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Teaching Concepts through Interdisciplinary Modeling Problem: Energy Conservation Problem

Disiplinler Arası Modelleme Problemi Yoluyla Kavram Öğretimi: Enerji Tasarrufu Problemi

Yunus Güder, PhD Student, Adiyaman University, Institute of Science, yunusguder2010@hotmail.com
Ramazan Gürbüz, Prof., Adiyaman University, Faculty of Education, rgurbuz@outlook.com

ABSTRACT. The main purpose of this study is to see how students develop models and how they learn some particular scientific concepts with interdisciplinary modeling problem. For this purpose, researchers have developed "Energy Conservation Problem" which is an interdisciplinary modelling problem in collaboration with Science teacher. The problem was applied to 7th grade students in groups of 3-4 in an Eastern city of Turkey. In the process of interdisciplinary problem solving, students learned some terms about Science discipline and after interrelating these concepts, discussed which factors to include in their prospective models and how to quantify them. The models of the students were different from each other because of students' first exposure to such a process, different way of thoughts in the groups and inherent complexity of the modelling problems.
Keywords: Model Developing Process, Interdisciplinary Modelling Problem, Interdisciplinary Problem Solving

ÖZ. Bu çalışmanın temel amacı öğrencilerin model geliştirme süreçlerini izlemek ve disiplinler arası bir modelleme problemi yoluyla bazı belirli fen ve matematik terimlerini nasıl öğrendiklerini görmektir. Bu amaçla, araştırmacılar Fen öğretmeni ile birlikte çalışarak disiplinler arası bir modelleme problemi olan "Enerji Tasarrufu Problemi" geliştirdiler. Geliştirilen bu problem, Türkiye'nin Doğu Anadolu Bölgesinde bir il merkezinde bulunan bir okulda 3-4 kişilik gruplar halinde 7. sınıf öğrencilerine uygulanmıştır. Disiplinler arası problem çözme sürecinde, öğrenciler fenle ilgili bazı kavramları öğrendiler ve bu kavramları birbirleriyle ilişkilendirdikten sonra gelecekteki modellerinde hangi faktörleri dahil edeceklerini ve nasıl ölçeceklerini tartıştılar. Öğrencilerin modellerinin birbirlerinden farklı olmasında öğrencilerin ilk defa böyle bir problemle karşılaşmış olmaları, gruplar içindeki farklı düşünme biçimleri ve modelleme problemlerinin doğası gereği karmaşık olması etkili olmuştur.
Anahtar Sözcükler: Model Geliştirme Süreci, Disiplinler Arası Modelleme Problemi, Disiplinler Arası Problem Çözme

ÖZET

Amaç ve Önem: Matematiksel modelleme, matematik ve bilimin doğasında var olan, matematikçilerin ve bilim insanlarının profesyonel anlamda uygulamalarını içeren, değerlendirilebilen, yenilenebilen döngüsel bir yapıdan oluşur (Lesh ve Zawojewski, 2007; Romberg, Carpenter ve Kwako, 2005). Modelleme sadece matematik ve fen bilimine özgü bir kavram değildir. Mühendislik, ekonomi, sosyal bilimler, çevre bilimi hatta güzel sanatlar gibi diğer disiplinler de bir dizi karmaşık problemleri çözmede etkili matematiksel modellerden yararlanırlar (Lesh ve Sriraman, 2005b). Bu çalışmada 7. sınıf öğrencilerinin Matematik ile Fen ve Teknoloji alanlarında disiplinler arası ilişkilendirme becerisini geliştirmek için araştırmacılar, Fen ve Teknoloji öğretmeni ile birlikte "Enerji Tasarrufu Problemini geliştirmişlerdir. Geliştirilen bu problemde Fen ve Teknoloji disipliniyle ilgili *güç, motor gücü, güç birimleri (watt-kilowat)* ve bu birimlerin birbirine dönüşümü gibi kavramların öğretimi gerçekleştirilmiştir. Ayrıca problemde beyaz eşya alımında dikkat edilmesi gereken özellikler verilmiş ve öğrencilerin gerçek yaşam problemleri ile bağlantı kurmaları hedeflenmiştir. Problem, nicel verilerden çok nitel verilerden oluşmaktadır. Karmaşık yapıdaki bu problemde öğrencilerin verileri nasıl bir araya getirdikleri, model kurarken hangi değişkenleri dikkate aldıkları ve bu değişkenleri nasıl birleştirdikleri incelenmiştir.

Yöntem: Bu çalışma, çok katmanlı öğretim deneyi (English, 2003; Lesh ve Kelly, 2000) doğrultusunda kavramsal olarak zenginleştirilmiş bir ortamda çalışan katılımcıların farklı yönlerden gelişimini ortaya koymayı amaçlamaktadır. Çok katmanlı öğretim deneyi, öğrencilerin matematiksel yapıları tanımlamak ve açıklamak için modeller geliştirdikleri, öğretmenlerin öğrencilerin modelleme faaliyetlerini anlamaya yönelik modeller (değerlendirme araçları) geliştirdikleri, araştırmacıların ve

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öğretmen eğitimcilerinin de öğretmen ve öğrencilerin modelleme faaliyetlerini anlamaya yönelik modeller oluşturdukları üç aşamadan oluşan öğretim deneyleridir (Lesh & Kelly, 2000). Çalışmanın birinci aşamasında, öğrencileri düşünmeye zorlayan ve onları model kurmaya teşvik eden modelleme problemleri 4 hafta boyunca öğrencilere uygulanmıştır. İkinci aşamada araştırmacılar, Fen Eğitimi alanında doktora yapan Fen ve Teknoloji öğretmeniyle iş birliği yaparak "Enerji Tasarrufu Problemi" geliştirmiş ve bu problem araştırmacılar tarafından 7.sınıf öğrencilerine uygulanmıştır. Üçüncü aşamada ise, araştırmacılar uygulama sürecinde gözlemler yapmış, çıkarımlarda bulunmuş ve katılımcıların gelişimlerini raporlaştırmışlardır.

