# Investigating the effects of mathematics problems prepared in the context of sustainability on academic achievement, attitudes and awareness of sustainability

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The concept of sustainability, which is important both in the national and international arena, constitutes the contextual perspective of this research. This study aims to investigate the effect of mathematical problems prepared from this point of view on academic achievement, academic attitude and awareness of sustainability. For this purpose, three sub-problems were determined. This study used exploratory sequential design, which is one of the mixed research methods. The study used an easily accessible sampling. 32 students studying in the second semester of the 7th grade were included in the study. The implementation of the study, which lasted 14 weeks, included the discussion, solving and interpretation of mathematical problems prepared in the context of sustainability. In the study, quantitative data were collected using the Academic Achievement Test (AAC) and the Scale on Attitude Toward Mathematics (SATM). Qualitative data of the study were collected using diagnostic forms, individual evaluation forms and individual interview forms. Parametric tests were used in the quantitative analysis, and a t-test was used for dependent groups. In the process of analyzing qualitative data, descriptive and content analysis was used. Findings show that there is a statistically significant difference between the pre-test and post-test academic achievement results and a significant increase in SATM. The qualitative findings support the quantitative findings. They also show the effects of mathematical problems prepared in the context of sustainability on sustainability awareness, the themes of interest, sensitivity and consciousness, and related sub-themes with pre- and post-application frequency values.

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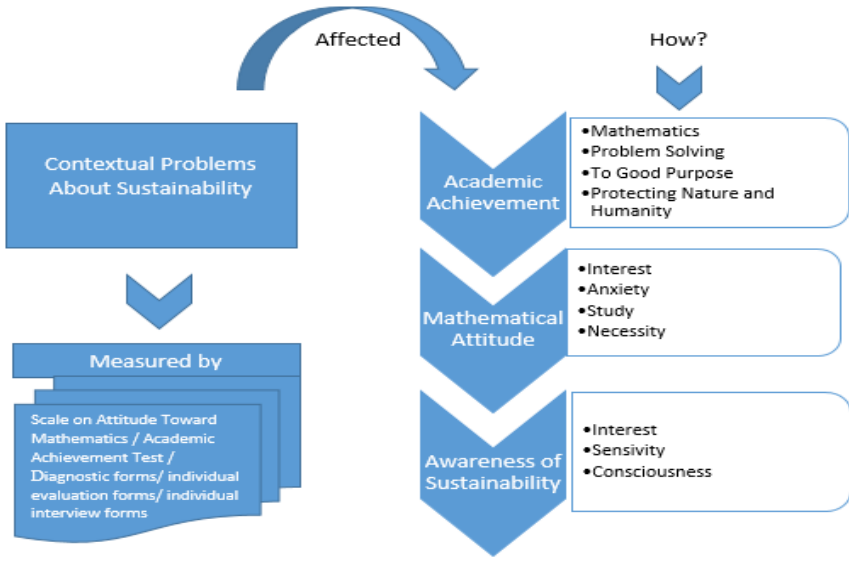

# 1 Introduction

What makes it difficult to learn mathematics – a field which we always need and use in our daily life? How can we overcome the bias that mathematics is difficult and complex by using the mathematics that we experience in our daily life situations? To what extent does mathematics, which comes our way in a contextual situation that is important for our world, affect our learning? These questions have led us, educators, to think about how we can use the internationally important concept of sustainability in predicting the use of mathematics in daily life.

There are many studies revealing that "mathematics is difficult" (Gafoor & Kurukkan, 2015; Godino et al., 2011; Simmers, 2011) and "mathematics-related anxiety level affects learning" (Ashcraft et al., 2007; Faust et al., 1996). In addition to these studies, previous literature (Boaler, 1993; Surya & Putri, 2017; Widyatiningtyas et al., 2015) demonstrates that mathematics can be learned in different ways (realistic mathematics teaching, creative drama, cooperative learning), in different places (in and out of the classroom), and in different contexts (using words in different situations). The common point of the above-mentioned studies is that mathematical concepts are handled based on real life models, that mathematics is an indispensable part of daily life, and accordingly, studies express that learning can be possible by developing a positive attitude towards mathematics.

## 1.1 Attitudes toward mathematics

Koballa and Glynn (2007) define attitude as a person's general and lasting positive or negative feelings about an object or subject. Attitude towards mathematics is defined as a long-term positive or negative emotional disposition towards mathematics (Belbase, 2013; Haladyna et al., 1983; McLeod, 1992).

Negative attitudes towards mathematics reflect children's prior experiences with mathematics (Dowker et al., 2016), affect students' conceptual understanding of mathematics (Chan & Reynolds, 2022; Dowker et al., 2019), and can negatively affect mathematics achievement (Iddrisu et al., 2023; Levine, & Pantoja, 2021). It is seen that students with low mathematics achievement avoid mathematics-related learning and drop mathematics courses at high rates (Al-Zoubi & Younes, 2015).

In addition to the studies showing the relationship between mathematics achievement and attitudes towards mathematics (Al-Mutawah & Fateel, 2018; Michelli, 2013; Mubeen et al., 2013), attitude towards mathematics and academic achievement; the

method used (Duatepe-Paksu & Ubuz, 2009; Fleming et al., 2004; Zakaria et al. 2010); material (Baki & Güveli, 2008; Johnson et al., 1978) and technology use (Barkatsas et al., 2009; Eyyam & Yaratan, 2014).

## 1.2 Contextual learning

Learning environments structured with contextualized learning, which include a wide range of different methods, materials and technology use, affect students' attitudes towards mathematics (Awofala, 2014; Purba & Surya, 2020; Sanchal & Sharma, 2017; Uzel & Mert Uyangor, 2006; Van Eck, 2006; Topçu & İşleyen, 2022, Zakaria, & Syamaun, 2017) and cause positive changes in teachers' attitudes (Gravemeijer, 1994).

