achievement contributes positively to the achievement of the other achievement as well. Thus, it is inevitable that success brings success.

The idea of improving the mathematics achievement of students is even more important within the scope of the mathematics mobilization that has recently been initiated by the Ministry of National Education. Evaluation is the most important element in identifying the knowledge and skills of students that are effective in achieving these achievements. Even though evaluation has been perceived as an action taken at the end of the learning process for years, it has been realized that evaluation should be done throughout the learning process, and it has begun to be regarded as the most important element of learning. Even if all students are at the same level at the beginning of their education, students will be at different levels of cognition due to

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individual differences in the process, so evaluation turns out to be the most important element in effective teaching (Kültür, 2021).

Considering the necessity of process evaluation as well as result evaluation in the Turkish education system, the use of tools and methods called "alternative" and then "complementary" has been included in addition to traditional measurement and evaluation (MEB, 2020). In many studies conducted in our country on how competently the teachers use the alternative assessment tools, it is clear that there were many negative reasons such as the lack of financial means of schools and students, the attitude of parents, and the exam-oriented curriculum. It is obvious that since the curriculum was exam-oriented, written and oral exams were emphasized in terms of compliance with the system, which are the traditional assessments (Kâhtalı & Çelik, 2020) and that since central exams were result-oriented assessment, teachers had difficulty in applying the alternative assessment and evaluation approaches (Arseven, 2013; Karakuş & Yeşilpınar, 2013). Even though they were known by the teachers, they were not used. Therefore, it was emphasized in those studies that what formative assessment practices were like and how these activities could be applied should be demonstrated to the teachers through professional development studies (Arseven, 2013; Karakuş & Yeşilpınar; 2013; Önel et al., 2020).

Evaluation standards for school mathematics were introduced emphasizing that the assessment published in international standards was important not only what students knew or did not know, but also how they reasoned and what thought processes they adopted (Van de Walle, Karp & Williams, 2019, p.77). Four specific objectives were set, aimed at monitoring student progress, making decisions for instruction, assessing student achievement, and evaluating programs according to certain assessment standards. As far as the evaluations established for these purposes are concerned in line with their purpose, they are divided into three; diagnostic and placement purposes, summative purposes and formative purposes (MEB, 2020, p.5). Formative assessment, which is the subject of this study, is defined as the assessment carried out at every stage of the teaching process in order to support teaching, from seating arrangement to group work, supplementary worksheets, and activities throughout the teaching process (MEB, 2020).

There are two actions on the basis of the evaluation made for formative purposes; the first is the learner's understanding of the gap between the desired goal and his/her own purpose, and the second is the learner's action to close this gap in order to reach the desired goal (Black & Wiliam, 1998). Successful learning occurs when these two actions, which are the basis of formative assessment, are implemented. In many European countries, formative assessment is seen as an important strategy to acquire quality in education and guidebooks have been developed in order to guide teachers (Ozan, 2017).

In our country, Turkey, the "Mathematics Teacher Guide Booklet" prepared by UNICEF and the General Directorate of Assessment, Evaluation and Examination Services in 2020 focuses on formative assessment activities and serves as a guide for teachers in terms of application situations. Based on this guideline, the importance of demonstrating and disseminating the applicability of formative assessment has emerged in order to improve success in mathematics teaching.

In many international studies, it was reported that the formative assessment practices shaped the teaching practices by increasing student performance, that positive reflections were observed on students when teachers designed formative assessment practices effectively, that they were used to identify the gaps in learning, that the interactive formative assessments and feedback mechanisms contributed positively to students' understanding of the lesson, completing tasks, communication, interest in mathematics and social relations, and that the formative assessment approach increased students' success and metacognitive awareness

compared to the traditional approach (Agwagah & Ezieke, 2023; Fatima, 2022; Hiloma & Briones, 2022; Martin et al., 2022; Miller, 2019; Wafubwa & Csikos, 2022).

In the national sense, even though there are a small number of studies on formative assessment practices, some studies on pre-service teachers and other disciplines have been encountered. Nevertheless, no other study was available, apart from Tekin's (2010) study, which was conducted for secondary school students on formative assessment-based teaching in mathematics teaching. This shows the deficiency in the number of studies in the relevant literature.

On the other hand, when we look at the national and international exams, it is clear that the course students are the most unsuccessful is mathematics. According to the High School Entrance Examination (LGS) 2022 report, mathematics was the lowest course with an average of 4.74 in the mathematics subtest compared to other courses (MEB, 2022a) and similarly, according to the 2018 PISA report, Turkey was in the 42nd place among 79 countries in the ranking (MEB, 2022b), despite an increase in mathematics achievement compared to previous years, and this explains that scientific studies should be carried out in order to improve the success of mathematics on a national and international scale.

In the mathematics course curriculum, teaching circle and circular region is included at all grade levels, starting with recognizing the circle in the 1st grade and ending with the achievements of the circle and circular region sub-learning area in the 7th grade (MEB, 2018). Although the acquisitions of calculating the circumference of the circle and circular region are an important part of the curriculum, many students do not have sufficient level of the concepts of perimeter and area measurement (Aksu, 2019; Görgüt, 2020). It is thought that the lack of conceptual learning about circles and circular regions may affect the geometric knowledge acquired later, and it is predicted that this problem, which will be experienced especially at the secondary school level, will be difficult to correct in the following years (Aksu, 2019). In his study on secondary school students' misconceptions, Kara (2021) stated that some students confused the definitions of circle and circular region and used them interchangeably, had misconceptions about the relationship between diameter and radius, and some students had misconceptions about determining the location of the center of the circle. In the study conducted by Evirgen and İkikardeş (2019), in which seventh-grade students received student opinions about the subjects they had difficulty with, it was observed that the students had difficulty with the circle and angles in the circle. Since the mathematics course has a spiral structure, students' learning deficiencies are negatively reflected in another subject. Therefore, studies should be carried out to ensure that students' learning is permanent. It is predicted that with formative assessment-based teaching, students will learn the concepts of circle and circular region more effectively and permanently.

Considering this low accomplishment in mathematics lessons and the mathematics mobilization started in our country, it is undeniable that different methods should be used to improve success in mathematics teaching. The general aim of this study is to improve students' mathematics achievement through assessment tools carried out in the context of formative assessment. Therefore, an exemplary application for teaching of the subjects of circle and circular region based on formative assessment was implemented in this study.

2. METHOD

In the study, action research was utilized as a qualitative research design. Action research is an approach that aims to analyze the systematic data collection in an attempt to raise questions about the implementation process or to understand and solve a problem that has already emerged, carried out by a practitioner working in a school, such as a manager, teacher, education specialist, directly or with a researcher (Yıldırım & Şimşek, 2021, p.319). In this

study, action research was used as a method for the solution of mathematics failure in students by investigating the improvement of students' mathematics achievement with formative assessment-based teaching practice. In formative assessment-based teaching, the gap between the feedback received from the students and the teaching objectives and the knowledge acquired by the student is determined, new plans are made and developed on how to eliminate this gap, and the use of action research pattern in research to find solutions to the problems is in line with the nature of formative assessment in this context.