Bulgular: Çalışmada elde edilen bulgular bir grubun (G_5: Beşinci Grup) çözüm süreci örnek verilerek iki bölüm şeklinde incelenmiştir. Birinci bölümde grubun Enerji Tasarrufu Probleminde geçen Fen bilimlerine ait kavramlara verdiği cevapların *"Okuduğunu anlama ve birimler arası dönüşüm yapma", "Her bir ürünün enerji tüketimini hesaplama", "Ürünlerin özelliklerini "+" ve "-" sembolleri ile belirleme", "Her bir üründen en az enerji tüketen ikisini belirleme", "Gerekçelendirmeler yapma"* şeklinde olduğu görülmüştür. İkinci bölümde ise grubun Enerji Tasarrufu Problemine uygun geliştirdiği modellerde kullanılan değişken sayılarına göre *model-1*, *model-2*, *model-3*, *model-4* ve *model-5* şeklinde ele alınmıştır. Örneğin bir grup problemin çözümünde diğer gruplara göre daha çok değişkeni dikkate almışsa bu grup model-5 seviyesinde ele alınmıştır.

Sonuç ve Öneriler: Bu çalışmada öğrenciler hem küçük gruplar halinde hem de bütün sınıf olarak matematiksel fikirlerini paylaşıp bir model ortaya koymuş, Fen ve Teknoloji disiplini ile ilgili bazı kavramları (güç, motor gücü, watt, kilowat) öğrenmişlerdir. Öğrencilerin matematiksel fikirlerini ve anladıkları şeyleri aktarıp paylaşmaları gerekliliği disiplinler arası öğrenmenin gelişimini destekler. Disiplinler arası öğrenme deneyimleri yoğun olan bir müfredatta ekstra etkinlikler olarak görülmemelidir. Bu tür aktiviteler son yıllarda ülkemizde seçmeli ders olarak okutulan "Matematik Uygulamaları" dersinin temalarına entegre edilebilir. Böylelikle öğrencilerin temel kavram ve süreçleri tanımaları, geliştirmeleri, güçlendirmeleri ve zenginleştirmeleri sağlanabilir.

INTRODUCTION

In today's dynamic and digital world, mathematics, science, medicine, social sciences, finance, engineering, economy, and many other areas consist of complex systems. Complexity, which is the study of systems of interconnected components whose behavior cannot be explained solely by the properties of their parts but from the behavior that arises from their interconnectedness, is a field that has led to significant scientific, methodological advances (Sabelli, 2006). With the expansion of complex systems, new requirements have appeared for communication, collaboration, and conceptualization and these requirements have led to significant changes in the process of producing, analyzing, and transforming complex data, which include necessary, out-of-class mathematical and scientific skills (English & Sriraman, 2010). One of the many challenges that educators face is how to engage students in authentic problem solving involving complex systems within an interdisciplinary context. One approach is through mathematical modelling involving cycles of model construction, evaluation, and revision, which is fundamental to mathematical and scientific understanding and to the professional practice of mathematicians and scientists (Lesh & Zawojewski, 2007; Romberg, Carpenter & Kwako, 2005). Modelling is not just confined to mathematics and science, however. Other disciplines including engineering, information systems, economics, social and environmental science, and the arts have also contributed in large part to powerful mathematical models we have in place for dealing with a range of complex problems (Lesh & Sriraman, 2005a). Recently, researches have focused on mathematical modelling applications of every level and modelling applications have started to take their place in the curriculum more than ever Commen Core State Standards Initiative [CCSSM]; Department for Education [DFE], 1997; National Council of Teachers of Mathematics

[NCTM] 1989; 2000; TTKB, 2011, 2013). Upon examining mathematics curriculum in the literature, it is seen that there is limited interdisciplinary study in terms of mathematics (Sabelli, 2006; Sriraman & Steinthorsdottir, 2007).

STEM education is an educational approach designed to meet the need of educating creative individuals who think systematically, provide a critical perspective, transfer their learning to new and different problems in science, technology, engineering and mathematics. Mathematical modeling is one of the tools used in the STEM education approach. Mathematical modeling in school mathematics allows students to use mathematics in STEM areas in a flexible, creative and powerful way as needed. Because mathematical modeling supports mathematical literacy development (Steen, Turner & Burkhardt, 2007; Guthrie et al., 1999; Yıldız, 2013), productive tendencies towards mathematics (Lesh & Yoon, 2007) and a deep and integrated understanding of mathematical content and practices (Lehrer & Schauble, 2007).

With the help of Energy Conservation Problem, the teaching of such terms as power, motor power, power units (watt-kilowatt), and unitary transformations was achieved. The way students gathered data, which variables they took into consideration, and the way they integrated these variables were examined and reported in that complex problem. The main aim of this study is to see how students learn model development and some scientific concepts with interdisciplinary modeling problem. The theoretical framework for the theoretical structure of the problem is discussed below.

Theoretical Perspectives

Models-and-Modelling Perspective

The terms *model* and *modelling* have been defined in different ways in the literature. According to Lesh and Doerr (2003), model is whole of conceptual systems used to interpret and understand complex structures and external representations of these structures. Modelling is the process of using and creating different models by organizing, coordinating, and systematizing the problem situations.

Modelling is a critical tool in order to see the potential mathematics has in analyzing significant topics. In traditional problem solving process, students generally determine a suitable way of solving which involves basic steps and simple answers. On the other hand, in modelling problems students engage in and find out important mathematical structures and relationships. Morever, these problems can be used with literature, history, ecological sciences, physical sciences within an interdisciplinary context. Recently the studies on modelling have shown that modelling help students of all levels make sense of mathematical and scientific terms (Delice & Kertil, 2014, Bukova-Güzel, 2011; Tekin-Dede, 2016; Hıdıroğlu at al., 2014; Tekin-Dede & Bukova-Güzel, 2014; Şahin & Eraslan, 2016).

Students' developing effective models must be seen as one of the most significant purposes of mathematics and science education (Lesh & Sriraman, 2005a; Blum, & Galbraith Niss, 2006). Many institutions which have realized the importance of modelling in learning process have emphasized the importance of modelling in their teaching programme ([CCSSM], 2010; [DFE], 1997; [NCTM], 1989, 2000).

This study is theoretically based on Mathematical Model and Modelling Perspective (MMP), which was introduced by Lesh and Doerr (2003). Model and Modelling Perspective proposes multi-tier design research that covers student, teacher and researcher aspects and handles the research process as a kind of learning environment and material development process. Although MMP modelling problems in Mathematics education look like traditional problems, they have some distinctive features. i) While there is a fixed outcome with the use of data in traditional problem solving, there are multiple cycles and different perspectives in modelling problems. ii) Modelling problems provide richer learning contexts when compared with traditional ones. iii) Modelling problems are authentic and have interdisciplinary side. iv) Modelling problems are applied in small groups of 3-4. v) While in traditional problem solving process, students are expected to use formulas, algorithm, strategy, and mathematical ideas; in modelling process, students develop and revise significant mathematical ideas and structures (English, 2009; Lesh & Doerr, 2003; Lesh & Zawojewski, 2007). In addition to this, since there are meaningful and purposeful discussions of small groups in modelling process, communication, problem posing, and mathematical reasoning skills of students also develop.

