Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Vol. 18, Issue 1, June 2024, pp. 119-147. ISSN: 1307-6086

Research Article

Investigation of Emerging Mathematical Leadership in Mathematics Classroom: Application of Interdisciplinary Mathematical Modeling*

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Received : 13.03.2024 Accepted : 07.06.2024

Doi: https://doi.org/10.17522/balikesirnef.1452318

Abstract – The aim of this study is to determine the types of mathematical leadership that emerge in the process of applying Interdisciplinary Mathematical Modeling activities taken from real life. For this purpose, the researchers, working with a mathematics teacher and a science teacher, developed two interdisciplinary activities (the Stream Problem and the Energy Saving Problem). The activities were implemented in two groups of 3 and 4 students (11-12 years of age) studying in the 7th grade in a provincial center in the Eastern region of Turkey. In the application process, students put forward their own mathematical and scientific ideas by using their knowledge of mathematics and science in an integrated structure, and by supporting these ideas with group discussions, they produced different models (products). In the process of creating a model, it was observed that some students' came forth within the group, with their mathematical leaderships.

Keywords: Interdisciplinary mathematical modeling, mathematical leadership, middle school mathematics classroom.

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* This paper is formed in line with the corresponding author's thesis titled "Interdisciplinary Transition Through Mathematical Modeling".

Introduction

Leadership is one of those concepts that is quite difficult to define. McCleskey (2014) has argued that it may be futile to search for a single definition of leadership because the correct definition of leadership depends on the researcher's interest and the type of problem or situation being investigated. Leadership is one of the most widely used terms in many areas of human activity, such as education, business, politics, religion, sports, military, etc. Although it is difficult, it is quite important that the leadership has a good definition. Stogdill (1950) defined leadership as "the process (action) of an organized group influencing its efforts toward goal setting and goal achievement". Massarik et al. (1961) gave a similar definition to that of Stogdill, defining leadership as the interpersonal influence exerted in a situation and directed to the achievement of a specific goal or objectives through the process of communication. Kotter (1988) introduced a new perspective on leadership, defining leadership as "the process of directing a group (or groups) towards a specific direction, often in non-coercive ways". According to Mullins (2007), leadership is a process of social influence in which the organization seeks the voluntary participation of its subordinates in order to achieve its goals. Silva et al. (2019), discussing the above definitions, stated that leadership needs to be redefined and defined leadership as follows: "Leadership is the process of interactive influence that occurs when, in any given context, some people accept one among them as their leader, in order to achieve common goals". Like Silva et al. (2019), Stogdill (1950) and Kotter (1988), he has considered leadership as a process. According to Silva et al. (2019), the leadership process takes place in a specific context. If the context changes, the leadership process will also be affected by this. Similarly, Kellerman (2014) emphasized the influence of context in the leadership process. A leader can be defined as the person who assigns others to achieve certain goals, who selects, equips, educates and influences one or more followers with different talents and skills, and focuses them on the mission and goals of the organization (Bostancı, 2012; Winston & Patterson, 2006).

The complexity of the globe, which is changing rapidly every day, affects leadership as well. Although it is possible to talk about different types of leadership in the relevant literature (Gedik, 2020), the most emphasized ones are democratic leadership, authoritarian leadership (Arıkan, 2014) and charismatic leadership. In addition, Bolman and Deal (1991) state that leaders use different methods to define and solve problems and these methods are defined as leadership orientations (Turan et al., 2016). According to this perspective, there are four leadership orientations: structural framework (structure-oriented leadership), human resources framework (people oriented leadership), political framework (transformational leadership) and symbolic framework (charismatic leadership). The structural framework (structure-oriented leadership), which is based on logical thinking and a realistic approach to problems, pays attention to details, develops clear goals and reflects the results of the problems encountered to individuals. The human resources framework (people-oriented leadership), on the other hand, draws a framework that is closely interested in the feelings of the people in the group, supports them, encourages individuals to participate in the negotiation environment, and is open to new ideas. When the political framework (transformational leadership) is examined, it can be seen that these people are individuals with high persuasion skills, equipped with the ability to mobilize (control) people, are politically sensitive and talented, and are very adept at dealing with conflicts. Finally, the symbolic framework (charismatic leadership) consists of imaginative and creative individuals who inspire others, have strong communication skills, are open-minded, care about their culture and values (Dereli, 2003).

In this study, we focused on the types of mathematical leadership that emerge by taking into account the orientations of the students in the middle school mathematics class.

Mathematical Leadership and Theoretical Framework

The importance and leadership of mathematics has been as important as life itself for human beings since the earliest periods of human history. During the era of hunter and gatherers, people used mathematics to determine the weapons they used and the size of these weapons, as well as to determine the animals they would hunt. Between 2500 and 5000 B.C., as a result of the floods caused by the Nile river in Egypt, the boundaries of the landowners' were getting more and more blurry. Mathematics was used to re-define these boundaries (Baki, 2014). In the Sumerians, shepherds represented each animal with a clay cone, collected these cones in a clay bag or a clay cube, kept accounts of death, birth, purchase and sale, in short, they used mathematics to keep an eye of the herd that they looked after. The leadership of mathematics has also shown itself in the election of the chieftain of a tribe. In this tribe, the person who owned the most sheep was deemed as the chief of the tribe. If there were two candidates in the election, the sheep of each candidates were taken out of two adjacent pens, and the first one who had no more sheep to show lost the election. The journey of Pythagoras to learn mathematics, who claimed that numbers ruled the universe and was known as the father of numbers, the fact that Khwarizmi, who called the unknown a "thing", used algebraic expressions that could be considered high-level in his time, the discoveries made by Abu

Kamil, who used algebraic methods in solving problems, and many famous mathematicians that we cannot mention, and the use of their inventions in other branches of science, demonstrate the leadership of mathematics (Clark & Thoo, 2014; Fried, 2007; Heiede, 1992; Mann, 2011).