Since the researcher was also the mathematics teacher of the class in which he conducted the research, he took on the role of teacher researcher in this process. The researcher implemented the entire process himself. All progress was made by reaching consensus with the evaluation team before and during the implementation. At the same time, the field expert in the evaluation team is the researcher's thesis advisor. Process management was ensured by constantly obtaining expert opinion, taking into account scientific ethical principles. The formative evaluation tools used were revised in line with the opinions of the evaluation team. Each lesson was video recorded by the researcher. In addition, audio recordings were made of one-on-one interviews with students. The researcher personally conducted interviews and observations throughout the entire process. Observations during each lesson day and what was done in the lesson were noted by the researcher in the researcher diary. The data obtained throughout the research process was analyzed and interpreted by the researcher, progressed in line with the opinions of the field expert and evaluation team, and was reported by the researcher.

2.1. Study Group

Appropriate sample was used in the study. Appropriate sampling is defined as the collection of data from a sample that the researcher can easily access (Büyüköztürk et al., 2020, p.95). Therefore, the study was implemented with 36 seventh grade secondary school students at a state secondary school where the researcher taught. Two students who could not fully participate in the three-week application process due to health problems were excluded from the study. The remaining 34 students, 17 female and 17 male students participated fully in the implementation process. Analyzes of these 34 students were implemented.

It was identified from the readiness worksheets that all the students did not study and did not know the sixth-grade achievements about circle and circular region; therefore, the action plans were made based on this deficiency. When the students' mathematics achievement levels are examined, it is understood that their learning losses were high because they received distance education due to the pandemic the previous year. According to one-on-one interviews with students and school administration records, it was determined that only six to seven of the students regularly attended online classes. It was observed that the students with low success in mathematics courses also had low levels of readiness for the subject of circles and circular region, and when describing the students in the study. In this case, students whose mathematics grade point averages at the end of the first semester of the 2021-2022 academic year are between 0 and 54 are determined as low achievers, students with scores between 55 and 84 are determined as medium achievers, and students with scores between 85 and 100 are determined as high achievers (Table 1).

Table 1. *Mathematics achievement status of the students.*

Mathematics Achievement Status	Students
Low-achieving	S2, S3, S4, S5, S8, S9, S10, S13, S15, S16, S17, S20, S21, S24, S25, S26, S27, S28, S29, S30, S31, S33, S34
Medium-achieving	S1, S6, S7, S11, S12, S14, S18, S19, S32
High-achieving	S22, S23

As stated in Table 1, all students were coded as S1, S2, S3 …S34 based on the class attendance list, and the researcher was represented by using the letter A and the findings were reflected using these representations.

2.2. Data Collection Tool

In this study, in the three-week mathematics teaching implemented by using formative assessment tools, the success of the students regarding the subject of the circle and the circular region was aimed, and eventually, their success was attempted to be improved and their deficiencies, if any, were identified in the process. Therefore, observation and interview techniques were used throughout the process. Furthermore, formative assessment tools were used as data collection tools throughout the study process. Formative assessment tools (worksheet, rubric, performance-based assessment, checklist, quick techniques that can be used for formative assessment, observation form, self, peer and group assessment, concept maps, product file, dynamic software, digital media) were used by specifying the appropriate ones.

2.3. Data Analysis

The data obtained qualitatively were analyzed descriptively. With the formative assessment tools used in this study, the themes that contributed to the success of the students regarding the subject of circle and circular region were established. "Recognizing the center, radius and diameter by drawing a circle, Discovering that the ratio of the length of a circle to its diameter is a constant value, Calculating the length of a circle given its diameter or radius, Determining the relationship between the central angle, the arcs it sees and angle measurements" in the sixth and seventh-grade circle and circle teaching, The achievements of "Calculating the length of the circle and circle segment, Calculating the area of the circle and circle segment" were determined as the theme. The data obtained from the observations and interviews were coded, classified and presented under the relevant themes. Moreover, in line with the data obtained from the interviews, the mutual dialogues between the researcher and the students were represented with direct quotations.

2.4. Validity-Reliability

In terms of internal validity, the researcher is expected to be consistent both in the data collection processes and, in the analysis, as well as the interpretation of the data, and explain how this consistency has been achieved. While the researcher constantly questions herself and her research processes with a critical eye and checks whether the findings and results, he/she has obtained reflect the truth, making clear and understandable explanations to satisfy the reader provides internal validity (Yıldırım & Şimşek, 2021). In order to ensure the internal validity, various formative assessment tools were used in this study and the data collected from the students in the use of these tools were explicated in a clear manner.

Yıldırım and Şimşek (2021) reported that if the results of a study could be generalized to similar environments and situations, the research had external validity. Therefore, the fact that the study was conducted in a state secondary school, in which students with low, medium or high achievement in mathematics, was in a natural classroom environment for the whole class without making student selection demonstrated that the study had external validity. Even though the results obtained from the study cannot be generalized to all secondary school students, the experiences and observations obtained during the research process offer an exemplary application to formative assessment-based mathematics teaching.

In order to ensure internal reliability in the study, firstly, one-to-one interviews with the students, the researcher's observations, the data obtained from the formative assessment tools used were directly analyzed and presented descriptively. Furthermore, before the research process started, an evaluation team consisting of two mathematics teachers teaching at the

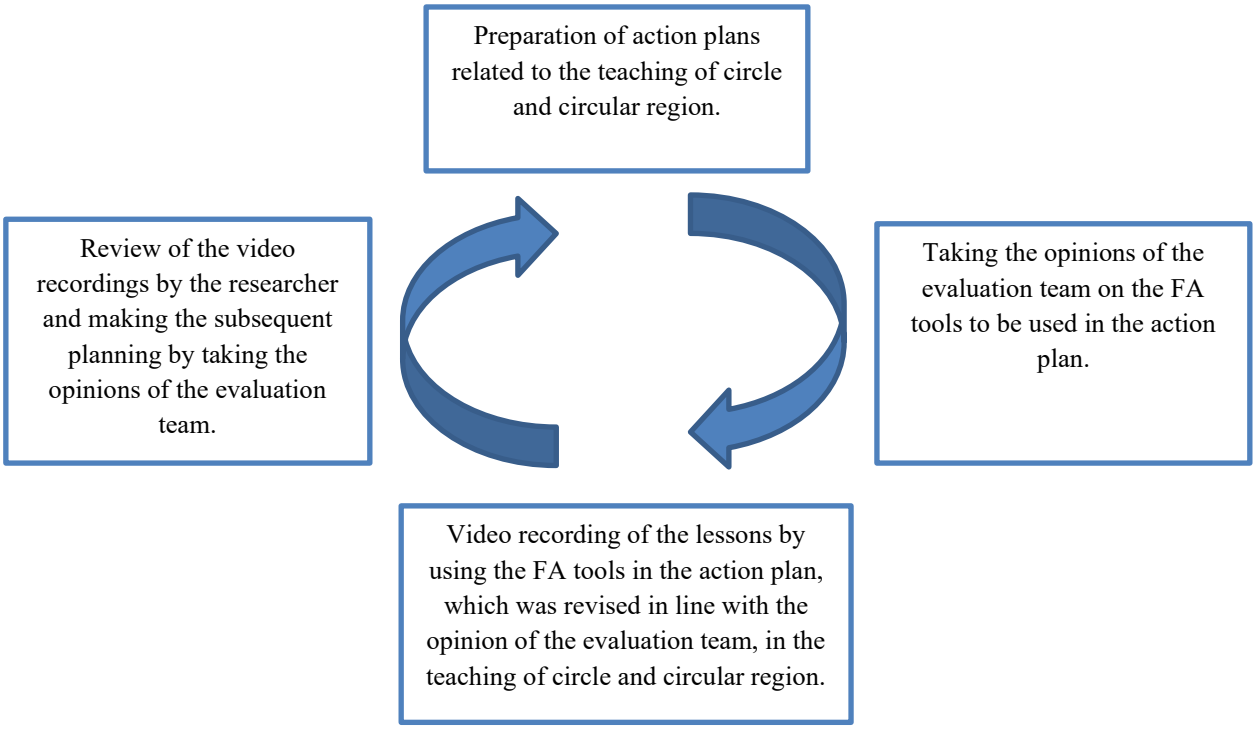
researcher's own school, a mathematics teacher teaching in a different state secondary school in the same province, and a field expert was formed. During the preparation of each action plan, the views of the evaluation team were obtained, and the necessary arrangements were made, and the plans were implemented. Moreover, the whole process was video-recorded, and revisions were made in line with the views of the field experts. Additionally, the data analyzes were compared with the field experts by making the analyzes. Thus, the obtained results were confirmed.