Design Principles of Interdisciplinary Modelling Problems

Energy Conservation Problem was developed according to 6 principles of Model Eliciting Activities (MEAs) (English, 2009; Lesh, Cramer, Doerr, Post, & Zawojewski, 2003a, p. 43). Model Eliciting Activities (MEAs) are open-ended interdisciplinary problem solving activities that encourage students to build models to solve complex real-life problems and encourage them to test their models. In order for an activity to be a MEAs, it needs to have the majority of the six principles developed by Lesh et al. (2000). These principles were derived from the work of teachers, students, researchers and teacher trainers in the workshops during sessions called 15-week multi-tiered teaching experiences. These principles are *(i) The Personal Meaningfulness Principle:* A modelling problem must enable a student to relate to and solve an authentic/real life problem with his/her already existing knowledge and experiences. The modelling problems serve to not only enrich the problem-solving component of the mathematics curriculum but also to help children link their learning meaningfully across disciplines (English, 2009). For example, Energy Conservation Problem integrates scientific, mathematical, and societal aspects. Students are expected to consider some points while buying domestic appliances. *(ii) The Model Construction Principle:* A modelling problem must lead the student to prepare and develop a solution oriented model and the student must end up preparing a model at the end of the activity. In Energy Conservation Problem, students developed a model by considering the necessary criteria. *(iii) The Model Documentation Principle:* A modelling problem must require students to write a report about their respective thoughts and solution ways of the problem. *The need to create representations such as lists, tables, graphs, diagrams, and drawings should be a feature of the problem* (English, 2009). For example, some of the students used "+" and "-" symbols in their models. Students have brought together both mathematical and social components when building their models. (iv) *The Self-Assessment Principle:* Students must carry out a self-evaluation about the correctness of his/her comments and results and also whether the model needs further revisions and developments. For example, in Energy Conservation Problem, groups had the opportunity of self-evaluation by comparing their models. *(v) The Model Generalization Principle*: The activity must enable students to prepare a general model and they should be encouraged to use it for other similar situations. Students can also use their Energy Conservation Problem models for other similar problem situations. *(vi) Effective Prototype Principle:* A modelling problem should enable the students to remember the solution even after months and years. Students may remember the models they have developed for this particular problem even years later.

MEAs has four central components named the newspaper article and the readiness or warm-up questions, the problem situation and the presentation of solutions (Lesh, Hoover, Hole, Kelly, Post, 2000; Chamberlin & Chamberlin, 2001; Tekin-Dede & Bukova-Güzel, 2014). The purpose of newspaper article and the readiness or warm-up questions is to introduce the context of the next problem situation and prepare them for problem situation. In problem situation, groups of students are asked to develop model/s in order to help a client and students are expected to write their models in detail by letter or e-mail to the client (Chamberlin & Chamberlin, 2001). This component is generally referred in the readiness questions (Chamberlin & Moon, 2005). In the presentation of solutions, each group presents their solutions to their classmates (Chamberlin & Chamberlin, 2001)

METHOD

Materials, Methods and Methodological Framework

Research methodology

This study aims to provide a multisided development for students who study in a conceptually enriched environment in accordance with multi-tier teaching experiment (English, 2003; Lesh & Kelly, 2000; Steffe & Thompson, 2000). In the first phase of the study, thought-provoking and promotive modelling problems were applied for four weeks. In the second phase, researchers developed "Energy Conservation Problem" with the Science teacher. In the third phase, researchers made observations and inferences during the application process of the problem and reported developments of the participants. Framework of the study is given in *Figure-1.*

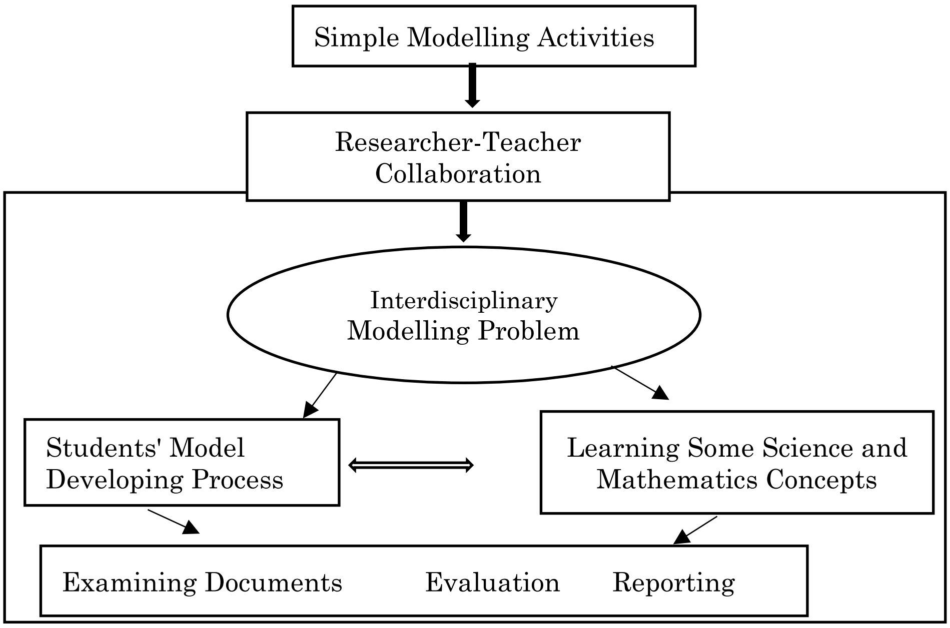


Figure 1. *Theoretical Framework of the Study*

Participants and Application Process

The problem was applied to 30 7th grade students in groups of 3-4 in an Eastern city school of Turkey. There are several reasons why other grade students were not included in the study: 5th grade students were not prepared for such activities because they were newcomers to secondary school, 6th grades were not in formal operational stage yet and 8th grades were preparing for TEOG exam. From 2012-2014 Educational year TEOG (Transition from Basic Education to Secondary Education) exam replaced SBS (Placement Test) applied in the previous years (MEB, 2013).The real purpose of this new system is to measure student's success in an extended period of time rather than based on a momentary performance (Eraslan, 2013:1). In the placement, 30% of the mean of the Grade Point Average of the 6th, 7th and 8th grades and 70% of the central exam scores given at the end of the 8th grade are taken into account (MEB, 2013). TEOG exam is given by teachers each term of the 8th grade for six fundamental courses Students take the exams which include question from Turkish, Mathematics, Science and Technology, TR History of Revolution and Kemalism, Foreign Language and Religious Culture and Moral Knowledge subjects.