Students' awareness of mathematics used in daily life situations can be achieved when they come across these situations and predict the situations encountered by associating them with daily life. The contextual approach has an important place in this process of prediction. The contextual approach is a concept that helps teachers to teach students to relate the learned content to real-life situations so that students can learn, and encourages students to apply it in their lives and to make connections between the knowledge they already have (Ekowati et al., 2015). Ekowati et al. (2015) state that learning with the contextual approach is more meaningful for students, it includes no information transfer from the teacher to the student and that learning takes place naturally through student activities and work experience. In addition, it is emphasized that the determined learning strategy is more important than the results achieved, and that it is possible to study with the curriculum without changing the existing order.

Contextual teaching and learning can manifest itself in physical, intellectual and social contexts related to constructivist processes such as critical thinking, inquiry learning and problem solving (Glynn & Winter, 2004). Contextual learning can be accepted as a learning approach that recognizes and demonstrates the natural conditions of knowledge (Surya et al., 2017). Surya et al. state that a contextual learning approach will make it meaningful for students to create knowledge that they would apply in lifelong learning through relationships inside and outside the classroom. In addition, these studies also emphasize that it also provides an opportunity to predict how students learn in the context of the material they are studying.

Contextual learning has an important place in mathematics teaching, and there are studies in the literature in which the lesson is structured with the help of contextual problems (Boaler, 1993; Chapman, 2006; Önal, 2015; Surya et al., 2017; Ulusoy

& Kepceoğlu, 2018). It is important to enable students to reach mathematics with contexts, to explain mathematical thinking and understanding students have, to offer strategies for solving mathematical problems and, accordingly, to compare the lesson with rich contexts that can be made mathematical (Van den Heuvel-Panhuizen, 2005).

So, how should these contexts be decided and how should relationships be structured? Johnson (2002) lists eight components of contextual learning as follows: making meaningful connections, learning independently, doing meaningful work, collaborating, thinking critically and creatively, helping people grow and develop, reaching a high standard, and using authentic assessment. On the other hand, Glynn and Winter (2004) explain strategies that can be used for contextual learning as inquiry learning, problem-based learning, cooperative learning, project-based learning and authentic assessment.

Based on the abovementioned eight components of contextual learning and alternative strategies that can be used, this study focuses on mathematical problems prepared with the concept of sustainability, which is emphasized not only throughout the country, but also throughout the world.

### 1.3 Sustainability and sustainable awareness

Sustainability is defined as the management of the ecosystem, organisms, land, sea, and atmosphere resources that people benefit from in a way that can achieve optimum sustainability, which is included in the World Nature Charter adopted by the International Union for Conservation of Nature (IUCN) in 1982. Another aim is to perform this management in a way that does not endanger the integrity of ecosystems and species (Brouder, 2010).

Sustainable development, which is an important step for sustainability, has become a basic policy as adopted by all members countries of the UN at the UN Conference on Environment and Development held in Rio de Janeiro in 1992. Within the scope of sustainability, world leaders have agreed on seventeen global goals, the implementation of which is expected to begin in 2015 and continue until 2030 (United Nations, 2015). In the document entitled "The 2030 Agenda For Sustainable Development," these goals are defined as ending poverty and hunger, health and quality life, quality education, gender mainstreaming, clean water and sanitation, accessible and clean energy, decent work and economic growth, industry, innovation and infra-

structure, reducing inequalities, sustainable cities and communities, responsible production and consumption, climate action, aquatic life, terrestrial life, peace, justice and strong institutions and partnership for the goals.

Changing society's behaviour patterns regarding sustainable awareness starts with educating children from an early age. It is known that consumers who are aware of the awareness of sustainability issues are less likely to purchase products that can harm nature (Aruga, 2020); the higher the awareness, the higher the purchasing awareness for sustainable or green products (Li et al., 2020).

In recent years, increasing awareness of environmental and social issues such as climate change, water scarcity, and human rights (Li et al., 2020) has increased the demand for education to develop students' knowledge and competencies in sustainability (Lee & Perdana, 2023). Curriculum-based service learning in schools can help students develop sustainability awareness, thus providing a transformative educational experience to challenge their stereotypes and personal values (Sterling, 2013).

In addition, the United Nations Educational, Scientific and Cultural Organization [UNESCO, (2017)] emphasizes that mathematics is a useful tool for dealing with human physical needs in sustainable ways, and there is a need to encourage the use of real contexts as opposed to imaginary ones.

### 1.4 Research questions

The concept of sustainability, which is important both in the national and international arena, constitutes the contextual perspective of this research. This study aims to investigate the effect of mathematical problems prepared from this point of view on academic achievement, academic attitude and awareness of sustainability. The study's sub-problems are as follows:

1. Do mathematical problems prepared in the context of sustainability have any effect on academic achievement? If so, what are the reasons behind these effects?
2. Do mathematical problems prepared in the context of sustainability have any effect on students' attitudes toward mathematics? If so, what are the reasons behind these effects?
3. Do mathematical problems prepared in the context of sustainability have any effect on sustainability awareness? If so, what are the reasons behind these effects?

## 2 Method

This study used exploratory sequential design, which one of the mixed research methods. The exploratory sequential design evaluates trends and relationships using quantitative data and explains mechanisms or results behind emerging trends (Creswell et al., 2003). In other words, the rationale for quantitative data is explained by an in-depth data collection process.

### 2.1 Participants and application process

The study needed participants who could examine the effects and causes of mathematical problems prepared in the context of sustainability on academic achievement, academic attitude and awareness of sustainability. Since the system in Türkiye requires a national exam in the 8th grade and the subject of equations is handled in the 7th grade, 32 students studying in the second semester of the 7th grade were included in the study. Out of these 32 students, 19 were female and 13 were male students. The study used an easily accessible sampling. The study was conducted only in classes, where the mathematics teacher was willing to participate.

After obtaining the necessary permissions from the relevant ethics committee, the researcher attended the classroom lectures of the participants for two weeks before starting the implementation. In the subsequent 14 weeks, the study was carried out in the classroom environment with the participants who gradually got used to the researcher. The application included discussing, solving and making sense of the mathematical problems prepared in the context of sustainability first individually and then in the classroom environment. The names of the application-related themes and activities carried out with the participants are given in Table 1.