To this day, we can see that mathematics continues to be the leader of all sciences. As a matter of fact, Gauss's "mathematics is the queen of the sciences" statement, supports this claim. With the development of technology, it can be said that companies that develop completely mathematics-based software are the leading companies in the world. In fact, it is known that these companies make serious contributions to the economy of the countries where they are located. Therefore, mathematics is a leading science because it helps us to understand our surroundings, the environment, nature, our globe and the universe and to gain control over them. Being a leader who leaves a mark requires mathematics knowledge, as it is the leading science.

Although the person who is a leader in mathematics (mathematical leader) is generally better at reasoning skills, self-confident and patient, he may become prominent in the classroom microculture with his/her different characteristics. These features include the development of mathematical thinking skills, the ability to develop different strategies in problem solving, and the ability to make joint decisions by caring about the opinions of others. At the same time, the mathematical leader may show the ability to manage and direct the person or people in the learning environment without realizing it. For example, the answer to a problem posed in a learning environment can be shaped according to the answer of the person who is the leader in mathematics for that particular environment. In other words, the mathematical leader's answer can affect the answers of other people in the group. Nevertheless, other people in the group usually wait for the answer of the person who is considered to be the leader in mathematics, before answering the problem. This shows that mathematical leadership is also important in group studies.

When we evaluate the mathematical leadership framework, different approaches come to the fore in the literature. The trait approach emphasizes that some people are natural leaders and that they have physical characteristics and abilities that distinguish these natural leaders from others (Koçel, 2003). For this purpose, psychological tests were used to find out the characteristics of the leader (Yukl, 1998). According to this approach, the characteristics that a leader must have in the context of mathematics are as follows (Daft, 1991): physically; one must be active, intelligent, knowledgeable, and speak fluently; as a personality, one must be creative, outspoken, honest and take responsibility, socially; one must be cooperative and kind. This approach, which examines the leadership process by only considering the leader variable, has not been very successful. In research, it has been determined that sometimes, leaders in mathematics do not have the same characteristics, and it has also been observed that although there are group members who have more than the characteristics of a leader, they do not emerge as mathematical leaders (Koçel, 2003).

In another approach, the behavioral approach, it is emphasized that what makes a leader successful and effective in mathematics is the leader's behaviors during the leadership process, rather than the leader's characteristics. Whether the leader delegates authority, the way he plans and controls, the way he sets goals, etc. are considered as important factors that determine the effectiveness of the leader. Various applied research and theoretical studies have contributed to the development of behavioral leadership theory. For example; Osborn and Hunt (2007) revealed the existence of two main axes in defining leadership behavior; “establishing structure” and “showing understanding”. Rensis Likert's System 4 Model divides leadership approaches into four groups; exploitative, protective (paternalistic, helpful), consultative management style, and participatory management (Bingöl et al., 2013). The common point of these studies is that leaders pay attention to two things when demonstrating leadership behavior; person and behavior. Studies have confirmed the hypothesis that person-oriented leadership is more successful in the long run, however, various criticisms have been made, ranging from that the concepts used are simplified and generalized to the validity of the methodology used (Dereli, 2003).

In the contingency approach, the basic assumption is that different conditions affect mathematical leadership style. There is no one-size-fits-all leadership style. The main idea of this approach is that a task- or relationship-oriented leadership style cannot be valid in all situations and conditions, that in some cases a task-centered leadership style can lead to effectiveness, and in some cases, on the contrary, a relationship-centered leadership style can be efficient and effective.

There is no single definition accepted by everyone regarding the concept of mathematical leadership, and there is no single type of leadership style suitable for every group. Studies on leadership that have been carried out to date and are still being conducted have revealed different mathematical leadership styles that take into account (a) the environmental conditions, (b) the process in which leadership is experienced and (c) the personal characteristics of the leader (Çelik & Sünbül, 2008). In this context, the current study evaluated mathematical leadership based on the tendencies exhibited by students in a given situation, based on the contingency approach.

Problem Status and Purpose

In this study, in the context of mathematical leadership, middle school students were brought together in groups with interdisciplinary mathematical modeling activities that are related to real life, which can contain more than one solution which are functional, contain complexity compared to classical mathematics problems, and provide science and mathematics concepts together in the same activity. Interdisciplinary Mathematical Modeling (IMM) activities are open-ended, interdisciplinary problem-solving activities that challenge students to build models to solve real-life problems and encourage them to test the models they have built. In this study, considering the theoretical structure of IMMs, two IMM activities were developed that include the learning areas of Mathematics and Science disciplines. IMM activities are inherently complex. IMM makes it possible to create different solutions to problems via using information from different disciplines. The developed IMM activities were distributed to two groups of three and four students, and these groups were asked to work collaboratively and put forward a mathematical model. In the process of creating a model related to IMM activities, it was observed that the students had to cooperate, discussed the positive and negative aspects of the model they created in a purposeful way, and some of them took an active role in the decision-making process about how the final version of the model should be, as a group. In summary, in the process of building a model, it was observed that some students' mathematical leaderships became prominent compared to other members of the group. Therefore, the aim of this study is to examine what kind of mathematical leadership emerges in students in the model building process of interdisciplinary mathematical modeling activities. In this context, the problem of the research is as follows: What are the types of mathematical leadership observed in students during the interdisciplinary mathematical modeling process?

Method

In this study, a multi-tiered teaching experiment (Lesh & Kelly, 2000) was used to determine the types of leadership that emerge in the solution process of interdisciplinary mathematical modeling problems. Multi-tiered teaching experiments, by their very nature, provide learning experiences for all participants and create environments that promote maximum learning. In multi-tiered teaching experiments, participants cannot think independently of each other, even if they are at different levels of learning. Mathematical modeling activities are often used in classroom applications of research designed according to multi-tiered teaching experiments (Lesh & Kelly, 2000).

In the first phase of this study, in which the multi-tiered teaching experiment method was used, the researchers conducted semi-structured interviews with mathematics and science teachers within the scope of interdisciplinary learning and mathematical modeling. In the second stage, the researchers, together with mathematics and science teachers, developed two IMM activities that included the achievements of these two disciplines. In the third stage, the applications of the developed IMMs were made in the teachers' own classrooms. In the implementation process, each teacher implemented the relevant part in regard to his/her own discipline. This study focuses on the discipline of mathematics and the types of mathematical leadership that emerge in the application process of the relevant experiments.