Data Collection Tool and Analysis

Before the students were engaged in the "Energy Conservation Problem", they worked cooperatively on simple, preparatory modelling problems (warming activities) for four weeks. In these problems, the students determined the mathematical concepts and the relations between these concepts and developed a mathematical model from these concepts. The information about the "Energy Conservation Problem" which is applied after the warming activities is as follows:

a) Reading text about the main components of the problem. In this text, the aim was to teach science terms. Based on the information in the text, reading comprehension and several unitary transformation questions were prepared *(See Appendix).*

b) Table about power, motor power, and operating time of four different brands of appliances. Students were expected to add power to motor power based on the information in the table and to multiply the result with operating time and to transform the final result to kilowatt. For example (A) = [(970 +10) x 365]/1000 = 357,7 kw Refrigerator (B) = [(950+5) x 365]/1000 = 348, 575 kw

Since energy consumption of B is less than the other brand, B must be preferred. Therefore, students were expected to choose the least energy consuming appliance by making the same calculation for each of them. This activity was also believed to develop students' reading comprehension and interpretation of tables.

c) *Table displaying features of the appliances*. In this table, features of four different brands of appliances were given. Groups decided which features to take into consideration while buying. For example, while buying a refrigerator, they were expected to prefer one having large internal capacity, glass racks, and more storage time in power failure. The problem was applied to 7th grade students in groups of 3-4 for 40 minutes during each 4 weeks.

The data of the study consist of written answers of groups, video recordings in which students think aloud during the solution process, observations of the researchers, and development reports of the participants. Data analysis was carried out in two ways: the constant comparative analysis (Strauss & Corbin, 1990) and retrospective analysis. In the constant comparative analysis, data is continuously compared with valid assumptions. Data goes through multiple analyses, initial hypotheses are continuously tested and revised (Cobb & Whitenack, 1996), and general themes are created. In retrospective analysis, a general evaluation is carried out after the process is finished in order to see to what extent initial aims have been achieved. For this study, each group was given a code (G_1, G_2 and etc.) in data analysis. Data evaluation was carried out in two phases. In the first phase, the answers to readiness questions were analyzed in a cyclical way and the interpretations of (G_5) were presented as an example. In the second phase, the models of all groups were analyzed under five themes (*model-1, model-2, model-3, model-4,* and *model-5*). Different variable numbers used by the students to solve the problem have been influential in the naming of models. For example, if one group used more variables in the solution of the problem than the other groups, this group was considered at the level of *Model-5*. Retrospective analyses of students' videos have revealed interactions of modelling processes. Specifically, for the data reported here, students' solution papers were repeatedly reviewed and coded to address the research questions, with the coding refined over several months to identify the major understandings. To ensure the reliability of the research, multiple exchanges were made between the authors and the data were refined. For example, when analyzing the models developed by the students, firstly the analysis were considered under the four headings (*model-1, model-2, model-3, model-4*) and then it was decided to analyze the models under the five headings (*model-1, model-2, model-3, model-4, model-5)* as a result of the in-group author evaluations.

FINDINGS

In this section, answers of (G_5) to preparatory questions and examples from model types of all groups are given. The English equivalents of the Turkish words are given in parentheses.

Development Cycles of (G_5) During the Process of Problem Solving

Cycle one: Reading comprehension and unitary transformations.

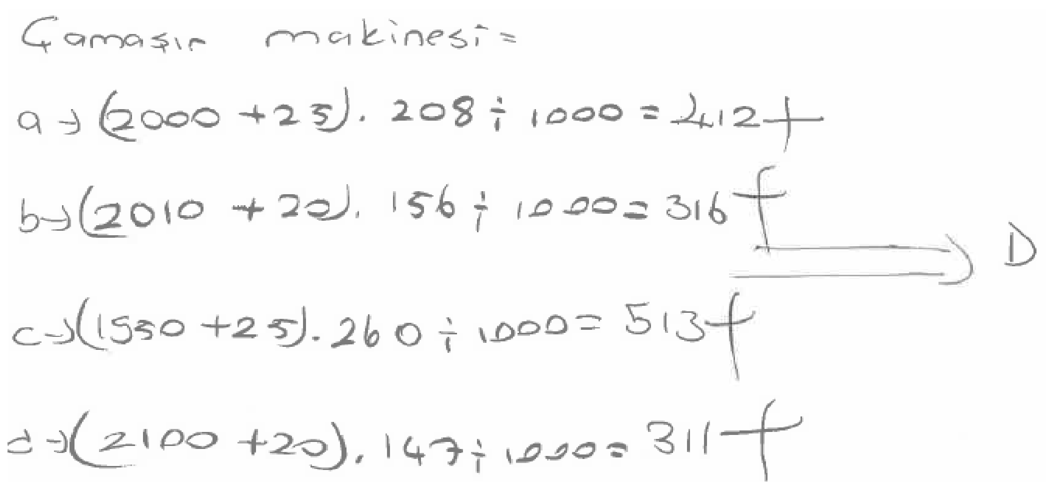
G_5 firstly answered readiness questions based on the text. The questions covered science terms in the text, unitary transformations and features to take into consideration while buying appliances. The answer given by the group (G_5) to the question about science terms is "Power is the amount of energy spent in a unit of time. Electrical power unit is watt (W). While calculating electrical power, motor power of the device is also taken into consideration. Motor power is the amount of energy spent by the motor to which device is attached. The total power spent is the sum of average power and motor power."

One of the readiness questions was about the features to take into consideration while buying the appliances. The answer of G_5 is "While buying dishwasher, those which have more programs and least water consumption are preferred. Recently dishwashers with stainless steel are also preferred." The answer of the group to the question about unitary transformations of science terms is as follows:

Cycle two: Calculating energy consumption of each appliance.