**Table 1.** Mathematical problems prepared in the context of sustainability and related learning areas

| Week | Theme | Activity name | Related learning and sub-learning area |
|---|---|---|---|
| 1 | Respect for cultural values | We list our history in chronological order! | Numbers |
| 2 | | Motifs at the Antalya Museum | Symmetry |
| 3 | Environmental education | I am measuring the perimeter of the square using recycled materials | |
| 4 | | I am measuring the perimeter of the triangle using recycled materials | Measuring perimeter |
| 5 | Economic welfare | End poverty: I spend my money no more than I have to | Currencies |
| 6 | | Investments to end poverty | Data collection and evaluation |
| 7 | End hunger | I am learning what safe, nutritious and adequate food means! | Weight measurement |
| 8 | | I am learning how to share: ratio-proportion | Ratio proportion |
| 9 | Healthy individuals | We reduce traffic accident-related injuries | Speed problems |
| 10 | | I am taking precautions against the pandemic | Transformation geometry |
| 11 | Quality education | We end gender inequalities | Data analysis |
| 12 | | We get to know our world for world citizenship | Reading graphs |
| 13 | Clean water and sanitary conditions | We are learning about our water footprint | Measuring liquids |
| 14 | Sustainable cities and communities | We are integrating people with disabilities into society: | Measuring areas |

When Table 1 is examined, it is seen that the themes created are shaped within the framework of the "Sustainable Development Goals" determined by the UN and which mathematics learning area the activities serve. The activities were not given to the students before the lesson. Before each activity, teachers, researchers and participants talked about the theme in the classroom environment. Interactions, ideas and situations in their environment related to the subject were discussed. Mathematics problems prepared in the context of sustainability related to the theme of the week were given to the students, and first they were asked to solve them individually and then, to exchange ideas about the questions with their peers. For each activity, at least three students' solutions were discussed in the classroom, and alternative solutions were shared.

## 2.2 Data collection tools and processes

In the study, quantitative data were collected using the academic achievement test (AAT), prepared for mathematical problem-solving acquisitions as created by the researcher, and the Scale on Attitude Toward Mathematics (SATM) developed by Önal (2013). Qualitative data of the study were collected using diagnostic forms (DF), individual evaluation forms (IEF) and individual interview forms (IIF). The tools and processes used are listed in Table 2.

**Table 2.** The application process of data collection tools

| Week | Content | Process |
|---|---|---|
| 1 | Application of quantitative data collection tools as a pre-test | AAT-SATM-DF |
| 2-14 | Problem 1-14 | IEF |
| 16 | Application of quantitative data collection tools as a post-test | AAT-SATM-DF |
| 17 | Conducting interviews for qualitative data | IIF |

When Table 2 is examined, it is seen that before and after the implementation of the study, quantitative data tools (AAT and SATM) and qualitative data tools (DF) were applied, and IEFs were applied after each activity. What follows is information about the data collection tools and what was done for validity and reliability checks: The Academic Achievement Test (AAT), prepared for mathematical problem-solving acquisitions, was developed by the researcher. It consisted of 30 questions, each of which had four (4) options. The reliability of the questions evaluated by four mathematics educators was determined as less than 50% for two questions and as 80% for the remaining 28 questions. A pilot of 28 questions was conducted on 62 students in the 7th grade. One of the questions in the AAT was found to be semantically incomplete, and the other two were found to be too long by the students, so three questions in total were excluded.

The Scale on Attitude Toward Mathematics (SATM) developed by Önal (2013) consists of 22 items and four factors. These factors were determined as interest, anxiety, study, and necessity. The scale items are 5-point Likert type, consisting of the following options: "Strongly Agree", "Agree", "Uncertain", "Disagree", and "Strongly Disagree". The internal consistency coefficient (Cronbach's alpha coefficient) for the whole scale was 0.90. The internal consistency coefficient (Cronbach's alpha coefficient) of the factors constituting the scale was 0.89 for "Interest" (number of items 10), 0.74 for "Anxiety" (number of items 5), and 0.69 for "Study" (number of items 4), and 0.70 for "Necessity" (item number 3). At the same time, it was confirmed that the

scale formed a four-factor structure with confirmatory factor analysis. The Cronbach Alpha was found to be .88 for this study.

The study's qualitative data were collected using diagnostic forms (DF), individual evaluation forms (IEF) and individual interview forms (IIF). The DF includes questions about the demographic characteristics of the participants and sustainability awareness before the application. The IEF is a tool consisting of four open-ended questions prepared by the researcher to determine the topics that are learned that day and considered important by each student every week. The IEF, on the other hand, is a form consisting of five semi-structured questions prepared for the interview for students whose attitudes, academic achievement and sustainability awareness have changed after the application.

In order to increase the validity and reliability of the tools developed to collect qualitative data, a validity study was first conducted. In order to examine the suitability of the diagnostic forms (TF), individual assessment forms (IAF) and individual interview forms (IIF) used as data collection tools for the purpose of the study, the opinions of three academicians and two mathematics teachers who are experts in the field of mathematics education were taken. After the opinions were received, sentences that might have semantic problems were corrected and the validity of the data collection tool was tried to be increased. The interviews were transcribed and based on the transcripts, the researchers and three academicians who are experts in mathematics education created codes and themes for the purpose of the research through content analysis independently and unaware of each other. The researchers discussed the consistency of the codes and themes with the experts who analyzed the codes and themes. Miles and Huberman (1994) conceptualized this similarity, which they called internal consistency and conceptualized as the consensus between coders: $\Delta = C \div (C + \partial) \times 100$. In the formula, $\Delta$: Reliability coefficient, $C$: The number of topics/terms on which there is consensus, $\partial$: Represents the number of topics/terms on which there is no consensus. According to the coding audit, which gives internal consistency, the consensus among the coders was found to be 98%. After the necessary arrangements, the codes and themes mentioned in the findings section were finalized.

Subjectivity arising from the researcher affects the credibility, validity, and reliability of qualitative research, and an important way to ensure validity, reliability, and credibility is the selection and use of objective methods (Baltacı, 2017). For this reason, in this study, where objective methods were selected and used, it was also ensured that the statements of the participants were frequently confirmed during the interview

process in order to increase credibility. In addition, the statements of the participants were directly included in the findings section, thus increasing the transferability of the research.