By reporting the stages, she followed in the study in detail and clearly, the researcher have shown that the results depend on the data she has collected and that her own assumptions or prejudices have not affected by the results (Yıldırım & Şimşek, 2021). In this study, in order to ensure external reliability, subjective judgments were avoided, and the contents obtained from the documents obtained from the students, the images obtained from the in-class video recordings, and the one-to-one interviews with the students were all presented as they were. What were done in data collection, processing, analysis, interpretation and reaching the results were all clearly explicated. The raw data of the study were saved to be examined by others and the whole application process was video recorded.

2.5. Action Research Process

The action research process consists of five basic steps: identifying the problem situation, planning data collection, collecting and analyzing data, preparing action plans in line with the findings, sharing and reporting the action plan and results by examining the relevant literature (Johnson, 2019). The action plans made during the study process were examined by an evaluation team of four people, including an expert in the field, two mathematics teachers teaching in the researcher's own school, and a mathematics teacher teaching in a different public secondary school in the same province. The nature of formative assessment (FA) is that it is a cyclical plan that is tailored to the student and is constantly revised according to the level of the student in the classroom. In this sense, it shows parallelism with action research. Therefore, action plans were constantly revised in line with the suggestions of the evaluation team according to the classroom climate, and action research process steps were implemented (Figure 1).

Figure 1. *Action research process.*



The action plans applied while following the action research process are as follows:

1. As an action plan, it was planned to apply a readiness test in order to measure the existing knowledge of the students about the subject of circle and the circular region. Students were given worksheets consisting of four questions and were asked to complete them according to the necessary instructions. In the first question; they were asked to draw a circle in the given unit on squared paper using compasses and ruler and show its radius and diameter on the figure. In the second question; they were asked to find the circumference lengths of circles given radius lengths and pi values, using relations. In the third question; they were asked to explain the difference between a circle and a circle. In the fourth question; they were asked to write the measures of a right angle (90^0), supplementary angle (180^0), and full angle (360^0). Student worksheets were evaluated and presented in Table 3. As a result of this test, it was obvious that the students were not at a sufficient level regarding the subject of circle and the circular region, more than half of the class could not attend the classes due to the pandemic, and they could not acquire the sixth-grade achievements.

2. As an action plan, after it was established that the students could not acquire the achievements of the sixth grade, one week (5 lesson hours) of the present study was allocated to the achievements of the sixth grade, with the suggestion of the teachers of the group and the expert opinion. Prepared lesson plans were reviewed by the evaluation team and required arrangements were made. In the first week, students were offered the learning achievements of recognizing the center, radius, and diameter of a circle by drawing a circle, discovering that the ratio of a circle's length to its diameter was a constant value, and calculating the length of a circle given its diameter or radius. Various formative assessment tools were used while offering these gains (See Table 2). Students were constantly evaluated with these tools and their weaknesses were observed and action plans were implemented for the achievements to be offered.

3. As an action plan, it was decided to move on to the seventh-grade achievements, as it was observed that the students acquired the achievements offered in the previous week with the formative assessment tools applied. With the views of the evaluation team, lesson plans were prepared to identify the relationship between the central angle, its arcs and angle measures, and calculate the length of the circle and the circle segment. The action plans were revised by continuously evaluating the students with formative assessment tools.

4. As an action plan, it was observed that the students achieved the previously given objectives, and a lesson plan was prepared together with the views of the evaluation team for the achievement of calculating the area of the circle and circle slice, one of the seventh-grade achievements. This was the last week, and the plans were revised by constantly evaluating the students using the necessary formative assessment tools.

Table 2. *FA tools used based on the learning outcomes during the implementation process.*

Implementation Process	Learning outcomes	FA tools used
1st week	• Recognizes its center, radius and diameter by drawing a circle. • Recognizes that the ratio of a circle's length to its diameter is a constant value by measuring it. • Solves problems that require calculating the length of a circle given the diameter or radius.	- Readiness worksheet - Worksheets - Group work and group work checklist -Activities: (Discovery of Pi-Poster making-Geometry board) and activity (Ferris wheel) - Homeworks - Quick evaluation (Plickers) - Performance based evaluation (Wordwall, EBA) - Information card - Quick techniques (Thumbs down-thumbs up, Red-green card) - Peer evaluation - E – portfolio
2nd Week	• Recognizes the relationships between the central angles, the arcs it faces and the angle measures in the circle. • Calculates the length of the circle and the circle segment.	- Self assessment - Team work - Homework (worksheet, textbook) - Quick evaluation (Plickers) - Quick techniques (Thumbs up-thumbs up, Red-green card, Question box) - Performance-based assessments and assignments (EBA, Wordwall) - Peer evaluation - Activity (Central angle and arc measure, Skill-based question study) - Separate homework assignments for certain people who are weak - E - portfolio
3rd week	• Calculates the area of the circle and circle segment.	- Performance-based assessments and assignments (Wordwall, EBA) - Activity (EBA, Skill-based question study-pizza slices) - Worksheets - Homework (Textbook, worksheet) - E – portfolio - Problem solving analytical rubric - Team work - Output card - Quick techniques (Thumbs up-thumbs up, Red-green card, Question box)

* FA: Formative assessment

In line with the prepared action plans, the study was conducted with a three-week implementation period, and the data obtained are presented in the findings section.

3. RESULTS

While the results regarding the improvement in the achievements of the students were presented, the readiness of the students was identified initially and the insufficiencies in the achievements of the sixth grade in the teaching of the subjects of circle and circular region were revealed. Therefore, the results of the circle and circular region teaching based on the formative assessment applied for the insufficiency of the students and the student achievement

development towards the target that the students were expected to gain were presented. After the results related to the achievement development of the sixth-grade achievements, the findings of the student success improvements in the seventh-grade achievements were presented.

3.1. Results Related to Student Readiness and Students' Achievement Development Regarding Sixth Grade Achievements

In order to measure the readiness of the students, before the application process started, the students were given worksheets consisting of four questions and they were asked to answer it according to the required instructions. In the first question, they were asked to draw a circle in the given unit on the squared paper using a compass and ruler and show its radius and diameter on the circle. In the second question, they were asked, using the relation, to find the perimeters of the circles, whose radius and pi values were given. In the third question, they were asked to explain the difference between a circle and a circular region. In the fourth question, they were asked to write the measure of right angle (90^0), supplementary angle (180^0) and full angle (360^0). Student worksheets were evaluated and presented in Table 3 can find a sample table and a figure presented here.