G_5, in this cycle, found total expended power by adding motor power to power of each appliance based on the table consisting power, motor power and operating time of four different brands of appliances. Then, group multiplied total power and operating time and calculated the amount of energy consumption in watts. Then, they transformed the amount of energy consumption in watts into kilowatts and identified the appliance having the least energy consumption. The answers are as follows:

(Çamaşır makinesi: Washing machine)

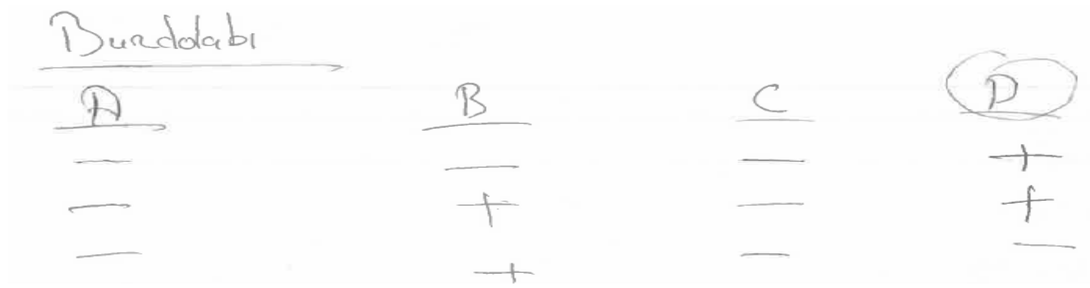


Cycle three: Identifying the features of appliances with the symbols of "+" and "-".

The group took the table in which features of the appliances are given into consideration.

In this cycle, group used *"+" and "-"* symbols for the features of the appliances based on the reading text in Energy Consumption Problem. For example, they used "+" for refrigerators which have large internal capacity, glass racks, and more storage time in power failure and *"-"* for the ones which don't have these features. The symbols are as follows:

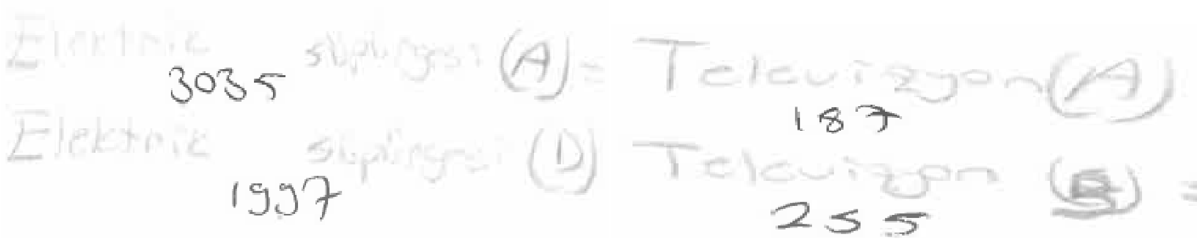
(Buzdolabı: Refrigerator)



Cycle four: Identifying two of each appliance having the least energy consumption.

In this step, the group identified two brands of each appliance having the least energy consumption based on the amount of energy consumption calculated in cycle 2. Parts of the process are as follows:

(Elektrik süpürgesi: Vacuum cleaner), (Televizyon: Television)



Cycle five: Giving justifications.

In this step, the group gave justifications as to why they chose the particular brands based on the features of the brands. They are as follows:

For refrigerator, B was chosen because refrigerators which have glass racks and more food storage time are generally preferred.

For washing machine, D was chosen because washing machines which have more washing capacity are mostly preferred depending on the number of family members and those having more washing programs and squeezing speed are more preferable.

The Variety of Models among Groups

Groups developed some models after solving the problems as follows: (The English equivalents of the Turkish words are given in parentheses)

Model one.

In this model, two groups (G_8, G_{10}) calculated energy consumption of each appliance and identified the brands having the least energy consumption. They didn't take the features of the appliances into consideration. The model developed by G_8 is as follows:

(B Marka: B Brand), (Buzdolabı: Refrigerator), (Çamaşır makinesi: Washing machine)

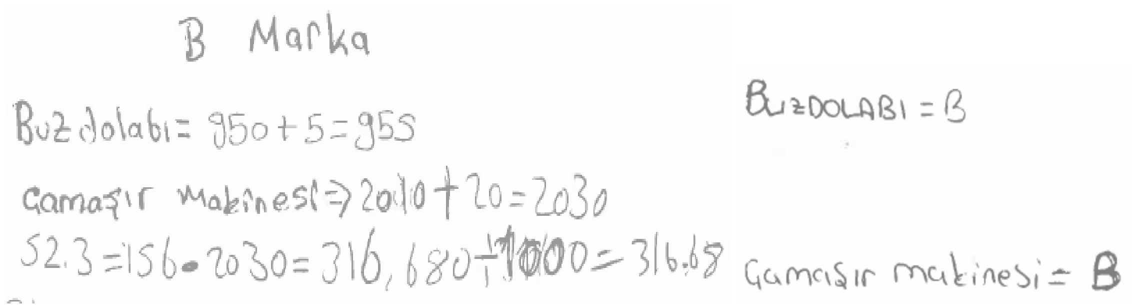


Figure 2. *The model developed by G_8 for buying refrigerator and washing machine*

Model two.

G_2 calculated the amount of energy consumption, identified two brands for each appliance having the least energy consumption, and used "+" for advantages and "-" for disadvantageous appliances. After that, the group identified two brands for each appliance yet didn't decide which brand should be bought. Part of the model is as follows:

(Enerji: Energy), (Özellikler: Features), (Buzdolabı: Refrigerator)

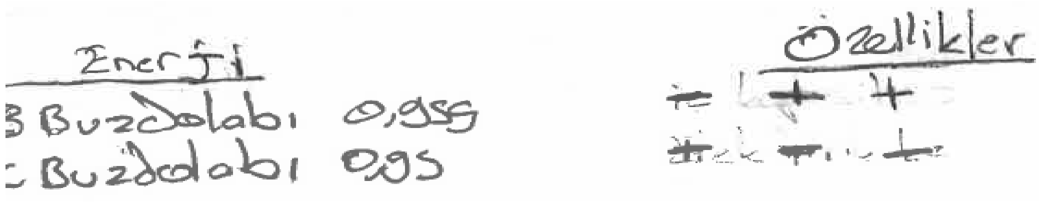


Figure 3. *The model developed by g_2 for refrigerator*

Model three.