The ethical dimension of the study was initiated by obtaining permission from campus-based institutional review boards (IRBs). The teacher who wanted to participate in the study was identified and the necessary permissions were obtained from the institution where the teacher worked. The class size was 32 students and an informative letter was sent to the families of these students. The participants were asked in writing whether they would participate in the study and the forms were signed by the families. The study was conducted with the students whose permission was obtained.

## 2.3 Data analysis

Since the study employed quantitative and qualitative data collection tools together, data analysis methods differ.

After the pilot application for the AAT, the distinctiveness of test items was determined to be between 0.50 and 0.80 with the TAP (Test Analysis Program). The test's average difficulty level was 0.58 and distinctiveness was 0.44. The test's KR 20 and KR 21 results were found to be 0.87 and 0.89 in the program, respectively. The reliability level generally accepted in scales is 0.70 (Tezbaşaran, 1996), and it was decided that the reliability level of the tool developed for this study was acceptable in terms of reliability. The tool was finalized with a total of 25 questions. The 25 questions were applied to 32 participants as pre-test and post-test.

The Attitude Scale Towards Mathematics (ASTM) primarily. The normality of the distribution was examined with the Shapiro-Wilk method. Kolmogorov-Smirnov and Shapiro-Wilk tests are used to examine normality. The Kolmogorov-Smirnov method tends to reject normality when the sample grows (Pallant, 2016), while the Shapiro-Wilk method is known to be statistically powerful only in small samples (Pituch & Stevens, 2016). According to the results of the analysis, it was seen that the scores showed normal distribution characteristics ($p=0.82$). Descriptive statistics of the scores are presented in Table 3.

**Table 3.** Application descriptive statistics on scores

| Score | Max. | Min. | Skewness | Kurtosis |
|---|---|---|---|---|
| Pre-test for Scale on Attitude Toward Mathematics | 112 | 88 | 0.22 | 0.52 |
| Post-test for Scale on Attitude Toward Mathematics | 188 | 151 | -0.48 | -0.76 |

George and Mallery (2001) stated that the data show a normal distribution if the skewness and kurtosis values are between -2 and 2, and they concluded that the data show a normal distribution since they are between these values. For this reason, parametric tests were used in the quantitative analysis, and a t-test for dependent groups was carried out first since it was examined whether there were significant differences between the pre-test and post-test applications and the scores of the participants.

In the process of analyzing qualitative data, descriptive and content analysis (Yıldırım & Şimşek, 2013) were used. Yıldırım and Şimşek (2013) emphasize the stages of creating a framework for descriptive analysis, processing data according to the thematic framework and defining and interpreting the findings, and for content analysis, coding the data, finding themes, organizing codes and themes, and finally defining and interpreting the findings. The themes and sub-themes for each sub-problem are listed systematically and demonstrated in the findings.

## 3 Findings

The findings obtained in line with the purpose of the study are presented below for each sub-problem separately.

### 3.1 The effect of mathematics problems prepared in the context of sustainability on academic achievement and possible reasons

The results for the scores that the students in the study group achieved in the academic achievement pre-test and post-test applied to them before and after the application are given in Table 4.

**Table 4.** Analysis results of scores achieved in mathematical academic achievement pre-test and post-test

| Pre-Test-Post-Test | N | $\bar{X}$ | S. deviation | t | p |
|---|---|---|---|---|---|
| Pre-Test | 32 | 4.28 | 1,078 | -6,392 | .000* |
| Post-Test | 32 | 9. 82 | 1,012 | | |

*p<0.05

Table 4 shows that there is a statistically significant difference between the pre-test and post-test results of the study group (p =.000). The mean of the group was 4.28 and 9.82, respectively. According to this result, mathematics problems prepared in the context of sustainability have a positive effect on academic achievement.

Table 5 represents the qualitative findings that support the quantitative findings; that is, the reasons that increase academic achievement.

**Table 5.** Factors affecting academic achievement

| Theme | Sub-Theme | f |
|---|---|---|
| Mathematics | A sense of practicability since it has been realized that mathematics is in every part of life | 30 |
| | Recognizing the areas of use of mathematics | 28 |
| | Realizing that mathematics is important for nature, the environment and humanity | 22 |
| Problem solving | Feeling like a protagonist because the problems are realistic | 18 |
| | The feeling of solving a daily life problem rather than solving a mathematical problem | 24 |
| To good purpose | Doing work that adds value to society | 24 |
| | Making life easier by supporting people with disabilities | 8 |
| Protecting nature and humanity | Feeling that you are recycling the waste as you solve problems | 12 |
| | Feeling that you are part of nature when you solve the problem | 17 |
| | Feeling integrated with humanity | 21 |
| | Feeling that you are stepping into your future | 19 |

Table 5 shows that the academic achievement of the students is gathered under the following themes: about mathematics, problem solving, to good purpose (in a way that is good or helpful purpose), protecting nature and humanity. The participants stated that the mathematical problems prepared mainly in the context of sustainability had an effect on realizing the areas of use of mathematics, and they felt that they could do it because they saw that mathematics was in every part of life. They stated that their desire to solve problems increased due to the fact that problem solving creates a feeling of solving problems related to daily life problems rather than a real mathematical problem and that they feel like the hero of the plot thanks to verbal problems. Participants also stated that solving problems served a deeper purpose and that they gained a perspective to protect nature and humanity. The number of participants who stated that they felt adding value to society while solving the problems prepared in this way is in the majority, and it is seen that the number of participants

who stated that they felt integrated with humanity under these themes is also in the majority.

For example, two participants stated that their desire to solve the problem increased when they felt like becoming the hero of the plot in which they felt like a civil engineer when solving the 14th problem. The problem and sample solutions are given in Figure 1.