Participants and Implementation Process

Text The participants of the study consisted of two teachers (Mathematics, Science) working in the central school of a province in the Eastern Anatolia Region of Turkey and 7th grade students (12-14 years old) selected from the same school. In the selection of teachers, volunteering and professional experience were prioritized. The science teacher has 10 years of professional experience and adopts a constructivist philosophy in teaching. In addition, the mathematics teacher has 8 years of professional experience and has a master's degree in the field. Both teachers include modeling activities while teaching and encourage their students to create models. Therefore, it can be said that teachers have experience in conducting the modeling activity.

The participating students (4 girls, 3 boys) live in an environment with moderate socioeconomic levels. It was also found that their average score of the 6th grade mathematics course was 87/100. It can be said that this situation has a positive effect on the participant group in terms of their readiness. When the students were evaluated individually as a result of the interviews with the class counselor in the context of their mathematics backgrounds, it was revealed that;

The student with the code S1 comes from a middle-level and non-crowded family structure in terms of socioeconomics. He is the only child of the house. It can be said that he usually participates in classroom discussions and has a good communication with his friends. However, although his 6th grade mathematics achievement score was lower than the class average, it was evaluated that he did not refrain from trying different approaches, especially in problem solving, and was able to explain his solutions.

The student with the code S2 comes from a family structure whose socioeconomic status is not good. He is the eldest of three children. It is emphasized that he does not communicate much with anyone in social life and is introverted. He is one of the students with the best 6th grade achievement score. It was observed that he participated in classroom discussions in mathematics and science courses, but did not participate much in other courses.

The student with the code S3 comes from a family structure with a good socioeconomic status. He is the younger of two children. He is very good in social life and has good communication with his peers. His 6th grade achievement score is above the class average. It was observed that he is active in classroom discussions in all courses.

The student with the code S4 comes from a family structure whose socioeconomic status is not good. He is one of the twin children of the house. He is very good in social life and has good communication with his peers. His 6th grade achievement score is below the class average. He is not very active in classroom discussions during lectures. He remains in the background in problem solving and discussions.

The student with the code S5 comes from a middle-level and non-crowded family structure in terms of socioeconomics. He is the elder of the two children. He social life and communication skills with his peers is not very good. However, he quite enjoys reading books. When his knowledge of this particular subject is sought, he can express himself very well. He is one of the students with the best 6th grade achievement score. He loves to put out a product and to do experiments. In lectures, in class discussions, he can explain the solution of problems well. It has been widely seen that he exhibits unusual approaches to solving problems. He is also a student of the Science and Art Education Center.

The student with code S6 comes from an intermediate-level family structure in terms of socioeconomics. He is the middle one of the three children of the house. He is very good in social life and has good communication with his peers. His 6th grade achievement score is above the class average. Although he is not very active in classroom discussions in Mathematics and Science, he is more active in linguistic lessons such as Turkish and Social Studies. His academic achievement score of the mathematics course is lower than other courses. He has difficulty in solving problems and remains in the background in discussions about solutions.

The student with the code S7 comes from a family structure with a good socioeconomic status. He is the youngest of four children. He is very good in social life and has good communication with his peers. His 6th grade achievement score is above the class average. He is going to a music course in order to learn to play an instrument. In the classroom, he is usually active in all classroom discussions. It has been observed that he exhibits different approaches to solving problems, makes justifications by establishing a cause-and-effect relationship while explaining his solutions.

During the application process of the research, the students were divided into two groups of three and four individuals (group A: S2, S5, S1 and group B: S3, S4, S6, S7). The first of the developed activities was applied to groups in 3 lecturing sessions and the other in 4 lecturing sessions. Each lecture session lasted approximately 40-60 minutes. In all lecture sessions, the science teacher answered the students' questions about the discipline of Science, and the mathematics teacher answered their questions about the discipline of Mathematics. In the first lecture, the teachers informed the students about the problem and introduced the main components of the problem to the students. In the second lecture, the students worked in groups on the concepts in the problem and prepared a list of the givens/requests related to these concepts. The teachers observed the students, gave them tips where necessary, but did not directly intervene with their actions. After the students discussed the concepts related to the discipline of Science in the problem with the science teacher, and the concepts related to the discipline of mathematics with the mathematics teacher, the applications of the third and fourth lecturing sessions were started. In the third and fourth lecture sessions, students identified variables to build a mathematical model of the problem, and tested the model. During the model building process, teachers have overseen the groups, gave tips where necessary, and encouraged students to build models.

Data Collection

Teaching experiments are predominantly concerned with how students do something, just as they are interested in what they do. For this reason, the data collected are usually qualitative rather than quantitative. Cobb and Steffe (1983) state that the qualitative data from the teaching experiments are fed by two main sources: the teaching and the interviews or observations made at regular intervals. Therefore, the data collection tools of this study are video recordings containing the explanations of the students during the implementation process of the developed IMM activities (see APPENDIX 1, APPENDIX 2) and the observations made by the researchers. In addition, the researchers kept notes on both intragroup and intergroup discussions. These notes were evaluated together with video transcripts and this was how the data analysis had been performed.

Data Analysis

In the first step of the analysis, the dialogues of the group members were transcribed and converted into a written text. The discourses in the text were examined according to two characteristics by making explicit coding; narratives and the use of words (Sfard, 2008). The narratives contain mathematical propositions that students accept as legitimate in the process of creating models to solve the problem. The mathematical words used by the students to explain their preferences are shown in bold in the explanations. Each member of the research team participated in the labeling (identification) of these two traits, and the acceptance of problematic definitions was discussed and approved.

In the second step, in which axial coding (Strauss & Corbin, 2007) was performed, the common features of the narratives and mathematical words that were ultimately confirmed were determined in the context of mathematical leadership.

In the third step, in which selective coding (Strauss & Corbin, 2007) was performed, it was attempted to infer mathematical leadership when different narratives shared characteristics related to the same topic around a center. In this process, students' defensive, approving or rejecting discourses were considered as a reference in determining mathematical leadership. In addition, cases in which students actively participated in discussions or listened attentively to other students trying to create new meanings were also used to judge that mathematical leadership was occurring.