The most common model is that developed by 5 groups (G_4, G_5, G_6, G_7, G_9). Firstly the groups identified two brands of each appliance having the least energy consumption and then decided which brand should be bought by giving justifications based on the features of the brands. Parts of the model are as follows:

(Televizyon: Television), (C Marka: C Brand), (Enerji: Energy), (Özellikler: Features)

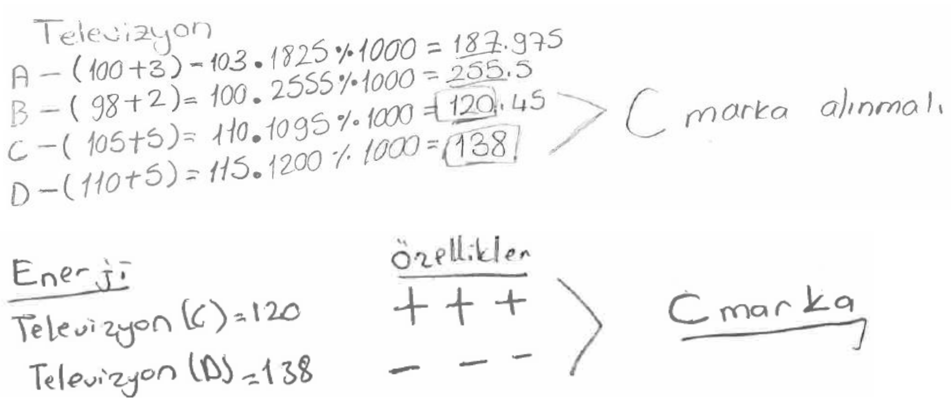


Figure 4. *The model developed by G_4 for television*

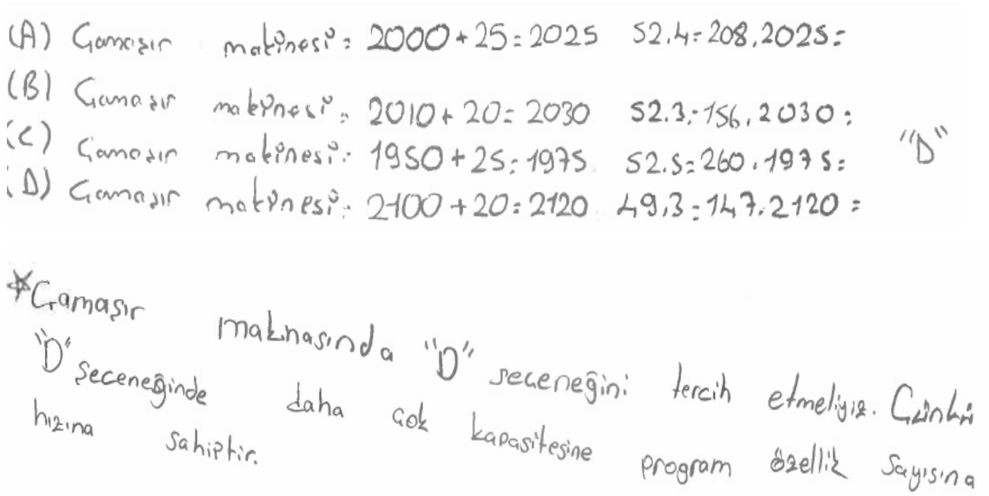


Figure 5. *The Model developed by G_9 for Washing Machine*

(Çamaşır makinesi: Washing machine)

(We should prefer D. Because it has a high capacity, speed and more programs)

Model four.

In this model, G3 calculated energy consumption amount of each brand and identified which brands should be bought based on the table including the features of the brands. Yet, they did not give justifications. The model is as follows:

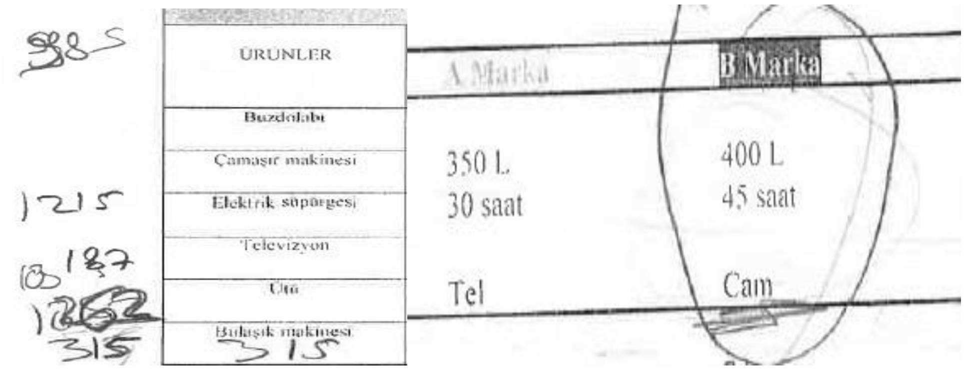


Figure 6. *The model developed by G3 for refrigerator*

(Ürünler: Appliances)

(Buzdolabı: Refrigerator) (Çamaşır makinesi: Washing machine)

(Elektrik süpürgesi: Vacuum cleaner) (Televizyon: Television)

(Ütü: Iron) (Bulaşık makinesi: Dish washer)

(A Marka: A Brand) (30 saat: 30 hours) (Tel: Wire)

(B Marka: B Brand) (45 saat: 45 hours) (Cam: Glass)

Model five

(G_1) firstly calculated energy consumption amount of each brand, identified two brands having the least energy consumption and then decided which one to buy by comparing their features. In these comparisons, the group often used "but", "yet". The model is as follows:

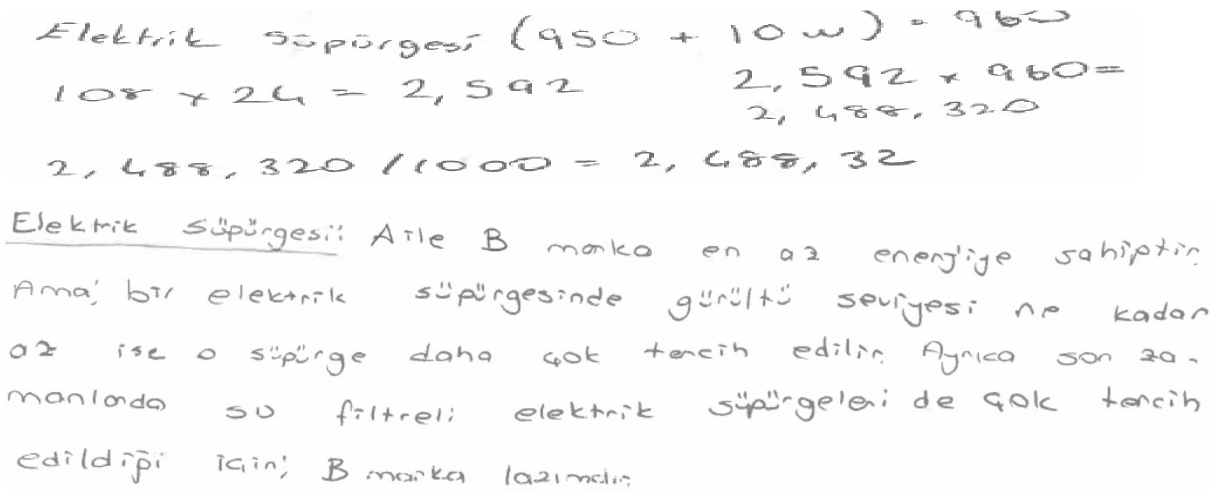


Figure 7. *The model developed by G_1 for vacuum cleaner*

(Elektrik süpürgesi: Vacuum cleaner)