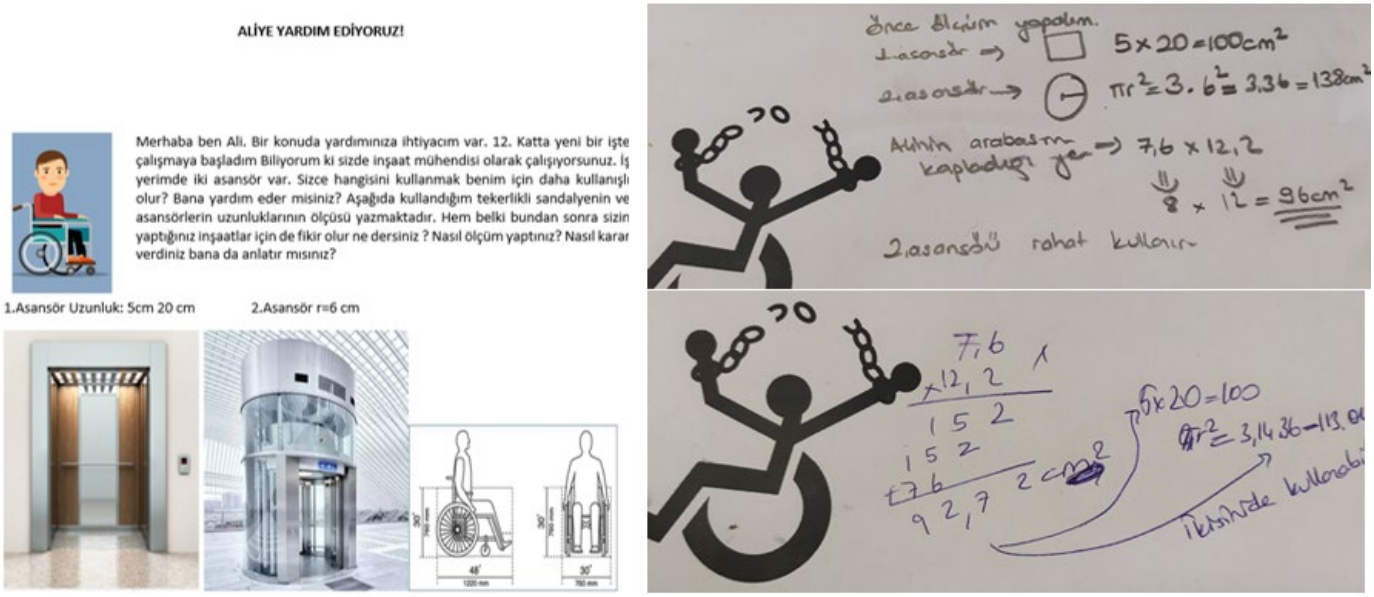


Figure 1. 14th Problem and a student's solution

Since the study was conducted in Türkiye, the solutions are given in the original language. Contextual problem on the left side is in the form of;

> "Hi, I'm Ali. I need help with something. On the 12th floor, I've started a new job and I know that you are a civil engineer. There are two elevators at my workplace. Which one do you think would be more convenient for me to use? Can you help me? Below are the measurements of the wheelchair I use and the elevators. Maybe it will also be an idea for the constructions you do in the future, don't you think? How did you measure? Can you tell me how you decided?"

and solutions are given on the right side.

The first solution was calculated approximately and the second solution was calculated by performing operations. Participants at the end of both solutions;

> S1: I really felt like an engineer building an elevator and I was very happy to think that I helped.

> S2: When my teacher first asked the question, it felt very strange, but then I said that I could be in Ali's place, and I felt that Ali's problem would not be solved if I, the hero of the event, did not solve the question, so I wanted to solve it.

expressed their thoughts as follows.

## 3.2 The effect of mathematics problems prepared in the context of sustainability on attitude toward mathematics and possible reasons

The results of the analysis on the effect of mathematics problems prepared in the context of sustainability on the attitude toward mathematics are given in Table 6.

**Table 6.** Analysis results of pre-test and post-test scores from the Scale on Attitude Toward Mathematics

| Measurement | n | $\bar{X}$ | S. deviation | t | p |
|---|---|---|---|---|---|
| Pre-test total score | 32 | 110.79 | 7.69 | -26.63 | 0.00* |
| Post-test total score | | 184.84 | 14.11 | | |
| Pre-test score from interest sub-scale | 32 | 29.38 | 4.48 | -25.78 | 0.00* |
| Post-test score from interest sub-scale | | 53.79 | 6.53 | | |
| Pre-test score from anxiety sub-scale | 32 | 43.01 | 4.61 | -17.24 | 0.00* |
| Post-test score from anxiety sub-scale | | 26.79 | 2.11 | | |
| Pre-test score from study sub-scale | 32 | 23.32 | 2.42 | -31.21 | 0.00* |
| Post-test score from study sub-scale | | 36.32 | 4.55 | | |
| Pre-test score from necessity sub-scale | 32 | 30.07 | 2.52 | -13.50 | 0.00* |
| Post-test score from necessity sub-scale | | 36.71 | 5.14 | | |

*$p<0.05$

The results in Table 6 show that the participants of the study showed a significant increase in scores from the pre-test to the post-test in general in the Scale on Attitude Toward Mathematics, which revealed that the increase was statistically significant ($t_{(14.11)}= 26.63$, p=0.00). When the results of the sub-scales of the Scale are examined, it is observed that the average scores of the participants from the post-test are significantly higher than their average scores from the pre-test. In other words, it was observed that the students' scores from the interest sub-scale (($t_{(6.53)}= 25.78$, p=0.00), from the post-test application of the anxiety sub-scale (($t_{(2.11)}= 17.24$, p=0.00), from the post-test application of the study sub-scale (($t_{(4.55)}= 31.21$, p=0.00) and from the post-test application of the necessity sub-scale (($t_{(5.14)}= 13.50$, p=0.00)) of the scale were significantly higher than their scores from the pre-test applications of the above-mentioned sub-scales.

Table 7 represents the qualitative findings that support the quantitative findings, that is, the reasons that increase the attitude towards mathematics, with the sub-scales of the scale, the themes and accordingly, the sub-themes, and the frequencies of these sub-themes.