Table 3. *Evaluation of students' responses.*

Questions	Learning outcomes	Students who failed to acquire any learning outcomes	f
1.Question	Able to show center, radius, diameter on a circle.	S1,S2,S3,S4,S5,S6,S7,S8,S9,S10,S11,S13,S15,S16,S17,S18,S20,S21,S24,S25,S26,S27,S28,S29,S30,S31,S32,S33, S34	29
2.Question	Able to calculate the circumference of a circle.	S2,S3,S4,S5,S6,S8,S9,S10,S13,S15,S16,S17,S20,S21,S24,S25,S26, S27, S28,S29,S30,S31,S32,S33,S34	25
3.Question	Able to explain the difference between a circle and a circular region.	S4,S5,S8,S9,S15,S18, S20, S26, S27,S28,S30, S31,S33	13
4.Question	Able to write perpendicular, supplementary and full angle degrees.	S9,S10,S13,S20,S26,S31	6

As is clear in Table 3, more than half of the class failed to draw the circle given in a certain unit and failed to show its center, radius and diameter. 25 students in the class could not find the circumference of the circle given the radius. This fact proved that the students failed fully learn the concept of the circle and could not make sense of the pi number we used to calculate the circumference of a circle. Looking at the students' answers to the third question, it was clear that 13 students failed to explain the difference between a circle and a circular region. It was observed that 21 people who were able to explain made a comment from memory as "*the circle is empty; the circle is full". Finally, 6 students could not write the concepts of right angle, supplementary angle, and full angle, and 28 students wrote "right angle 90 degrees, supplementary angle 180 degrees, full angle 360 degrees*".

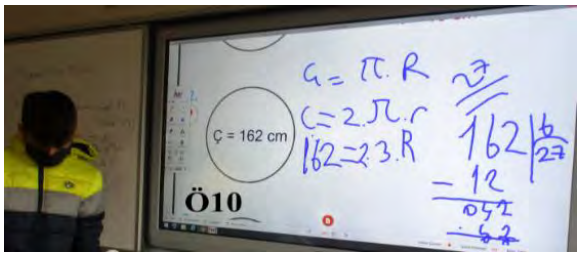
Considering the readiness of the students, the first week of the application process was given priority to the achievements of the sixth grade and the achievements of "Recognizing the center, radius and diameter by drawing a circle, discovering that the ratio of a circle's length to its diameter is a constant value, Calculating the length of a circle given its diameter or radius" were attained. It was observed that the students with low mathematics achievement acquired the achievements of showing the center, radius and diameter by drawing a circle in the process (Figure 2).

Figure 2. *Drawings of the student coded S13 and S27.*

The fact that the students coded S13 and S27, with a very low success in general, and never learnt the subject before were asked by the researcher to draw the circle and show its radius and diameter, one the acquisitions of drawing a circle and showing its radius and diameter, were able to draw a circle and show its radius and diameter, was an important indicator of success for these students.

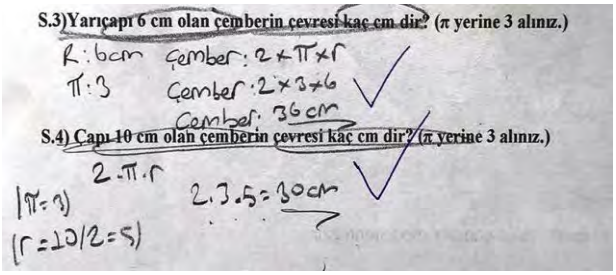
Considering that more than half of the class had never acquired the achievement of *"calculating the length of a circle with a given diameter or radius"* since the students had problems participating in the lessons during the period when the lessons were conducted with distance education due to the pandemic, it was observed that the fact that almost all of the class acquired the achievement with the formative assessment-based teaching applied in the process illustrated the improvement. In the formative evaluation process, being able to solve the questions and improving him/herself in line with the feedback given by the teacher led to an improvement in the performance of the students. Notably, the students with normally low in-class performance increased their success as they experienced the feeling of being able to correctly answer the questions and success (Figure 3).

Figure 3. *Class participation of the students with low in-class performance.*



As is clear in Figure 3, when the readiness level of the student coded S10 with low in-class performance was measured, it is obvious that he could not calculate the circumference of a circle whose radius or diameter was given (See Table 2). With the assessment tools, the student with the code S10 acquired the achievement and demonstrated this in the classroom. By making explanations on the board by the researcher teacher both individually and for the whole class in the classroom, the students were asked to perform individually, students' deficiencies were detected on the digital applications and their e-portfolios, and they were able to make up for their deficiencies in the achievements thanks to the feedback provided. For instance, it was observed that the student coded S28, whose success in mathematics was low, lacked in the acquisitions of being able to show the center, radius, diameter on the circle in readiness, to calculate the circumference of the circle, and to explain the difference between the circle and the circular region (See Table 2). Considering this deficiency, with the help of group work, worksheets, activities, homework, Plickers, Wordwall, EBA platforms, rapid techniques, peer assessments and various formative assessment tools applied in the form of flashcards, the student coded S28, like every other student, was also able to prove his improvement on paper, which was an important indicator of success (Figure 4).

Figure 4. *Turkish and English versions of the worksheet of student coded S28.*



Q.3) What is the perimeter of a circle with a radius of 6 cm? (take 3 instead of π)
Q.4) What is the perimeter of a circle with a diameter of 10 cm? (take 3 instead of π)

As seen in Figure 4, with the formative evaluation activities carried out during the process, the student with the code S28, using the relation, was able to calculate the circumference of the circle whose radius was given in the first question; in the question below, he realized that he had to use the radius length of the circle, whose diameter was given in the relation, and was able to calculate the radius length and calculate the length of the circumference of the circle. The fact that the student coded S28 could make sense of the concepts of radius and diameter and use them in the calculation of the circumference of the circle, knowing how to write them on the worksheet, proved the success of the student.

At the end of the one-week period, the worksheet consisting of 10 open-ended questions containing the achievements of the sixth-grade was given to the students and the results are presented in Table 4.

Table 4. *Mid-term evaluation achievement distributions.*

Mid-term Evaluation	f (Frequency)	(Percentage) %
Those with 6 or more correct answers	25	76%
Those with 5 or fewer correct answers	8	24%

When the answers given to the worksheet, consisting of open-ended questions including the achievements of calculating the radius and diameter length, understanding the meaning of the number pi, and calculating the circumference of the circle, were examined, it turned out that the class had a success rate of 76%. Individual assignments were prepared for the students with deficiencies, a separate group was created on the EBA platform, video narrations and study questions were sent for the missing achievements, and these students were followed up and the seventh-grade achievement was initiated by eliminating the deficiencies of these students.