(A and B brands have the least energy but the less loudness level in vacuum cleaners, the more preferable they are. Moreover, recently vacuum cleaners with water filter are in demand. That's why B is chosen).

DISCUSSION AND CONCLUSION

In this study, it was aimed to see students' model developing process and their level of learning some science and mathematics concepts through interdisciplinary modelling problem. When solution report of the G_5 is examined in the findings, it was seen that the answers given to the preparatory questions were mostly correct. The answers of these preparatory questions could be elicited from the reading text that included main components of the problem. The fact that most of the answers were correct may be associated with reading comprehension skill. Cunningham and Stanovich (1997) in their study on the relationship between early reading acquisition and ten-year later reading ability, found that reading comprehension had a positive effect on problem solving. Guthrie et al. (1999) argued that the amount of reading and understanding had a significant effect on cognitive factors. Yıldız (2013) in his study on the effect of reading comprehension on 5th grade students 'academic success, found that reading motivation directly affected fluent reading, reading comprehension, and academic success. In readiness questions part, other groups had the same results as G_5. When the answers of the G_5 in parts (b) and (c) were examined, it was seen that the group had suitably integrated data, correctly made unitary transformations, and carried out a well-directed identification of the features to take into consideration when buying domestic appliances. The group can be said to have made a better association of the parts of (b) and (c) with part (a), which was reading comprehension part. In reading comprehension part (a), there are clues with regard to the parts (b) and (c). It was seen that the group made an effective use of these clues. Group discussion was thought to be effective in the G_5's correct integration of these parts which included different components. This assumption is in parallel with the studies (Bukova-Güzel, 2011; Delice & Kertil, 2014; English, 2006; Erbaş et al., 2014; Galbraith & Clatworthy, 1990; Galbraith, Henn, & Niss, 2007; Hıdıroğlu et al., 2014; Maaβ, 2006; Şahin & Eraslan, 2016; Tekin-Dede & Yılmaz, 2016; Tekin-Dede & Bukova-Güzel, 2014) which revealed the importance of group discussions for solution of modelling problems. The Energy Conservation Problem was handed out to the students with three parts (reading text, table of power, motor power and operating time, table of appliance features). In this process, the students were supposed to find energy consumption of each brand in kilowatts for a healthy transfer to subsequent steps. In order to do that, the students must add motor power to the power of each brand, multiply the result and operating time together, and then write the final result in kilowatts. In the second phase of modelling, the students are supposed to decide which appliance to buy based on the table of features. After these, the groups were supposed to end up with a model by integrating these two processes. In short, the students were expected to organized and integrate data. The students developed different models in the groups but failed to notice some points. For example, while some students created their models by just calculating energy consumption, why did other students use both the amount of energy consumption and features of appliances? Why did some groups give justifications while the other did not? Why did some groups use unitary transformations while the others did not consider this? Why did some groups use "+" and "-" symbols?

It can be argued that the groups that set a model systematically by taking both of variables into consideration went through a more reflectionist and effective discussing process. These groups may have included members having a better reasoning ability than those in other groups. In addition, it may be because the groups may have included students of high leadership ability and open to discussions, which contributed to formation of systematic models. The fact that the problem had an authentic nature and the groups involved the students who were intrinsically motivated to and knowledgeable about domestic appliances may have significantly contributed to modelling process. The fact that models of the students were different from each other can be explained with the students' different way of reasoning in the groups and inherent complexity of the modelling problems. The studies in the literature emphasized multi interpretation cycles of the students during the process of problem solving and predicted that different approaches would be adopted by students while solving problems (Doerr & English, 2003; English, 2006; 2007; 2009). It is possible to see studies (Doerr & English, 2001; English, 2013; Lesh, Doerr, Carmona, & Hjalmarson, 2003) supporting this assumption.

Modelling problems provide an interdisciplinary learning context. For example, in the Energy Conservation Problem, the students learnt some science terms along with using mathematical knowledge, formed relationships between these terms, and discussed which factors to include in their prospective models. While digitizing the data, the students identified value points, used range values and some factors in order to calculate the amount of energy consumption. They formed new formulas while doing these operations and justified their models by doing different lists. The studies in the literature found that designs prepared in accordance with interdisciplinary principles have positive effects on students' mathematical success, critical thinking, motivation, and class participation (English, 2009; Hamilton at al., 2008; Yoon at al., 2010). In addition, in this problem, the students learnt which points to take into consideration for domestic appliances with in-group intentional discussions. These discussions and the knowledge taken out of the problem contributed to students' language development and social and communication skills.

According to Zawojewski et al. (2003), in traditional problem solving activities, since the result is expected to be numeric, it doesn't need to be shared and thus the social aspect is very weak. On the other hand, mathematical modelling activities have authentic nature, which contributes to students' social side and enables them to carry out meaningful discussions. In modelling activities, each student in the groups interprets the problem with his/her external representation and these interpretations are discussed in groups. After each student's model is discussed and evaluated, the most suitable one is formed. In the process of group discussion, group members feel the necessity of developing their language and communication skills.

In this study, students formed a model by sharing their mathematical ideas both in group and whole class contexts and they learnt some concepts (power, motor power, watt, and kilowatt) about Science. Interdisciplinary learning experiences shouldn't be regarded as extra activities in an already intensive curriculum. Such kind of activities can be integrated to "Mathematical Applications" course. In this way, students can be enabled to be familiar with, develop and strengthen basic terms and processes.