**Table 7.** Factors affecting attitude towards mathematics

| Theme | Sub-theme | f |
|---|---|---|
| Interest | Enjoying the lesson very much because students think they are part of the solution | 28 |
| | Enjoying reasoning in everyday-life situations | 17 |
| | Increasing self-confidence as they feel like the hero of the plot | 24 |
| | Feeling joy during mathematics classes as if they are using it to solve a real-life problem. | 21 |
| | Thinking that they feel complete while solving the problems | 11 |
| Anxiety | Decreased anxiety since the problem is solved by discussion in the classroom | 18 |
| | Not being affected by the success of their friends when they feel like they are working for a common goal | 29 |
| | No anxiety due to feeling like the hero of the plot | 22 |
| Study | Listening attentively and assuming that the activities come from real life | 19 |
| | Thinking of repeating the subject with daily life situations | 17 |
| | Studying without worrying about grades | 8 |
| Necessity | Realizing that the teacher is not boring | 12 |
| | Participating in problem solving willingly as an individual sensitive to sustainability, not out of necessity | 21 |
| | Realizing that mathematics is used in social life | 28 |

Table 7 demonstrates that the frequency values of the sub-themes of "not being affected by the success of their friends when they feel like they are working for a common purpose under the theme of anxiety of mathematics problems prepared in the context of sustainability" and "taking great pleasure in the lesson because they think that they are part of the problem solving in the interest theme" are high. The participants also stated that feeling like the hero of the plot when solving the problems related to the interest sub-scale increased their self-confidence, and therefore their attitudes towards mathematics changed positively, and that they felt happy to see the problems as a real-life situation, feeling completed with solving the problems. They stated that feeling like the hero of the plot and discussing the problems under the anxiety sub-theme in the classroom reduced their anxiety.

Under the study sub-theme, they stated that they listened carefully because they were in real life situations, that they repeated the topic they knew but related it to daily life, and that studying without grade anxiety increased their academic achievement.

They stated that for the problems under the necessity sub-scale, they thought that their teacher was not boring while they were studying the mathematics problems prepared in the context of sustainability. Although the problems were boring, they participated in the solution as an individual sensitive to sustainability, not because of necessity but also because they realized that they used mathematics in social life.

## 3.3 The effect of mathematical problems prepared in the context of sustainability on sustainability awareness and possible reasons

Table 8 shows the effects of mathematical problems prepared in the context of sustainability on sustainability awareness, the themes of interest, sensitivity and awareness, and related sub-themes with pre- and post-application frequency values.

**Table 8.** Themes and sub-themes of sustainability awareness

| Theme | Sub-theme | Pre-application f | Post-application f |
|---|---|---|---|
| Sustainability Interest | Following environment-related publications (TV, radio, magazines, books, etc.) | 3 | 12 |
| | Participating in environmental events | 2 | 9 |
| | Following the publications, developments and what can be done about hunger in the world | 1 | 13 |
| | Familiarity with the cultural values of oneself | 2 | 12 |
| | Following the publications, developments and what can be done about clean water and sanitary conditions | - | 11 |
| | Following the publications, developments and what can be done about quality education | - | 3 |
| | Following the publications, developments and what can be done about raising healthy individuals | 2 | 18 |
| | Following the publications, developments and what can be done for economic welfare | - | 12 |
| | Following publications, developments and what can be done for people with disabilities (sustainable city) | 4 | 21 |
| Sensitivity to Sustainability | Warning anyone who harms the environment | 6 | 28 |
| | Not harming the environment | 12 | 29 |
| | Participating in environment-related volunteer activities | 3 | 19 |
| | Warning anyone who harms cultural values | 1 | 9 |
| | Warning people who use water unnecessarily and pollute nature | 5 | 30 |
| | Warning uneducated individuals about compulsory education | - | 9 |

| | | | |
|---|---|---|---|
| | Warning an individual who has unhealthy habits | - | 11 |
| | Warning people around in situations that may cause economic difficulties | 2 | 25 |
| | Warning anyone about wrongdoings to people with disabilities (sustainable city) | 4 | 28 |
| Sustainability consciousness | Using recycled products | 2 | 29 |
| | Sharing environmental awareness and knowledge | 3 | 30 |
| | Protecting and supporting cultural values | 1 | 15 |
| | Having a better understanding of clean water | - | 19 |
| | Demonstrating personal development regarding quality education | - | 5 |
| | Paying attention to the requirements necessary to be a healthy individual | 2 | 27 |
| | Taking personal steps to ensure economic well-being | 2 | 25 |
| | Taking measures for people with disabilities (sustainable city) and informing people about these measures | 2 | 29 |

Table 8 shows that before and after the application for the interest theme on sustainability, participants have an increased frequency of following publications (TV, radio, magazines, books, documentaries, etc.) on the environment, hunger, cultural values, clean water and sanitary conditions, quality education, healthy individuals, economic well-being and people with disabilities. After the application, the participants stated that they watched documentaries such as “Dancing with the Birds, Our Planet, Chasing Coral, Cowspiracy: The Sustainability Secret, Mission Blue" and that they wanted to take part in what could be done to protect cultural values in Antalya and in foundations established for people with disabilities.

For the theme of sensitivity towards sustainability, it was observed that the participants stated that they had an increased willingness to take action for the environment, hunger, cultural values, clean water and sanitary conditions, quality education, healthy individuals, economic welfare and adverse situations for people with disabilities, to participate in voluntary activities compared to the pre-application period, and that they began to exhibit behaviors more sensitive to their environment.

After having learned how many liters of water get wasted per day online in the problem titled "We are Learning about our Water Footprint" (Figure 2), they stated that they learned about measuring liquids and that they realized that they could minimize their water footprint by taking precautions based on the suggestions on the last screen (Figure 3).