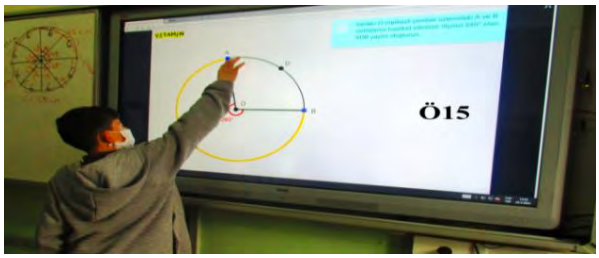
3.2. Results Related to the Success Regarding the Seventh-Grade Achievements

Results related to the success regarding the seventh-grade achievements were presented under the sub-headings of identifying the relationship between the central angle, the arcs it faced and angle measures, calculating the length of the circle and the circle segment, and identifying the area of the circle and slice of the circle.

3.2.1. *Determining the relationship between the central angle, the arcs it faces, and the measures of the angle*

Regarding the seventh-grade achievements, the students clearly got accustomed to the application process, and they managed their own learning by taking an active role in the course content enriched with various formative assessment tools. Considering the state of the classroom before the implementation process, few students participated in the lesson, while the whole of the class actively participated in the formative assessment activities throughout the process. For instance, the student coded S15 was an average success student, and while his in-class participation was weak, he fully participated in the activities held during the process (Figure 5).

Figure 5. *Digital activity participation.*



As is clear in Figure 5, the student came to the board and observed the relationship between the central angle and the arc measure dynamically on the smart board in the digital application. The student's performance development was evaluated as formative by asking different questions by the researcher teacher. With the immediate feedback given by the researcher after the answers received from the student, the student coded S15 improved his own success by making sense of the relationship between the central angle and the arc he saw.

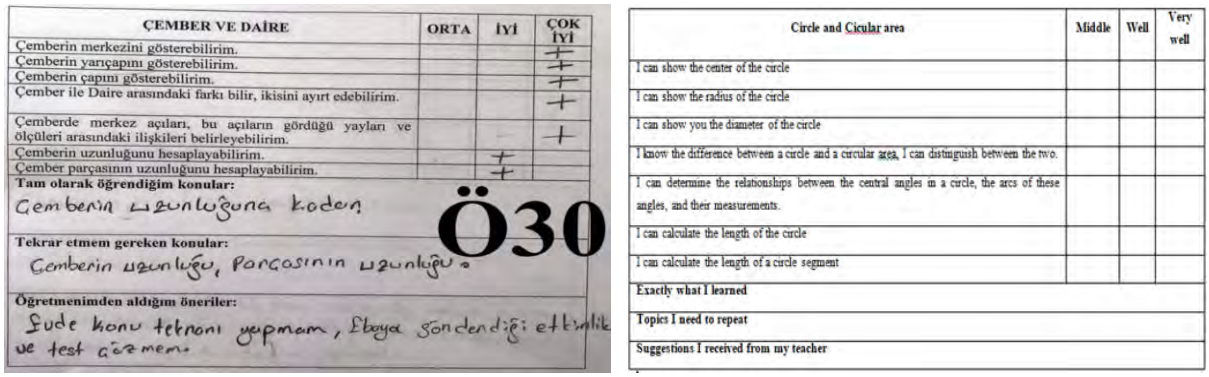
In addition to the digital materials, concrete materials such as geometry boards were used to identify the relationship between the central angle in the circle and the arc measure seen in the circle, and various in-class group activities were used to enable the students to learn more effectively (Figure 6).

Figure 6. *Images related to the activity.*

In the formative evaluation performed using the geometry board, the relationship between the angle and the arc was observed through group studies, as is observed in Figure 6. By forming groups of two, following the instructions on the given worksheet, the students were allowed to discover the central angle and the arc measure seen by the central angle on the geometry board. After the students, who followed the instructions in the worksheet by proceeding in a semi-circle, quarter-circle, answered the questions on the worksheet by discussing it with their friends, the researcher teacher proceeded in the form of a question and answer, and it was established where the students had deficiencies. The students, whose deficiencies were observed, were given immediate feedback by the researcher teacher, and the students' deficiencies were eliminated, and they were enabled to acquire the achievement.

In some of the group studies carried out during the process, peer assessment and self-assessment were used as formative assessment tools. The peer assessment and self-assessment used were influential in the teacher's planning of the next lesson and having information about the students (Figure 7).

Figure 7. *Turkish and English versions of the self-evaluation form of the student coded S30.*



ÇEMBER VE DAİRE	ORTA	İYİ	ÇOK İYİ
Çemberin merkezini gösterebilirim.			+
Çemberin yarıçapını gösterebilirim.			+
Çemberin çapını gösterebilirim.			+
Çember ile Daire arasındaki farkı bilir, ikisini ayırt edebilirim.			+
Çemberde merkez açıları, bu açıların gördüğü yayları ve ölçüleri arasındaki ilişkileri belirleyebilirim.			+
Çemberin uzunluğunu hesaplayabilirim.		+	
Çember parçasının uzunluğunu hesaplayabilirim.		+	

Tam olarak öğrendiğim konular:
Çemberin uzunluğuna kadar

Ö30

Tekrar etmem gereken konular:
Çemberin uzunluğu, Parçasının uzunluğu.

Öğretmenimden aldığım öneriler:
Şuda konu tekrarı yapmam, Ebeya gönderdiği etkinlik ve test çözmem.

Circle and Cicular area	Middle	Well	Very well
I can show the center of the circle			
I can show the radius of the circle			
I can show you the diameter of the circle			
I know the difference between a circle and a circular area, I can distinguish between the two.			
I can determine the relationships between the central angles in a circle, the arcs of these angles, and their measurements.			
I can calculate the length of the circle			
I can calculate the length of a circle segment			
Exactly what I learned			
Topics I need to repeat			
Suggestions I received from my teacher			

After the process of acquiring achievements was completed, a self-evaluation form was prepared for the students, as seen in Figure 7, and the students were asked to evaluate themselves. In the self-assessment of the student, coded S30, with poor mathematics achievement, he could show the center, radius and diameter of the circle very well, learn the difference between the circle and the circle, identify the relationship between the center angles in the circle and the arc measures seen by these angles, and calculate the length of the circle and the circle segment well. He also emphasized that he should study again the last subject of the circle and the length of the circle segment.

The student coded S30 saw his shortcomings in his self-evaluation and stated what he should do about his deficiency. Therefore, additional study questions were given to the student coded S30 and his efforts were followed up. In this way, the researcher teacher made up for the deficiencies of the students by identifying the subjects that the whole class had deficiencies in, planning the next lesson, giving homework for the students who were missing and following up. The self-assessments used because the class was crowded were an effective formative assessment tool in guiding the teacher by providing extensive information about the subjects covered in a short time about the students.

In addition to the self-evaluation form, individual interviews were held with the students who showed success in the lesson at the end of the lesson. In the individual interviews, the statement of the student coded S13, *"I used to be worse in this subject, but now I started to get better. I didn't solve many questions in the past, now I started to solve them, I started to like it a little bit, now it's been better now..."* was the indication that the student could make his own self-assessment and these self-assessments were related to the existing competence level of the student. Another student coded S16 said, the statements *"I don't know, I haven't been doing homework properly since I started 7th grade, that is, I didn't study enough for my lessons. Since these activities have been available, the photocopy worksheets and the things you downloaded from the internet were all good, math is the only I study willingly now, it will be better if it continues like this until the 8th grade"*, showed that the study performance of the student who had low success in the course and was not interested in the course changed for the better.