In the final stage of the analysis, the inferred mathematical leads were compared and correlated with the data obtained from the observation notes kept by the researchers. Thus, a contribution has been made to the consistency of the determined leadership types (Yıldırım & Şimşek, 2011). The results were presented based on the nature of the data and contributed to the transmissibility of the research results to similar situations.

Results

One of the activities included in this study, which focuses on the types of mathematical leadership that emerge during the implementation process of IMM activities, is the stream activity (see APPENDIX 1). In this activity, which was developed for gains such as the ability to create tables and graphs, to analyze and interprete data, and determine possible outcomes, students were expected to create a model indicating the pollution rates of the waters by using data such as invertebrate insect species, fish diversity, and mineral variety in samples collected from streams from different villages. The type of mathematical leadership inferred in group A during the model creation process is reflective leadership. The narrative about the legitimacy of this type of leadership is shown in Table 1.

Table 1 A Section from the Dialogue Held by Group A in the Process of Solving the Stream Problem

Narrative	The type of leadership that is inferred	Scope
S5: Write (S1 writes from A to E). Salinity: 330, 358, 349, 327, 342. Phosphorus: 20, 25, 35, 30, 40. Nitrate: 25, 35, 30, 45, 40. Nitrogen: 7, 14, 12, 10, 8. pH: 6.8, 6.5, 7, 7.2, 6.7 **S2:** (raising his voice) Let's check the **fish species again** (they check as a group for a while). Ok. **S5:** Salinity… **S1:** The one with the most salinity will be contaminated. **S5:** Phosphorus? **D1:** Should be minimal. **S2:** Look, read here (finds something wrong with the model and shows the reading part). **If the pH is greater than 7, it is clean**. **S5:** then the pH value should be high.	Reflective leader	Actively analyzing previous experiences and actions

When the narrative in Table 1 is carefully examined, it is clear that in group A, S5 wanted to study the mineral structures in order to create a model. However, his lack of communication skills with his peers must have hindered his perception as a leader, and S2's suggestion that fish species should be rechecked was accepted by the group. In their field notes, the researchers stated that the students, especially in group A, evaluated their first discourse based on S2's answers and structured their thoughts around his explanations. In this context, S2, although personally introverted, showed leadership properties in terms of mathematical communication skills within the group. S2 repeatedly reviewed and questioned the variables he wanted to be included in the model. Thus, he had the opportunity to test the accuracy of the ideas he focused on. In addition, S2's rechecking of fish species and re-examination of the activity text indicate that he aims to minimize possible errors in the model. This way of thinking can be associated with the concept of reflectivity, which means actively analyzing previous experiences and actions so that the best model emerges. For example, a student can do reflective thinking by reviewing the mistakes he made in a problem and finding solutions to prevent its recurrence. Therefore, the type of mathematical leadership inferred in this group was coded as reflective leader. S2 analyzed all the variables to come up with the model, and in doing so, actively encouraged in-group discussion. The fact that the group members do not object to S2 shows that this understanding or attitude is perceived by the group members as a leader. “... Let's check again", "If Ph is greater than 7, it is clean". These statements shaped the interaction between class members and allowed students to create and present their own mathematics. When the situation of the same activity in group B was examined, the type of negotiant leader was deduced. The narrative about the legitimacy of this type of leadership is shown in Table 2.

Table 2 A Section from the Dialogue Held by Group B in the Process of Solving the Stream Problem

Quotation	The type of leadership that is inferred	Scope
S3: Which one was the most murky? **S6:** E. **S3:** Then E is the dirtiest. **S6:** Because A is the least murky, so A is the cleanest. **S3: What was T**? **S7:** T is here… **S3: How is the salinity?** It has the maximum salinity, from clean to dirty, so it should be D. **S4:** A has the least amount of phosphorus. The cleanest (according to phosphorus) that is. The one with the least amount of nitrate is A. Again, the cleanest. In terms of nitrogen, again, A is the cleanest. **S3:** Yes	The negotiant leader	To ensure that variables are negotiated by bringing them into the discussion environment

When the above narrative was carefully examined, it can be seen that the students in group B evaluated the variables requested by S3 one by one, not the variables they directly determined, during the model creation phase. S3's high communication skills made him perceived as a natural leader within the group. S3 brought the murkiness variable to the discussion environment and asked the group to discuss this variable. After S6's discourse, he confirmed the value of this variable, making the group accept this value. The fact that S6's mathematics grade was lower than the other subjects made S3 skeptical and he brought salinity to the discussion environment and allowed it to be negotiated. S7's answer must not have satisfied S3, and after S4's answer, he similarly approved the evaluation of these variables. The fact that the group did not object to S3 and left the final approval to him showed that they accepted this situation and considered his views (actions or statements) legitimate. Indeed, according to the field notes the researchers kept, S3, in its role as the final validator, encouraged the group to build models. S3 is a student who has good communication with his peers. Within the group, both his negotiating the variables and his perception as an approving authority indicated that he showed deliberative leader characteristics. Questions such as “Which one is the murkiest?”, “How is the salinity? are indicative of the characteristics of a negotiant leader.

Another activity implemented in the classroom microculture is the energy saving activity (see APPENDIX 2). In this activity, students were expected to perform arithmetic calculations, perform conversions between units and create a model by combining variables. In the process of model building, students in both groups A and B had discussions to test the accuracy of mathematical operations and reasoning, and exhibited controlling approaches in the context of mathematical leadership. In short, the understanding that enables this type of mathematical leadership, which we call controlling leadership, to be accepted by students is the presence of leaders who closely follow the roles of group members in the problem-solving process, distribute roles and check the accuracy of the solutions. The narrative about the legitimacy of this type of leadership is shown in Table 3. The narrative shows that students in group A tend to check data on solutions of problems by establishing cause and effect relationships.