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Appendix

ENERGY CONSERVATION PROBLEM

Mr. Serhat and Mrs. Meral who are both teachers went to a domestic appliance store which sells four different brands of them. They wanted to buy refrigerator, washing machine, dish washer, television, vacuum cleaner, and iron for their new house. Since the prices of the brands were not very different from each other, the couple couldn't decide which one to buy. Thus, they will benefit from tables including power, motor power, operating time and some other features of the four brands of appliances. Power is the amount of energy expended per unit of time. Electrical power unit is Watt (W). While calculating power, motor power of the appliance is also taken into consideration. Motor power is the amount of energy expended a unit of time by the motor to which the device is attached. The total expended power is the sum of average power and motor power. The expended energy amount of electrical devices also depends on the operating time. For example, a night light with a 200-watt light bulb expends 200 joule energy in a second and 400 joule energy in two seconds, which shows that the more time electrical devices operate, the more energy they expend. While calculating the power of a device, if the time duration is taken as hour, then power unit is kilowatt. 1 kilowatt (kW) is equal to 1000 watt. The features of the appliances are as follows:

While buying refrigerator, there are other features to take into consideration apart from energy consumption. Refrigerators with glass racks are mostly preferred because they are more useful when compared to those with wire racks. Internal capacity of refrigerators changes according to the number of the people in the family. Refrigerators with more storage time in power failure are also mostly preferred.

While buying washing machine the number of family members are important. In crowded families, those with high washing capacity are preferred. If the program number and squeezing speed of a washing machine is high, it becomes more preferable.

For vacuum cleaners, storage volume, kind of filter, loudness level are important features. Storage volume changes according to number of family members. The less loudness level in vacuum cleaners are, the more they are preferred. Moreover, recently vacuum cleaners with water filter are in demand.

While buying television, screen resolution, screen size, refresh rate are important criteria. Televisions with high screen resolution are more preferred. For LCD televisions, screen size is inch. 1 inch is approximately 2.5 cm. Moreover televisions with high refresh rate are mostly bought.

For irons, vapor pressure, iron base, and water capacity are important features. Those with high vapor pressure and ceramic base are mostly preferred.

Dish washers with more programs and least water consumption are preferred. Recently, dish washers with stainless steel are in demand.

READINESS QUESTIONS

- *Define power and motor power.*
- *What are the features to take into consideration apart from energy consumption while buying refrigerator and washing machine? Explain briefly.*
- *What are the features to take into consideration apart from energy consumption while buying dishwasher and vacuum cleaner? Explain briefly.*
- *What are the features to take into consideration apart from energy consumption while buying iron and television? Explain briefly.*
- *What is the relationship between Watt (W) and kilowatt (kW).*
- *Fill in the blanks.*

a) 4 W = ……… kW　　　　*b) 0,25 kW = ………W*

Problem: Mr. Serhat and Mrs. Meral will choose from 4 different brands of appliances by taking energy consumption into consideration. Create a model by thinking energy consumption and features of the appliances in the tables below so that the couple is resolved to choose the brands you will recommend. (Appliances may be of different brands.)

A BRAND				
APPLIANCES	POWER (WATT)	MOTOR POWER (WATT)	OPERATING TIME (DAY-WEEK)	OPERATING FREQUENCY
Refrigerator	970 W	10W	365	Continuous
Washing machine	2000 W	25W	52 week	Four times a week
Vacuum cleaner	990 W	15W	104 days	30 minutes
Television	100 W	3W	365 days	5 hours
İron	1000 W	10W	52 week	Five hours a week
Dish washer	1200 W	15W	52 week	Five times a week

B BRAND				
APPLIANCES	POWER (WATT)	MOTOR POWER (WATT)	OPERATING TIME (DAY-WEEK)	OPERATING FREQUENCY
Refrigerator	950 W	5 W	365	Continuous
Washing machine	2010 W	20 W	52 weeks	Three times a week
Vacuum cleaner	975 W	10 W	100 days	30 minutes
Television	98 W	2 W	365 days	7 hours
İron	1075 W	10 W	52 weeks	Four times a week
Dish washer	1215 W	15 W	52 weeks	Three times a week

C BRAND				
APPLIANCES	POWER (WATT)	MOTOR POWER (WATT)	OPERATING TIME (DAY-WEEK)	OPERATING FREQUENCY
Refrigerator	940 W	10 W	365	Continuous
Washingmachine	1950 W	25 W	52 weeks	Five times a week
Vacuum cleaner	950 W	10 W	108 days	24 minutes
Television	105 W	5 W	365 days	3 hours
İron	1050 W	10 W	52 weeks	Six times a week
Dish washer	1125 W	15 W	52 weeks	Six times a week

D BRAND				
APPLIANCES	POWER (WATT)	MOTOR POWER (WATT)	OPERATING TIME (DAY-WEEK)	OPERATING FREQUENCY
Refrigerator	1000 W	9 W	365	Continuous
Washingmachine	2100 W	20 W	49 weeks	Three times a week
Vacuum cleaner	900 W	8 W	110 days	20 minutes
Television	110 W	5 W	300 days	4 hours
İron	1100 W	10 W	52 weeks	Three times a week
Dish washer	1150 W	15W	52 weeks	Four times a week

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KIND	A BRAND	B BRAND	C BRAND	D BRAND
REFRIGERATOR				
Internal capacity	350 L	400 L	450 L	500 L
Storage time in power failure	30 hour	45 hour	40 hour	45 hour
Type of rack	Wire	Cam	Tel	Tel
WASHING MACHINE				
Capacity	3kg	7 kg	6 kg	7 kg
Number of program	3	5	9	7
Squeezing speed	800	900	1100	1000
Vacuum Cleaner				
Storage volume	2 L	2,5 L	3 L	3,5 L
Type of filter	Vacuum bag	Water filter	Vacuum bag	Water filter
Loudness level	76 dB	78 dB	80 dB	77dB
IRON				
Base type	Ceramic	Teflon	Ceramic	Teflon
Vapor pressure	5 bar	4,5 bar	4 bar	5,5 bar
Water capacity	1200 ml	1300 ml	1000 ml	1100 ml
TELEVISION				
Screen resolution	1920x1080	1900x1000	1850x980	1800x960
Screen size	47 inch	46 inch	45 inch	44 inch
Refresh rate (HERTZ)	200 Hz	175 Hz	200 Hz	180 Hz
DISH WASHER				
Number of program	2	3	6	5
Color	Lively black	Lively maroon	Stainless steel	Stainless steel
Water consumption	10 L	12	13 L	14 L