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Herkese Merhabalar,

On on beşinci yılımızın ikinci sayısında toplam dokuz makale yer almaktadır.

Bu sayıda katkıda bulunan gerek yazarlarımıza gerekse hakemlerimize çalışmalarından dolayı teşekkür ederiz.

Saygılarımla.

Editör

Prof. Dr. Hülya GÜR

Preface

Greetings to everyone,

In this edition of our journal, we have a total of nine articles related to science and mathematics education.

Thanks to everyone for contributing and/or becoming the reviewer of our journal.

Editor

Prof. Dr. Hülya GÜR

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Araştırma Makalesi / Research Article

Use Of Idealizations In Physics Textbooks

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Abstract – Idealizations have a very important place in the nature of physics. In this study, it is aimed to examine the content of secondary school physics textbooks in terms of the use of idealizations. For this purpose, the data obtained by examining the 9th, 10th, 11th and 12th grade high school physics textbooks were shared. Qualitative research method was used in the research and the data were obtained by document review technique. The research data were analyzed by three researchers using content analysis method. Evaluations were carried out with the subjects that idealizations should take place predominantly. In this context, 26 subjects/concepts were evaluated and it was determined that the textbooks were insufficient in terms of the use of idealizations as a result of the research. It is one of the important results of the study that the use of idealizations in textbooks increases as the grade level increases. Considering that idealizations are an important element of physics learning, it is thought that this situation should be emphasized.

Key words: physics education, idealization, physics textbook

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Introduction

In its broadest sense, physics is the discipline related to the 'hows' of the universe. Physics is a scientific branch investigating the matter, energy in relation to matter and every concept linked with space-time. “Just like all the other physical sciences, physics is also established

upon experimental observations and quantitative measurements. The main goal in physics is to detect the limited number of basic laws governing the natural phenomenon and harness them in developing the theories that can suggest relevant results for prospective experiments. These basic laws employed in theory development are expressed via the mathematical language, bridging the theory with experiment" (Serway & Beichner, 2000, p. 3). In this law and the modellings expressed via mathematical language, idealizations are frequently mentioned. Idealizations represent novel systems some of which specific features are closer to the features in target system (Norton, 2012). In general, idealization is performed to omit small variables, non-disclose the definition of certain variables, imagine limiting situations and accept the permanency or unity of some variables. Idealization is used when we develop physical models, equations or laws about "the real world' by employing sensory-data and as a result 'physics world' is recreated as the simile of real word. In another saying, with respect to exploration, idealization plays a crucial role generally by simplifying and bringing real world closer. Idealization is a key player also in applying physics concepts or physics world in order to grasp and estimate the real world. Broadly, idealization is performed by guiding experiment design, clarify and minimize the inconsistencies between real world and physics world by altering the conditions of idealization (Song, Park, Kwon & Chung, 2000). Scientists mostly aim to simplify what is presented; it is widely attested that if a model is correct in its basis, it can be made more complex afterwards (Fowler, 1997). Some theorists argue that idealizations are major players in the modeling and representation of physical phenomenon. Traditional view states that in reality use of idealizations is pragmatically right: so as to make them solvable and simplified we are required to include idealizations to our equations. Another perspective claims that idealizations are much better at explaining and characterizing dominant features of physical phenomenon. In a different saying, that means these idealized models are much more detailed and much more explanatory than less-idealized models (Batterman, 2009).

Remembering the fact that idealizations have a significant role in the nature of science it is critical that students learn the idealizations and gain awareness on this concept. Song et al.,(2000) argue that in science, particularly in physics, greater attention must be paid to the role of teaching and idealization in learning activities because idealization itself is a main component of learning physics. Idealization approach helps students to notice the association and inconsistency between the real world and physics world. Besides, it may be useful to foster students' creative analysis activities which assist them in actively engaging with idealization. In their research, Cahyadi and Butler (2004) concluded that concurrent teaching of the situations