Table 3 A Section from the Dialogues of Group A in the Process of Solving the Energy Saving Problem

Quotation	The type of leadership that is inferred	Scope
S2: Vacuum cleaner (brand D) 99.88 kilowatts. **S5:** Let's look at the TV. 103… **S2: You add it as 100+3, right?** **S5:** Yes **S2:** Okay, tell me. **S5:** 103 times 365 **S1:** 37,595 **S2:** Are you sure? **Did you divide by 1000?** **S1:** I'm sure. **S5:** 1010 times 364 divided by 10... (They calculate the energy consumption of the brand A iron. They convert 52 weeks into days). **S2: Divided by 1000 (There are laughs)** **S5:** Divide by 1000. **S5:** 367,64.	The controlling leader	Closely monitoring the roles of group members in the problem-solving process and checking the accuracy of the solutions

When the narrative in Table 3 is carefully examined, it can be seen that S2 tells S5 what actions to take by telling the values of each brand in the problem, together with their units. In addition, S2 tested which operations S5 performed mathematically by asking various questions. Then, combining the problem data, he told S1 what actions to take and asked him questions such as "Are you sure? Did you divide by 1000?" and checked the accuracy of the operations made. The fact that the group members do not object to this understanding or attitude shows that S2 is perceived as a leader who monitors the problem solutions of the group members and controls all the details. As a matter of fact, in the field notes kept by the researchers, it was stated that the students in group A validated their discourse through S2's answers and structured their own solutions after passing S2's control. Although S2 did not have good communication with his peers, he showed leading and controlling characteristics in this activity in terms of mathematical communication within the group. The main factor of him being in control is that he tells the group members what they shall do, reviews what they do and tries to prevent mistakes. When the situation of the same problem in group B is examined, the narrative about the controlling leadership type is shown in Table 4.

Table 4 A Section from the Dialogues of Group A in the Process of Solving the Energy Saving Problem

Quotation	The type of leadership that is inferred	Scope
S3: 357 thousand... 357.7. Now let's find refrigerator B. **You tell him (he looks at S7) he can multiply (S4), and I'll write it down.** **S6:** 955 times 365. **S4:** 348 comma 575. Divided by: 1000. Is equal to: ? **S3:** (**He takes the calculator from S4)**. One minute. 348,575 divided by 1000 equals (Judging by the result on the calculator) something like this came up. **Teacher:** Try again? **S3:** 955 times 365. 348,575. Hmm, okay, calm down, why didn't you tell me about this comma. **S7:** 348 thousand 575 divided by 1000 equals: 348 comma 575.	The controlling leader	Closely monitors the role of group members in the problem-solving process and verifies the solutions with a calculator

When Table 4 is carefully examined, it can be seen that the students in group B questioned the mathematical operations and the variables of each brand in the problem one by one in the model creation process. The group members checked the accuracy of the mathematical operations using a calculator by conducting mathematical discussions among themselves. S3 determined the values of each brand in the problem and told the group members what operations they should do on the calculator. Following this, the group members tried to find out the results of the operations with a calculator. S3 has determined who will perform the operations by distributing the tasks in the group. The fact that the group members do not object to this understanding or attitude shows that S3 is perceived as a leader who monitors the problem solutions of the group members and controls all the details. As a matter of fact, in the field notes kept by the researchers, it was reported that the role distribution of S3 was effective in group B and that the model was created according to the calculations of the people responsible for those roles. S3 is a student with strong communication skills. The main factor of him being a controlling leader is that he focuses on the roles of the group members and verifies the results using a calculator and also gives directions such as "You give the numbers (looks at S7) he can multiply (S4) and I can write the results down". He also takes the calculator from S4.

Conclusions, Discussions and Suggestions

In this study, IMM activities taken from real life were put to work in a middle school mathematics classroom setting and we focused on the mathematical leadership tendencies that emerged during the application process. The first activity, in which two different actions were employed, is an IMM activity (Stream problem) developed for the teaching of creating tables and graphs, data analysis and interpretation, and determining possible outcomes, and the other is an IMM activity (Energy Saving problem) that requires mathematical calculations and conversions between units, and aims to produce a model by combining variables. Two groups formed in the classroom microculture were asked to create a mathematical model suitable for the given specific problem and the types of mathematical leadership that emerged in this process were examined. In both activities, certain students within the group directed the interaction and were able to manage the process. It can be said that the mathematical leadership types that emerged in the study coincide with the leadership understanding defined by Silva (2016). In this context, the legitimate actions and discourses of the group members related to model building have created the context of mathematical leadership and have drawn an image that distributes mathematical roles and actively contributes to the formation of the model (Winston & Patterson, 2006).

Regarding the stream problem, in group A, S5's questioning attitude was prominent, while his lack of communication with his peers prevented him from being perceived as a leader by the other members of the group. It was found that the students in group A evaluated their first discourse through the answers of S2, who has an introverted personality trait, and structured their thoughts around his explanations. S2 has taken care to analyze the mathematical ideas that have been put forward by involving other members of the group in the process of creating a model. This action was considered legitimate in the group. In addition, reconsidering the variables given in the problem and questioning the answers of their peers shows that he aimed to minimize possible errors. This indicates solid behaviors that reveal reflective leadership. As a matter of fact, according to the literature, the personality traits such as inspiring others, having strong communication skills, being open-minded, caring about the culture and values, having strong imaginative and creative skills are also expected from leaders who are described as charismatic (Dereli, 2003). In this context, it can be said that reflective leadership is open to mathematical inquiry and legitimizes norms that minimize the possibility of error in classroom microcultures. However, it can be said that the reflective leader is closer to authoritarian temperament in terms of dominating individuals, observing what individuals do, controlling their activities (Turan et al., 2016), closely supervising learners, more speaking than listening and similar behaviors. When the application process of the same activity in group B was examined, it was seen that the response of the group was shaped according to the answers of S3. S3, who has high communication skills, was the one who made the final decision by filtering the answers of his peers through his own mental process. S3 took a skeptical approach to the answers of the group members, had the answers discussed and negotiated within the group. In this context “Which one is the murkiest?” and “How's the salinity? and questions similar to these indicate negotiant leadership. As a matter of fact, it is an attitude expected from leaders who are closely interested in the feelings of the people in the group, support them, encourage individuals to join the group and draw an open framework for new ideas (Dereli, 2003). In addition, it can be said that negotiant leadership includes behaviors belonging to the democratic leadership (Goleman et al., 2002). The democratic style helps to bring to the surface the ideas on how to perform the best mathematical model, or to generate fresh ideas for doing so. However, when these ideas are over-relied upon, it is inevitable to have too many conflicting ideas and it will be impossible to reach a consensus. In addition, a leader who lacks the ability to adapt to a wide variety of ideas will be more prone to adopt the wrong ones. It has been accepted as a principle that the type of leadership that is democratic, participatory and attaches importance to the solidarity of ideas is better than authoritarian leadership. However, it would not be wrong to say that this may vary according to the characteristics of the working environment and the group (Arıkan, 2001).