The formative assessment-based teaching implemented clearly contributed to the improvement in the student's success by positively changing the student's study performance. Another instance: the statement of the student coded S26, *"Actually I don't like to solve so many questions at home, especially in mathematics, but for some reason, I happen to a desire to solve questions at home about this circle,"* created the feeling of "I am able to" in the student since the main theme was to evaluate the student frequently and observe his deficiencies in the form of formative assessment-based teaching, taking steps appropriate to the level of the student. Furthermore, the researcher's observations during the process and the students' self-evaluations demonstrated the efficiency of formative assessment-based teaching in terms of planning the

following lesson. Such evaluations also generate success. The statements of student coded S20 as *"I learned a lot thanks to friends"* and that of student coded S4 as *"Elif explained the subject to me, I understood it, Ma'am"* illustrated the contribution of peer learning to success in formative assessment. In addition to the self- and peer-assessments, the information cards given to each of the students (Figure 8) determined what the students knew and did not know about the achievement that was explained on that day' and additional activities such as in-class lectures, sharing lecture videos via the digital platform, and individual assignments were made available to the weak students.

Figure 8. *Information cards for students coded S14 and S21.*

In the information card of the student coded S14, as seen in Figure 8, it is obvious that the length of the arc was equal to the central angle for that lesson, that he comprehended everything and that nothing was difficult for him. On the information card, the student coded S21 stated that he had fun in the lesson, participated, had difficulty regarding the subject of angles in the circle and did not understand it. By analyzing these two student profiles, the researcher teacher established what the students needed individually and planned the next lesson accordingly. While feedback was given to the student coded S14 that the concepts of arc length and arc measure were different, additional explanations were made for the student coded S21 and students with deficiencies like this student. In order to make up for the deficiencies, homework and digital activities were allocated and followed up, and the success development of the students was ensured.

In addition to concrete materials, digital platforms such as Geogebra, EBA (Educational Informatics Network), Wordwall were used to improve the success of students in a versatile manner. While some of the students fully participated in the practice activities sent via EBA during the process, some did not. As a result of the interviews with those who did not participate, negative situations were encountered such as the EBA platform having systemic problems, the fact that most of the students did not have a computer, so they had to log in on the smart phones and their phones did not have enough equipment to use the EBA platform. The statement of the student coded S17 as *"EBA is not available, I cannot access EBA, the smart phone cannot handle it"* and the statement of the student coded S16 as *"We have problems from EBA because we cannot access it; so, is better, do not send the practice activities on EBA, if you send 5 or 6 more activities on Wordwall, we will do them as well."* also represented the general level of the class as a whole. Therefore, in addition to the practice activities sent from EBA, Wordwall platform was also used as an opportunity for each student to have easy access. It was observed that student participation was higher because it was a game-based platform that students could easily access on their smart phones via the link. Assignments in the form of 10–15-minute quizzes were sent as links in a way that would not take the students' time and would attract their attention. The reports of the given assignments were reflected on the screen on the smart board and the students were given feedback collectively or individually (Figure 9). Giving feedback immediately was important in terms of thrusting the responsibility of homework of the students to and ensuring that the deficiencies were dealt with and corrected immediately. Moreover, using homework as a formative assessment tool in a crowded classroom also saved time.

Figure 9. *Report image of the Wordwall platform.*

As is clear in Figure 9, all the students were able to use this application and the following day, practice activities were carried out on the deficiencies of the students in the classroom. Hence, the success improvement of the students, who were frequently evaluated with formative assessment tools and given feedback, gained momentum.

The statistics offered by this program were recorded as the e-portfolio of the students and the progress of the students was followed up through these reports. Apart from the applications made on paper, digital platforms increased the motivation of the students as well. Statement of the student coded S26 *"It is easier in digital because sometimes I cannot easily find what is available in the book and where it is, or I have a problem. If there is information somewhere, I rack my brain for hours trying to remember and find which page that information was on, it gets very confusing.",* in fact demonstrated that giving homework from digital applications about what he learnt in the lesson on that day was clearer and more efficient for the student to know what to do. Similarly, the progress in the success of the students was observed more clearly and quickly. The positive performance of the students who received feedback on similar questions in the following practice activity was an indication that their success increased.

Moreover, the plickers application, which gives immediate feedback to the students in the classroom, was used to measure the students' readiness for the previous acquisition at the introduction to the course or for a short review at the end of the course (Figure 10).

Figure 10. *Plickers application.*

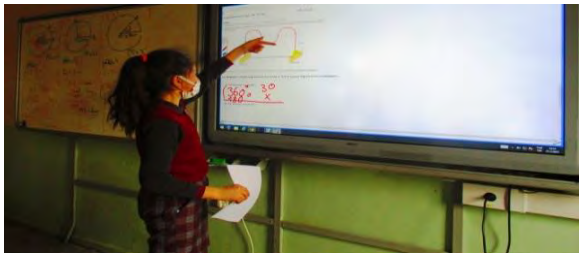
In this application, the whole class actively participated in the lesson, as each student lifted their own paper in order to answer the questions asked and saw his/her name on the board. In fact, the students who did not participate in the course at all (S8, S9, S17, and S25) felt more confident in this practice, which was one of the factors affecting the success of the students. As an indicator of their sense of security, the statement of the student coded S12 about the increase in the participation of the student coded S25, whose success in the course was very low, can be given as an example: *"I think it is a very useful activity, you don't criticize people; for instance, if you do it wrong, people laugh, and I get pissed about it. That's why I like that you do*

something like this. For instance, take a look at S25, because he doesn't study much, they laugh at him for doing it wrongly. But no one knows because you make a mistake. This caught my attention a lot." Similarly, the statement of student coded S6 *"They laugh when someone makes a mistake, sir; but, it is not clear who makes a mistake here"* and the statement of student coded S7 as *"I think the QR code activity is very good, everyone lifts it up directly, there is no chaotic sound concentration"* explicate the positive aspects of this practice in terms of allowing the shy students in expressing themselves better in the lesson, being able to answer questions more easily, being practical and giving immediate feedback to the student. Furthermore, the fact that students did not need a phone in this application demonstrated that the plickers application was a useful tool as a formative assessment tool.

3.2.2. *Calculating the length of the circle and the circle segment*

The students who learned how to calculate the circumference of the circle by giving the radius and diameter length were provided with various formative assessment tools in order to calculate the length of the circle segment. For instance, another tool used in the process was peer review. It was also an indicator of success that there were students whose self-confidence increased with the explanation of their friends and who never wanted to go to the blackboard for an activity but learnt with the explication of their friends and wanted to do the activity voluntarily (Figure 11). For instance, the student coded S27, who did not go to the blackboard and wanted to go that moment, explicated herself as in the following:

Figure 11. *Student codes S27 with increased self-confidence.*



R: You don't usually go to the board, I had you come to the board last time, but you went and sat back without solving it. Well, now why did you go to the board on your own accord?
S27: I asked Meryem and she explained it to me. My self-confidence increased when my friends explained it to me, that's why I went to the board.

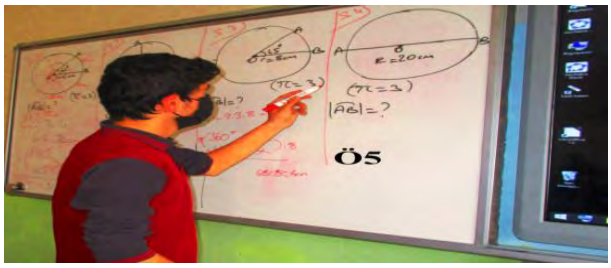
The observation of the student coded S7 as *"Hasan and Tugra never studied for their lessons, they simply ask each other when a group is formed, they learn because they explain one another what they do not understand"* illustrated that not only the researcher but also the students noticed each other's progress.