with and without idealization could motivate students to think more attentively and application of opposite situations could prove to be a useful teaching method. In the teaching of idealizations textbooks, which are essential components of curriculum and education, can accomplish a great mission. Literature review on existing studies reveals that in Turkey textbooks have been analyzed from several dimensions. Textbooks have been assessed many times with respect to scientific content, educational design, book model, information gap, language and teaching, applicability of activities and teachers' views (Ünsal & Güneş, 2004; Ayvacı & Devecioğlu, 2013; Gönen & Kocakaya, 2006; Yıldırım, 2007; Şen & Nakiboğlu, 2014; Karadağ, Dülgeroğlu & Ünsal, 2013; Arslan, Tekbıyık & Ercan, 2012). However in existing studies not any analysis towards idealizations in the textbooks could yet be detected. International literature is also much barren in this topic. In their researches Forjan and Slisko (2014;2017) analyzed three Slovenian high-school physics textbooks with respect to the use of idealizations and simplifications in mechanics, electrics, thermodynamics and waves units. Researchers then detected that in many of the books, idealizations and simplifications were not used correctly. In international literature limited quantity of analyses on the use of idealization in textbooks and lack of any research in national literature on this topic is the driving source of motivation in our research.

In our research the aim is to analyze the content of middle school physics textbooks with respect to the use of idealizations. In parallel with this goal, obtained data have been shared upon analyzing 9, 10, 11 and 12th grade high school physics textbooks.

Method

In this study qualitative research method has been employed and research data have been gathered via document analysis technique which is a frequently employed method in qualitative researches to collect data. Documents provide critical data resources for qualitative researches (Özmen & Karamustafaoğlu, 2019). In this study, Science High School 9, 10, 11 and 12th grade Physics Textbooks (MEB, 2019a; MEB, 2019b; MEB, 2019c; MEB, 2019d) were examined to collect research data. Physics Textbooks taught in Science High Schools were selected on purpose as it is believed that these books are in an advanced level and use of idealization is expected to be higher in percentage.

Obtained data from the research were analyzed via content analysis method. Although there are no preset standard ways for qualitative data analysis, in content analysis, underlying meaning behind the data is exhibited, interpreted and presented to the reader by employing tools such as dimension, code, theme and category (Corbin & Strauss, 2015). In this research

analyzed idealizations were divided into two. Idealizations stated in the unit contents and idealizations stated in the questions. While analyzing the content and questions, data were assessed below three categories namely sufficient, partly sufficient and insufficient. Prior to data analysis, expected idealizations in the content and questions were discussed by three researchers and were then detected after reaching consensus. Detected idealizations were sought after in the content and data related to sufficiency, insufficiency and partly sufficiency. For instance; as Hooke's Law unit in the 11th grade textbook is examined content-relevant idealization is stated such; *"it is valid in conditions when force applied to the coil is proportional with the coil's change of place, when flexibility threshold of the coil is not overrun"*. As definition in the textbook is viewed this explanation has been detected; hence content was deemed to be sufficient: "*Spiral coils; provided that they remain within the flexibility threshold when force is applied their dimensions change, when force is lifted they turn back to their former shape, they are the objects which have been fitted with flexibility quality. According to Hooke's Law F force applied on the coil and change ratio in the coil's dimension x is directly proportional …"*(MEB, 2019c, p. 110). Expansion unit in the 9th grade textbook for the content-related idealization was such; *"It is valid in situations when there is no pressure change; for liquids with cups of which expansion is insignificant, objects' dimensions can be omitted."*. As the textbook definition is read it becomes evident that the need to omit pressure change has not been mentioned and content was deemed to be partly sufficient. Definition stated in the book is such; *"In general the matters of which temperature rises demonstrates a proportional increase in their length, surface area and volume. In tall objects such as string, length change is deemed to be significant whereas in objects such as plates, surface change is deemed to be significant. In objects like prism of which three dimensions are all close to each other, in line with length and surface change, there is a significant change in volume too(Figure 5.5). Expansion of liquids is only recorded as volume change, in cups of which expansion is insignificant expanded liquid rises up in the cup (Figure 5.6). In matters, amount of dimensional change depends on the size of length, surface and volume at the start, level of temperature change and change coefficient specific to the matter."*(MEB, 2019a, p. 135). In the analysis of Impulse unit for the 11th grade, expected idealizations are stated such: "It *is valid in situations when there is momentum change, frictions are omitted, contact duration is not equal to zero. It is then assumed that one of the forces applied on the particle has short-term effect and this force is greater than other forces."* These idealizations were not mentioned in the content of the textbook and the unit was deemed to be insufficient. Given definition in