Regarding the Energy Saving problem, it is seen that in group A, the leader was S2. In the problem-solving process, S2 controlled the actions of the group members by organizing the data in the problem, directing them and telling them what actions they should take. The members of the group observed S2 and did not object to his actions. With statements such as "You add 100 and 3, right?" and "Did you divide it by 1000?", it has been observed that he verifies the data and operations of his peers and adopt a controlling leadership in solving the problem. In the implementation process of the same activity in group B, it was realized that S3 directed the group and distributed tasks in the group. S3 told the group members what operations they should perform on the calculator in the process of solving the problem and checked the results himself. The fact that the other members of the group did not object to S3 shows that they perceive him as a controlling leader. His discourse "You tell him (he looks at S7) he will multiply (S4) I will write the results down" and him taking the calculator from S4 are indicative of controlling leadership. Based on the fact that the leader himself determines which jobs will be done and how these tasks will be carried out, we can say that controlling leadership also has authoritarian characteristics. As a matter of fact, there are characteristics that overlap with controlling leadership in the context of characteristics that are based on clear logical thinking and realistic approach to problems, paying attention to details, developing clear goals, and holding individuals responsible for the consequences of the problems encountered. It can be seen that these people are individuals with high persuasion skills, equipped with the ability to mobilize people, are politically sensitive and talented, and are very adept at dealing with conflicts. "Hmm, okay, calm down, why didn't you tell me about this comma." This discourse shows that S3 is also mathematically effective in this regard.

As a result, in this study, the types of mathematical leadership legitimized by the students in the mathematics class of a secondary school where IMM activities were implemented included reflective, negotiant and controlling normatives. Although some of these normatives surprised the teachers who implemented it, it can be said teachers mostly agree with the general results obtained by the study. In this context, it is inevitable that the effects of these normatives on mathematics learning/teaching will open new horizons for both the teachers and educators working in the field.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

The authors declare that this study and no processes involved in conducting the study have the potential for conflicts of interest.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

CRediT author statement

Author 1: Conceptualization, Data curation, Formal Analysis, Methodology, Resources, Writing - original draft, review, and editing

Author 2: Conceptualization, Methodology, Writing – review, editing

Author 3: Conceptualization, Methodology, Writing – review, editing

Research involving Human Participants and/or Animals

Ethical standards were followed in the writing of this article.

Matematik Sınıfında Ortaya Çıkan Matematiksel Liderliklerin İncelenmesi: Disiplinler Arası Matematiksel Modelleme Uygulaması

Özet:

Bu çalışmanın amacı, gerçek yaşamdan alınmış Disiplinler Arası Matematiksel Modelleme (DMM) etkinliklerini uygulama sürecinde ortaya çıkan matematiksel liderlik türlerini belirlemektir. Bu amaçla, araştırmacılar bir matematik ve bir fen bilimleri öğretmeni ile birlikte çalışarak disiplinlerarası iki etkinlik (Dere Problemi ve Enerji Tasarruf Problemi) geliştirmiştir. Etkinlikler Türkiye'nin Doğu bölgesinde bir il merkezinde 7. sınıfta öğrenim gören 3 ve 4 kişilik (11-12 yaş) iki gruba uygulanmıştır. Uygulama sürecinde öğrenciler matematik ve fen bilimleri ile ilgili bilgilerini bütünleşik bir yapıda kullanarak kendi matematiksel ve bilimsel fikirlerini ortaya atmış, bu fikirlerini grup içi tartışmalarla destekleyerek birbirinden farklı modeller (ürün) ortaya koymuşlardır. Model oluşturma sürecinde grup içinde bazı öğrencilerin matematiksel liderliklerinin ön plana çıktığı görülmüştür.

Anahtar kelimeler: Disiplinler arası matematiksel modelleme, matematiksel liderlik, ortaokul matematik sınıfı.

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APPENDIX 1

Stream Activity

Since water is indispensable for all living things, its pollution leads to a decrease in biodiversity in nature. Substances mixed into water sources for various reasons cause pollution by changing their chemical, physical and biological properties, such as lakes, rivers, seas, oceans and groundwater. Due to water pollution, some life forms die, while others carry pollution throughout the food chain. In order to prevent this, we must protect natural water resources and prevent unnecessary water consumption.

One of the important water sources of our province is the Kadran Stream. The Kadran Stream starts from the Kadran Mountains and flows into the Göynük Creek and then into the Murat River. The local folk do fishing in this stream and also use it to irrigate their farmland. This stream is inhabited by creatures called invertebrates which do not posses any skeleton in their structures, as well as various species of fish and insects. There are five different villages (A, B, C, D and E) en-route where the Kadran stream flows. The village of A is located near the source of the stream, and the village of E is located near the river where the stream flows into. The villagers use this stream to irrigate their farmlands. The increasing pollution of the stream in recent years also negatively affects the products grown by the villagers.