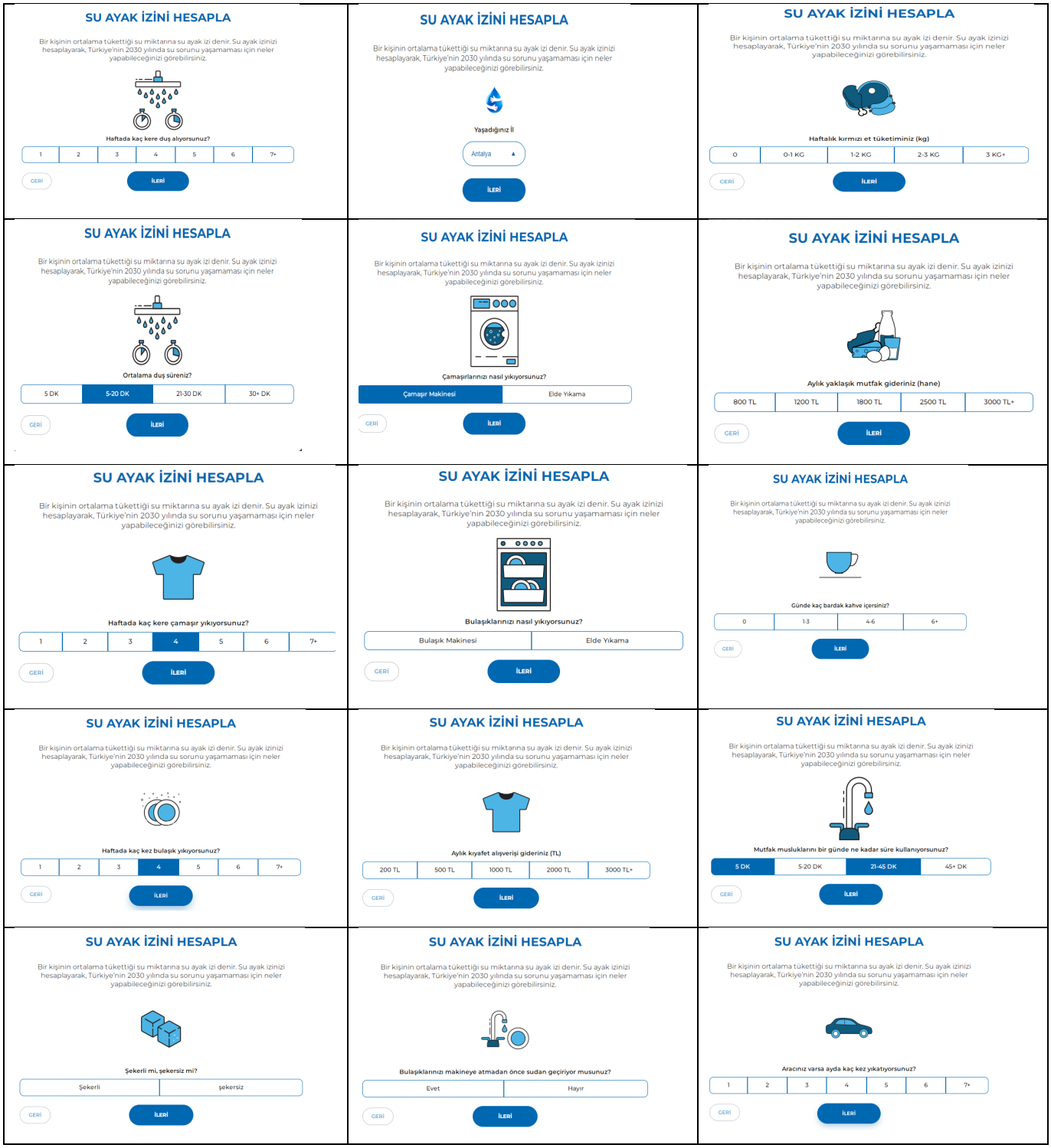


Figure 2. The exercise entitled ''We do we learn about our water footprint?''

Figure 2 shows the stages of the online activity and includes questions about calculating the daily water consumption of the participants at each stage. The personal water footprint calculation program (Figure 2) calculates how much water a person consumes directly and indirectly. The water consumed by the products purchased or

services utilized constitutes the indirect water footprint, while direct water consumption such as showering, washing dishes and brushing teeth constitutes the direct water footprint. The questions in the program reveal these situations and provide solutions. Online participants' total water footprint is calculated after they have answered these questions. The next stage is seen in Figure 3 which includes precautions to be taken to minimize the water footprint, and individual commitment.

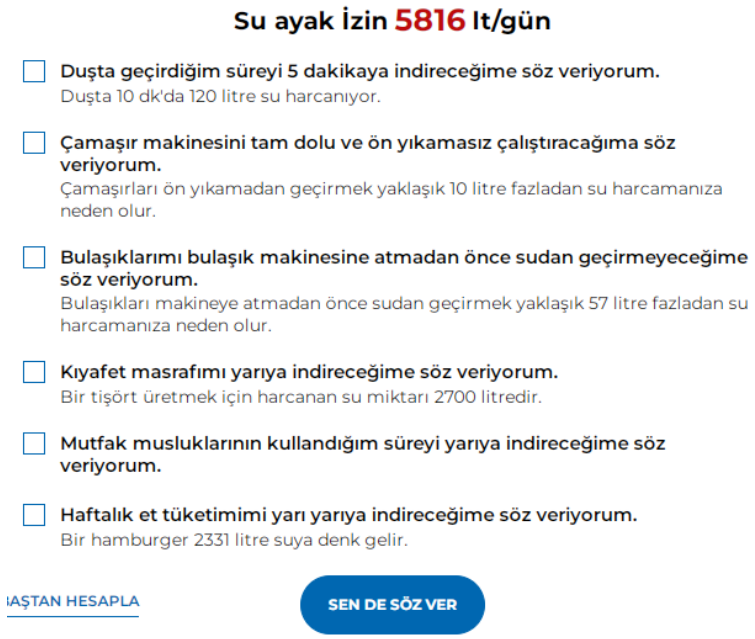


Figure 3. Recommendations to minimize water footprint

Figure 3 provides suggestions such as reducing the time spent in the shower to five (5) minutes, putting the dishes in the dishwasher without swilling them out, reducing the cost of clothing by half, reducing the use of kitchen faucets and reducing meat consumption by half.

The water footprint activity was considered positively by all the participants after the interview, and it was stated by the participants that the water footprint activity had a very important place in their awareness of sustainability.

It has been seen that mathematical problems prepared in the context of sustainability increase consciousness towards sustainability. The participants stated that they started to use the necessary materials for the environment, to avoid hunger, to enrich cultural values, clean water and sanitary conditions, quality education, healthy individuals, economic welfare and adverse situations for people with disabilities, shared their existing knowledge with people around them and took actions on these matters.

## 4 Conclusion and Discussion

This study demonstrated that mathematical problems prepared in the context of sustainability increased academic achievement in the field of mathematics. Participants expressed that the following factors affected academic achievement: raising awareness about mathematics, problem solving, serving a good purpose, and protecting nature and humanity. The situations emphasized most by the participants are that they had a sense of practicability since they have realized that mathematics is in every part of life, that they realized the areas of use for mathematics in real life, that they felt solving a problem related to daily life rather than a mathematical problem, and that they thought of doing work that adds value to society.