In some cases, on the other hand, the fact that a friend voluntarily helped a weak student extracurricularly and explained the subjects she could not understand was another indicator of peer learning (Figure 12).

Figure 12. *Extracurricular peer learning/teaching.*

Here, the fact that the student coded S5 wanted to observe his own effort and wanted really to learn, previously as a student who did not willingly go to the blackboard at the normal time' but now more willing to make the effort showed the success of the student (Figure 13). Considering that the basis of formative assessment is to evaluate each student according to their own potential, this finding showed the positive change in the student.

Figure 13. *The student coded S5 is able to show that she has learned successfully*.



As is clear in Figure 13, the student coded S5 calculated the length of the circle segment and was able to show it individually.

It is undeniable that the students' frequent exchange of knowledge and information with their groupmates in the group activities carried out during the process contributed to their success. So much so that, in the interviews with the students, the positive aspects of group work on themselves were indicated by the following statements of the students:

"Everyone can make up for each other's deficiencies in the activity, one helps the other when s/he cannot do it, and mostly these things are easier with cooperation." (S1)
"They couldn't do it, I helped them, and I showed them how to do it." (S6)
"I also like teaching to my friends; I reinforce what I teach as well. I think when the group is formed, everyone asks each other, and almost everyone can get on well with each other." (S7)
"Normally, I would cooperate with Kevser in such activities, I didn't communicate much. This time, I liked it when I did a nice project with all my friends. Thanks to this, I communicated more, I started to like my friends, and I always liked to communicate with them." (S11)
"Initially, I couldn't get along with some friends, afterwards, I started getting along better with them." (S17)
"I discuss questions with friends, they ask me as well and I help them." (S18)
"I learned to solve questions I didn't know from different perspectives. I also got different opinions of my friends and added them to my own, so I had an extra idea." (S23)
"For instance, we got along better." (S31)

Considering the comments of the students in general, it is possible to say that the contribution of peer learning to success was high. As a result of these positive feedbacks, various group activities as double, triple and hexadecimal groups were included throughout the implementation process, depending on the nature of the activities (Figure 14).

Figure 14. *Group work.*

As is clear in Figure 14, the students carried out their activities in groups of two and six according to the instructions in the worksheet given by the teacher. Students with a low level of success in the group showed improvement in their success by benefiting from the students with a high level of success. For instance, the dialogue with the student coded S12 is given below:

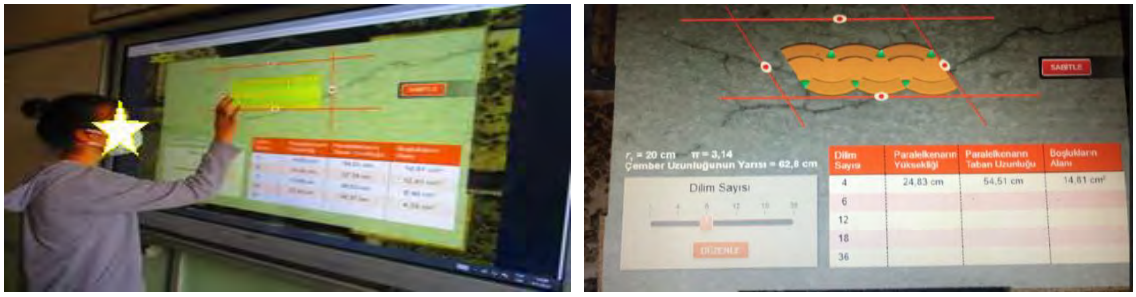
R: Do these two-person or six-person activities make any contribution to you?
S12: Yes, they do quite a lot. It's because there may be subjects that I do not know, I ask my friends, they teach me, this is how I learn.
R: Well, they make contributions to you, as far as I understand, you also make contributions to them.
S12: Yes, quite a lot
R: Well, is that a good thing?
S12: I think it's been great this way.
R: Actually, they criticized the group a lot regarding the seating arrangement,
S12: I think it's good in terms of sharing, the problem is that they talk a lot. Everything else is fine, when he asks about something he doesn't understand, they teach him one by one, if he doesn't understand, they ask someone else, s/he explains.

In addition to the positive aspects, the fact that there were disagreements and arguments in some groups according to the dynamics of the groups also demonstrated the negative side of this formative evaluation practice.

3.2.3. *Calculating the area of a circle and a circle segment*

After learning how to calculate the length of the circle segment, students started to learn how to calculate the area of the circle and the circle segment. The activity seen in Figure 15 in the Education Information Network (EBA) platform was applied to the students individually and the students were allowed to explore the area of the circle. During this exploration of the students, the students progressed with the questions asked by the researcher teacher, and feedback was given instantly according to the student's answers, allowing the students to discover the relation of the area of the circle.

Figure 15. *Individual in-class activities.*



In the activity in Figure 15 within the EBA platform, it is clear that the student coded S26, who had low mathematics achievement and had low in-class motivation before the application process, improved her in-class motivation and participated in the activity. In this activity, the students discovered the transition from the area of the parallelogram to the area relation of the circle by increasing the number of slices.

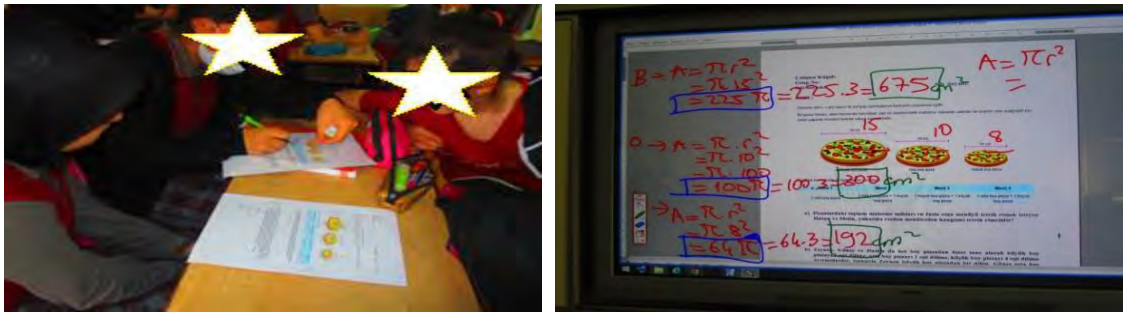
During the in-class activities, the students received immediate feedback, saw where they had deficiencies, and managed the process accordingly. In some cases, feedback was given individually while the students were solving on the board in some cases (Figure 16).

Figure 16. *Instant feedback to students.*

As is clear in Figure 16, the students who were identified to be deficient in in-class formative assessments were individually asked to come to the board and additional questions were asked to them. While the students were solving the questions about finding the area of the circle on the board, a formative evaluation in the form of question-answer was implemented, and the students were given feedback according to their answers, and the students were able to find the area of the circle and the circle slice.

In addition to the individual activities, in-class activities (Figure 17) performed by the students in pairs or trios were also used as a formative assessment tool in the process.