Teachers in the Environmental Conservation Club of our school organized a competition for 7th grade students to investigate the effect of pollution in Kadran Stream over the crops grown in these villages. In this competition, the students were divided into 5 groups and each group collected samples from the sections of the stream flowing into the villages. Thus, the samples taken will be examined and the pollution rates of the water taken from the villages will be revealed. The factors affecting the pollution rate of the water of the stream can be listed as follows: i) Invertebrates living in the water affect the pollution rate. While some invertebrates are very sensitive to pollution, others can be less sensitive. The sensitivity level of invertebrates is classified as follows: Between 5-10 "**Very Sensitive**", between 3-4 "**Moderately Sensitive**" and between 1-2 "**Less Sensitive**". The more invertebrates that are sensitive to pollution in a body of water, the cleaner that water is. ii) The diversity of fish species is the second factor in determining the pollution rate of the water. The number of fish living in a body of water is inversely proportional to the pollution rate of that body of water. In other words, the more fish species live in a body of water, the cleaner that body of water is. iii) Other factors affecting the pollution rate of water are factors such as the amount of dissolved oxygen, phosphorus, nitrogen, salinity of the water, weed species living in the water, and the pH level. The pollution rate of water is directly proportional to the amount of phosphorus, nitrogen, salt and harmful weed contained within it, and inversely proportional to its dissolved oxygen content. pH is a unit of measurement that indicates the degree of acidity or alkalinity of a solution. The pH value of water indicates the density of hydrogen ions within it. The pH density of water is measured with numbers ranging from 1 to 14. At pH 7, water is neutral. Waters with a high pH value are generally considered cleaner.

Preparation Questions

1) “What do you understand by the expression ”invertebrates"? Draw the image of an invertebrate creature.

2) How does the degree of sensitivity of invertebrate creatures change?

3) Why did the teachers of the Environmental Conservation Club organize such a competition? Please explain.

4) What are the factors affecting the pollution rate of water?

5) How do factors such as the amount of dissolved oxygen, phosphorus, nitrogen, salinity of water, harmful weed species living in water, affect its pollution rate?

6) What does pH mean? What pH numbers can water have?

THE PROBLEM OF DETERMINING THE POLLUTION RATE IN THE STREAM WATER

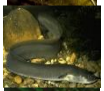
Teachers participating in the Environmental Conservation Club needed a model (system) to evaluate the data collected by students. The samples collected by the students from A, B, C, D and E villages are given in Table-1 and Table-2. Based on these samples, determine the pollution rates of the water collected from each village and develop a model showing the pollution rates of these waters so that teachers can easily evaluate the data of all 5 groups in this model you developed.

Good luck…

Species	Length	Features	Shape	Score	Number (Pcs)				
					A	B	C	D	E
		Very sensitive							
Caddis worm	above 20 mm	They live around the streams that flow rapidly into fresh waters. They have a silky structure that protects their soft tissues.		6	12	7	9	3	10
Dragonfly	18-50 mm	They are short and thick with wing pads and internal gills. All six legs they have are located around their heads.		6	7	6	10	14	9
May bug	10-20 mm	They live only in clean waters with high amounts of oxygen. They breathe using their gills.		7	5	7	2	4	6
Stonefly	above 50 mm	With their three-limb legs and long antennae, they need large amounts of oxygen.		8	3	4	5	2	1
Mite	5 mm	The adult ones swim and crawl freely. They usually live as parasites.		5	5	6	3	7	4
		Moderately Sensitive							
Freshwater shrimp	10-30 mm	It is also known as the brine shrimp.		3	3	5	7	2	4
Freshwater mussels		They are classified within molluscs. They have two shells.		3	4	4	4	3	5
Leech	3-15mm	They are worms that are segmented at one or both ends. In addition to living on plants, they can also roam freely in water.		3	8	7	4	10	12
Flatworm	2-5mm	Even if they lose a body part, they can reproduce it. They roam free.		3	7	8	5	6	4
Snail	10-20 mm	They resemble water snails, but are smaller.		3	5	5	6	3	4
		Less Sensitive							
Water scorpion	30 mm	They have legs that they use to hunt. They are carnivores and feed on small insects. They are usually found in mudflats of streams		2	6	8	10	7	6
Bloodworm		They resemble red thin worms. They have no legs.		2	7	5	5	4	6
Mosquito larvae		They can turn and curl. They have fins to swim in water.		2	8	6	3	5	9

Figure 1 Invertebrate Species Found in the Stream and Their Sensitivity Levels

Table 1 Species and Numbers in Each Region

Fish species	Example	A	B	C	D	E
Swordtail		5	2	2	1	1
Snake		0	0	0	1	1
Mosquito		3	5	3	2	3
Guppy		0	0	1	1	1
Carp		3	4	7	7	9
Types of Harmful Weeds						
Woodruff		2	3	3	3	1
Yellow		1	2	3	3	4
Wormseed		5	2	1	2	3
Devil's weed		2	3	3	1	1
Fireweed		1	1	4	4	2
Chemical Analysis						
Dissolved Oxygen		102	63	75	82	78
Blurriness		12	14	13	11	15
Salinity		330	358	349	327	342
Phosphorus		20	25	35	30	40
Nitrate (NO_3)		25	35	30	45	40
Nitrogen (NH_3)		7	14	12	10	8
pH		6.8	6.5	7	7.2	6.7

APPENDIX 2

Energy Saving Activity

Mr. Serhat and Mrs. Meral, both teachers, went to a large store selling household goods for the house they were going to move to. In this store, where there are four different brands, they will buy a refrigerator, a washing machine, a dishwasher, TV set, a vacuum cleaner and an iron. Since the prices of these four brands are close to one other, Mr. Serhat and Mrs. Meral could not decide which brand to buy. For this reason, they will decide which products they will buy, taking into account the energy, motor power, time to be used and the product features in Table 1 of each brand. Energy is the amount of energy expended per unit of time. The unit of electrical energy is Watt(W). The motor power of the device is also taken into account when calculating the energy. Motor power is the energy consumed by the motor to which the device is connected, per unit time. The total power consumption is the sum of the average power and the engine power. The amount of electrical energy consumed by electrical appliances also depends on the time they are used. For example, a night light powered by a 200 Watt bulb consumes 200 Joules of energy in 1 second, while the same lamp consumes 400 Joules of energy in 2 seconds. As the operation time of electric appliances increases, the amount of electrical energy they consume also increases. When calculating the energy consumption of a device in duration/hour, the unit of power is taken as kilowatts. 1 kilowatt (kW) is equal to 1000 watts. Some features about the products are given below:

 There are other features that should be considered in addition to its energy consumption when buying a refrigerator. Food can spill in refrigerators with shelves in the form of wires as they will have gaps between them. In refrigerators with glass shelves, this is not the case. Recently, refrigerators with glass shelves have become more popular. The internal capacity of refrigerators may vary depending on the number of people in the household. In addition, refrigerators with longer storage times in case of power failure are preferred .