This study bears similarity to studies, revealing that contextual problems affect mathematical academic achievement positively (such as Boaler, 1994; Mahendra, 2016; Nizar & Putri, 2018; Pratiwi & Widjajanti, 2019; Selvianiresa & Prabawanto, 2017; Sembiring et al., 2008; Yuwandra & Arnawa, 2019; Widjaja, 2013). However, since each study includes different contextual situations, the studies referred to above and this study are not the same in terms of context. For instance, in his study "When do girls prefer football to fashion?", Boaler (1994) prepared the problems in the context of football and fashion. Sembiring et al. (2008), on the other hand, used cakes and bread of their cultures in contextual problems and showed that these elements supported academic achievement. Selvianiresa and Prabawanto (2017) identified daily life situations as contextual problems in their study. This study differs from other studies in that it was prepared in the context of sustainability but produced the same result that contextual problems, when used as a tool, increase academic achievement, which is the common goal of all studies.

In addition, Selvianiresa and Prabawanto (2017) argued that contextual problems develop the ability to associate these problems with daily life and that this increases academic achievement. For this study, it can be said that the students associated mathematics with daily life and experienced the applicability of mathematics in a different field, namely sustainability, and this increased their academic achievement by highlighting the importance of the context of sustainability. Moreover, Selvianiresa and Prabawanto (2017) have emphasized that mathematics does not become a problem in contextual situations but becomes an important criterion in solving problems in real life, and this finding is in line with the findings of this study. In other words, the students in this study stated that they did something that adds value to society, that they made the lives of disabled individuals easier by supporting them, that they

recycled waste as they solved problems and that they felt that they were a part of nature when they solved problems, and they have made this a criterion in solving the problems in their lives.

In the study conducted by Önal (2013), it was determined that students found contextual problems difficult, long, containing detailed information, time-consuming and confusing questions and focused on numbers instead of focusing on the content of the problem and made random operations with numbers when solving contextual problems. This contradicts the findings of this study. It was observed that the participants did not take any random operations in this study. Since sustainability is interesting and serves a good purpose, the students focused not only on the operations, but also on the process. It can be said that focusing on the process also supports academic achievement.

In their study examining the effects of context on understanding and transforming the problem, Dündar and Ezentaş (2020) reveal that secondary school students have difficulties in using context information, especially in separating relevant and irrelevant information, handling the context in a way that the problem does not require, and ignoring the context of daily life. In this study, the unnecessary information given in the problem – such as the way of using/driving the vehicle of a disabled person, the knowledge of what the upper dimension or cultural heritage might be – attracted the attention of the students, and it was stated that they did not think about it before, but they realized that it was actually very important. This does not correspond to the results of the study by Dündar and Ezentaş (2020). This can be attributed to the high interest of students in activities aimed at raising social awareness.

Another result of the study is that mathematics problems prepared in the context of sustainability positively affect students' attitudes towards mathematics. Starting from the sub-scale of the scale, the factors affecting the attitude were determined as students' interests, concerns, studies and need for mathematics. These were stated by the students mainly as enjoying the lesson very much because they thought they were a part of the problem, not being affected by the success of their friends when they felt like they were working for a common purpose and noticing that mathematics was used in social life.

This overlaps with the idea of Noss and Baki (1996) that if mathematical activities in the curriculum are closely associated with daily life, they will help students develop

positive attitudes towards mathematics. In other words, associating the problems prepared in the context of sustainability with daily life enabled the students to develop positive attitudes towards mathematics.

In addition, this study shows similarity to the studies proving that contextual problems affect attitudes towards mathematics positively (Awofala, 2014; Purba & Surya, 2020; Sanchal & Sharma, 2017; Uzel & Mert Uyangor, 2006; Van Eck, 2006).

In their study, Widjaja (2013) emphasizes that regardless of the context, students' asking questions for an explanation, making explanations and taking an active role in discussions by justifying their reasoning can lead to meaningful learning. In this study, no finding supporting these findings was found for academic achievement, but for attitude towards mathematics. In other words, the students associated the increase in their attitudes towards mathematics not with their academic achievement, but with their reasoning and sharing ideas in an environment of discussion.

Another finding of the study is that mathematical problems prepared in the context of sustainability increased interest, sensitivity and awareness towards sustainability. Sustainability is generally associated with social disciplines in the national literature (Türkiye) (Ateş, 2020; Çobanoğlu & Türer, 2015), and it appears in the curriculum (Kaya & Tomal, 2011) intertwined with the achievements in different units in Life Science, Social Studies and Science and Technology courses. Another idea that supports this is that there are studies in the international literature (Petocz & Reid, 2003; Renert, 2011) that state that it is difficult to associate sustainability with mathematics teaching. However, as a counterargument to these ideas, Li and Tsai (2021) advocate associating sustainability with teaching mathematics as an interdisciplinary approach to learning and teaching that is developed in collaborative and authentic ways to enable students to see it as a way of thinking about the world and their actions. This study does not overlap with the studies conducted by Petocz & Reid (2003) and Renert (2011) but overlaps with the study of Li and Tsai (2021). This study reveals that when sustainability is used as a tool in mathematics teaching, it can be associated with the subject and results obtained from such activities are positive. In other words, if the problems in mathematics teaching can be prepared and applied in the context of sustainability, this can improve the awareness of the concept of sustainability as well as success in mathematics and attitude.

## 5 Suggestions

The study revealed that mathematics problems prepared in the context of sustainability increased the academic achievement and attitudes of the 7th-grade participants towards mathematics and increased their awareness of the concept of sustainability. Suggestions will be given to two different groups: researchers and practitioners. Researchers are advised to apply different contextual problems at different grade levels and examine them in terms of different variables. Researchers can also provide practitioners with action plans for contextual problem writing, implementation, and evaluation. Practitioners are advised to compare primary and secondary school students with contextually prepared problems, to prepare the problem-solving achievements in the curriculum in different contexts, and to associate mathematics with daily life.

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