Figure 17. *In-class group work.*



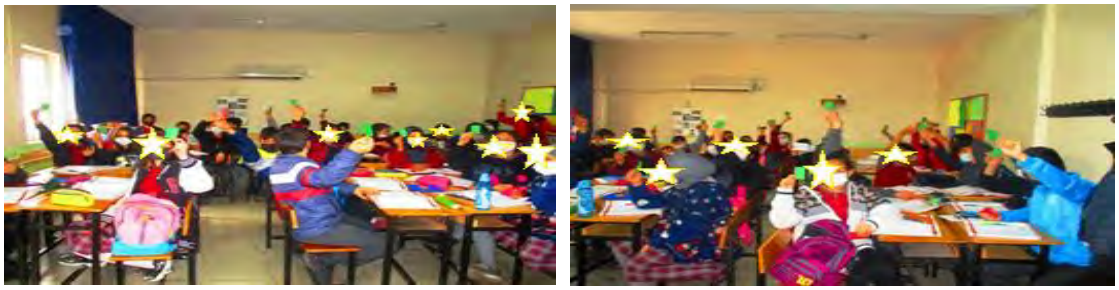
In Figure 17, the skill-based question, which included finding the amounts of pizza and pizza slices associated with daily life, was asked to the students who formed groups of two by cascading. After the students completed their worksheets in the given time, the questions were discussed and resolved on the smart board. In the study, which was carried out with the participation of the whole class, the students answered the questions with peer learning, and the researcher teacher gave feedback while the students were answering the questions on the board or walking around the classroom. Giving feedback and enabling students to see where they made mistakes positively contributed to the improvement of their success.

During the study process, the use of *thumbs up and thumbs* down (Figure 18), one of the formative assessment methods as instant feedback, was effective in terms of instantly recognizing whether students understood and in terms of working on it, and as a result, the students were always active in the lesson.

Figure 18. *Thumbs up thumbs down.*

If the students correctly understood the subject of circle and the segment of the circle slice at the moment of teaching, they put their thumbs up, if they didn't, they put their thumbs down. Even though the thumb was held sideways, it meant that they understood half, and those who had comprehension problems were helped to work on it again. The use of the red and green card used in the process was also one of the formative assessment tools used in the instant assessment (Figure 19).

Figure 19. *Use of red green cards.*



As is clear in Figure 19, it was a formative assessment tool performed by holding up the red, green card, the green card if the subject was understood, the red card if not understood, and both if it was half understood. Furthermore, the use of these cards to give feedback to their friends who correctly solves the question on the board should also be used by the students to know the subject, which then leads to success.

Many formative assessment tools were utilized in the process, and even the formative assessment tools used were reformatted according to the students' competence and various external factors. For instance, students were asked to create a question box by throwing their own questions into a box, and the questions were drawn from the boxes and solved on the board in the time given in groups in the class (Figure 20).

Figure 20. *Question box formative assessment tool.*

The question box tool used in this activity was composed of questions about the circle and the area of the circle segment that the students prepared themselves. Initially, the question box activity, which was applied after the circle and arc length acquisition were taught to the students, was applied secondly after the acquisition related to the area of the circle was comprehended. In the second application, which consisted of questions about the area of the circle, when the students with low success levels did not want to volunteer to solve it in the first application, the instruction was changed, and it was suggested that students who could not solve the question could go to their own groups and learn and solve them on the board (Figure 21). Question box activity was formatted according to students and classroom climate.

Figure 21. *Students who couldn't solve getting help from friends.*

As is clear in Figure 21, all the students who learned with the help of their friends with the question box activity actively participated in the lesson and their success levels clearly improved.

4. DISCUSSION and CONCLUSION

As a result, in the present study, it was investigated how the formative assessment-based application process in the seventh grades in mathematics teaching regarding the subject of circle and the circular region improved the success of the students and an exemplary application for the formative assessment-based teaching in mathematics teaching was presented. Various formative assessment tools used in the study enabled the students to recognize their deficiencies on the subject at that moment and paved the way for making plans in an attempt to make up for the student's deficiencies. Therefore, the students both increased their motivation by tasting their own success instantly, and the enhancing interest in the lesson improved the success of the lesson. It turned out to be clear that the process evaluation brought about success as the students progressed with the activities suitable for their level and were frequently evaluated and their deficiencies were made up for. The results obtained from this study also overlapped with the findings of previous studies that formative assessments were an important factor that augmented the learning levels of secondary school students and had a positive effect on their success (Austin Hurd, 2015; Kline, 2013; Collins, 2012; Tekin 2010).

As far as the results of this study are concerned, it was revealed that not only the students with high mathematics achievement, but also low and medium successful students made progress in this process with the FA tools used in the teaching of the subject of circle and circular region. With various FA tools used in the teaching of the subject of circle and circular region based on formative assessment, clear contribution was made to the formation of a participatory classroom environment, to the progress in success despite a crowded classroom, to more active participation of students with low achievement levels and the non-participation in this process, to the increase in their learning motivation (Black & Wiliam 1998; Burns et al., 2010; Miesels et al., 2003), to the increase in the self-confidence of students with high success levels by sharing the knowledge with low-achieving students, to the students' ability to recognize where they were weak and to manage the learning process themselves thanks to feedback, to the students' adaptation to the process at the end of two weeks and the demand for the lessons to be always like this, most importantly, to the students' feeling of being able to do and their participation and motivation to increase, and accordingly, to a decrease in their anxiety towards mathematics and to the achievement of success. This result overlaps with the result that formative assessment significantly increased students' academic success in many international studies (Kline, 2013; Burns et al., 2010; Foster & Poppers, 2009). The fact that the study significantly increased the success of students is in line with the result of Tekin's (2010) study that formative assessments in secondary school mathematics teaching had a positive effect on students' learning speeds and achievements.

Furthermore, the application of the study in a crowded classroom environment in a public secondary school demonstrated the applicability of formative assessment-based teaching in mathematics lessons. As far as the results are concerned, it is possible to say that appropriate formative assessment tools, which enabled the teacher to obtain information about the student faster, allowed the students to recognize their own success and improve their efficiency regarding success. The Teacher's Guide Booklet (MEB, 2020) sent to schools by the Ministry of National Education in 2020 focused on the importance of formative assessment-based teaching practice in mathematics education.

In fact, even though the importance of formative evaluation in both national and international education policies has been emphasized so much in recent years, there are only few studies in the national literature to validate its applicability (Ozan, 2017). Even though the positive aspects of formative assessment on students are commonly recognized by researchers, it is clear that scientific evidence applied to students has been limited (Bennett, 2011). Considering this lack of scientific evidence, the present study has clearly demonstrated that the formative assessment-based teaching application, based on the MEB (2020) guidebook, contributes to the students' mathematics achievement.

Furthermore, it is recommended that formative assessment-based mathematics teaching, which is widely used internationally, should be offered as part of the necessary teacher training in all schools in Turkey, its implementation should be tracked down, and it should be prioritized in the mobilization of teaching mathematics.

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Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research publishing ethics. The scientific and legal responsibility for manuscripts published in IJATE belongs to the authors. **Ethics Committee Number**: Eskişehir Osmangazi University, 25.01.2022, 2022-02.

Authorship Contribution Statement

Hilal Ozcan: Investigation, Resources, Methodology, Visualization, Software, Formal Analysis, and Writing-original draft. **Aytac Kurtulus:** Methodology, Supervision, and Validation.

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