 When choosing washing machines, the number of people in the family is also taken into account. Crowded families prefer machines with more washing capacity. The higher the number of programs and the speed of tumble dry spin of a washing machine, the higher they are preferred.

 When it comes to vacuum cleaners, their dust storage volumes, filter types and noise levels are taken into consideration. The larger the family, the bigger the dust bag usually is. Another reason for preference is the low noise levels in a vacuum cleaner. In addition, vacuum cleaners water filters have also been popular lately.

For a TV set purchase, features such as resolution, screen size, image refresh rate are taken into account. Since the images of TV sets with a higher resolutions will be clearer, they

are preferred. On LCD televisions, the screen size is specified in inches. 1 inch is approximately 2.5 cm. In addition, televisions with higher refresh rates are more popular.

Characteristics such as steam pressure, type of base and water intake capacities are taken into account when purchasing irons. Irons with ceramic bases with high steam pressure are preferred.

In the purchase of dishwashers, machines with a large number of programs and low water consumption are preferred. Recently, inox dishwashers which does not keep fingerprint stains are preferred.

Preparation Questions

1. What is energy and motor power? Please explain.
2. What are the features that should be considered in addition to energy saving in the purchase of refrigerators and washing machines? Please explain briefly.
3. What are the features that should be considered in addition to energy saving when purchasing dishwashers and vacuum cleaners? Please explain briefly.
4. What are the features that should be considered in addition to energy saving in the purchase of irons and TV sets? Please explain briefly.
5. What is the relationship between watts (W) and kilowatts (kW)?
6. Do the following operations.

a) 4 W = ………. kW b) 0,25 kW = ………W

Question: Mr. Serhat and Mrs. Meral will choose from the products of the following 4 different brands, taking into account their energy saving properties. In product selection, develop such a model by taking into account energy saving and the features given in the table so that this couple will be convinced and buy the brands you recommend. *Note: The products may be from different brands.*

BRAND A				
PRODUCTS	ENERGY (WATTS)	MOTOR POWER (WATTS)	NUMBER OF DAYS/WEEKS	FREQUENCY OF USE
Refrigerator	970 W	10W	365	Non-stop
Washing machine	2000 W	25W	52 weeks	4 Times a week
Vacuum cleaner	990 W	15W	104 days	30 minutes
TV set	100 W	3W	365 days	5 hours
Iron	1000 W	10W	52 weeks	5 Hours a week
Dishwasher	1200 W	15W	52 weeks	5 Times a week

BRAND B				
PRODUCTS	ENERGY (WATTS)	MOTOR POWER (WATTS)	NUMBER OF DAYS/WEEKS	FREQUENCY OF USE
Refrigerator	950 W	5 W	365	Non-stop
Washing machine	2010 W	20 W	52 weeks	3 Times a week
Vacuum cleaner	975 W	10 W	100 days	30 minutes
TV set	98 W	2 W	365 days	7 hours
Iron	1075 W	10 W	52 weeks	4 Hours a week
Dishwasher	1215 W	15 W	52 weeks	3 Times a week

BRAND C				
PRODUCTS	ENERGY (WATTS)	MOTOR POWER (WATTS)	NUMBER OF DAYS/WEEKS	FREQUENCY OF USE
Refrigerator	940 W	10 W	365	Non-stop
Washing machine	1950 W	25 W	52 weeks	5 Times a week
Vacuum cleaner	950 W	10 W	108 days	24 minutes
TV set	105 W	5 W	365 days	3 hours
Iron	1050 W	10 W	52 weeks	6 Hours a week
Dishwasher	1125 W	15 W	52 weeks	6 Times a week

BRAND D				
PRODUCTS	ENERGY (WATTS)	MOTOR POWER (WATTS)	NUMBER OF DAYS/WEEKS	FREQUENCY OF USE
Refrigerator	1000 W	9 W	365	Non-stop
Washing machine	2100 W	20 W	49 weeks	3 Times a week
Vacuum cleaner	900 W	8 W	110 days	20 minutes
TV set	110 W	5 W	300 days	4 hours
Iron	1100 W	10 W	52 weeks	3 Hours a week
Dishwasher	1150 W	15W	52 weeks	4 Times a week

Figure 1 Brands of Products

Table 1 Specifications of Products

Type	BRAND A	BRAND B	BRAND C	BRAND D
Refrigerator				
Internal Capacity	350 L	400 L	450 L	500 L
Storage Time in Case of Power Failure	30 hours	45 hours	40 hours	45 hours
Shelf type	Wire	Glass	Wire	Wire
Washing machine				
Washing Capacity	3kg	7 kg	6 kg	7 kg
Number of Programs	3	5	9	7
Tumble dry speed	800	900	1100	1000
Vacuum cleaner				
Storage Volume	2 L	2,5 L	3 L	3,5 L
Type of Filter	Dust bag	Water filter	Dust bag	Water filter
Noise Level	76 dB	78 dB	80 dB	77dB
Iron				
Type of Base	Ceramic	Teflon	Ceramic	Teflon
Steam Pressure	5 bars	4,5 bars	4 bars	5,5 bars
Water Capacity	1200 ml	1300 ml	1000 ml	1100 ml
TV set				
Resolution	1920x1080	1900x1000	1850x980	1800x960
Screen Size	47 inches	46 inches	45 inches	44 inches
Refresh Rate (HERTZ)	200 Hz	175 Hz	200 Hz	180 Hz
Dishwasher				
Number of Programs	2	3	6	5
Color	Glossy Black	Glossy Burgundy	Inox (no fingerprint stains)	Inox (no fingerprint stains)
Water consumption	10 L	12	13 L	14 L