the textbook is such: *"Multiplying force with application duration is called impulse. Impulse is a vectorial effect and its direction is in the direction of applied force. Its symbol is I."*(MEB, 2019c, p. 124). As units were analyzed by relevant questions, all of the questions below the title of this unit have been examined; units which mentioned idealizations that must be present in all questions were deemed to be sufficient, units which did not mention any of the idealizations in questions were deemed to be insufficient in terms of questions and units in which some questions contained idealizations whereas others omitted idealizations were deemed to be partly-sufficient. For example; as the two questions below the Kinetic Energy of Rolling Objects unit in the 12th grade book are analyzed it is seen that although in some questions required idealizations are stated, they have been omitted in others. One question not stated in idealizations is such; "*A cylindrical object of which mass is 8 kgs, radius is 0,5 m moves forward a horizontal surface with a constant angular speed of 10 rad/s. Compute this cylinder's a) Inertia moment b) Rotation kinetic energy c) Offset kinetic energy ç) Total kinetic energy."*(MEB, 2019d, p. 51). Another example stated in the idealizations is such; *"5 kg mass filled homogenous ball of which radius is r moves forward without sliding on a horizontal plane having insignificant friction. Since speed of mass center is 10 m/s how many Joules is the total kinetic energy of homogenous ball?"*(MEB, 2019d, p. 51). Kinetic Energy of Rolling Objects unit where such examples are stated was deemed to be partly sufficient in terms of questions. Analyses related to the content and questions focused on the units in which idealizations were expected to be dominant. All analyses are presented in the section of tables and findings.

In the research each unit was discussed by three researchers -one academic researcher from Physics Department and two graduate students in Physics Master's program. Discussions dwelled upon expected idealizations and a division was made between effective and ineffective idealizations. In the emergence of any disagreement discussions were continued until reaching consensus and only after reaching a joint agreement, then the next topic was analyzed. Additionally collected data were depicted elaborately by supporting with direct quotations. In order to enhance a research's internal validity it is important that researcher directly manifests the way he attained the results and provide inferences with relevant evidence (Yıldırım& Şimşek, 2008). Thus, it is aimed to ensure validity and reliability of the research. According to Yin (2003) a research should be conducted in a way that helps prospective researchers to reach the same results via applying identical methods. A well-studied documentation of the research is critical to ensure its reliability.

Findings

In this section, data obtained upon the analysis of textbooks with respect to the use of idealization have been presented. For each grade level data are prepared and presented separately as tables. In 9th grade textbook, 11 contexts/concepts have been analyzed and obtained data are as presented in Table 1.

Table 1 Usage Levels of Idealizations in the 9th Grade Textbook

SUBJECTS/CONCEPTS	CONTENT			QUESTİONS		
	Sufficient	Partially Sufficient	İnsufficient	Sufficient	Partially Sufficient	İnsufficient
1. Physics and the Universe			X			
2. Density	X				X	
3. Law of Gravity			X			
4. Newton's Second Law			X			X
5. Gravitational Acceleration and Weight			X		X	
6. Work			X		X	
7. Mechanical Energy		X			X	
8. Elastic Potential Energy			X			X
9. Heat Transfer and Thermal Equilibrium		X			X	
10. Expansion		X			X	
11. Coulomb's Law			X			X

Of all the 11 context/concepts analyzed in the 9. grade textbook, only 1 content in the unit was deemed to be sufficient whilst 7 context/concepts were deemed to be insufficient. Among the questions analyzed in the textbook none of the contexts/concepts were deemed to be sufficient while 6 were categorized as partly sufficient. In the unit, only Density context was deemed to be sufficient and idealizations were described such; *"Under constant temperature and pressure, amount of matter staying constant in unit volume is described as density. Density is symbolized with d and its unit in SI unit system is kg/m^3 ."* (MEB, 2019a, p.41). 5 context/concepts in 10th grade textbook were analyzed and attained data are as shown in Table 2.

Table 2 Usage Levels of Idealizations in the 10th Grade Textbook

SUBJECTS/CONCEPTS	CONTENT			QUESTİONS		
	Sufficient	Partially Sufficient	İnsufficient	Sufficient	Partially Sufficient	İnsufficient
1. Ohm's Law			X		X	
2. Fluid Pressure	X			X		
3. Beam Approach	X					
4. Focal Length in Spherical Mirrors			X			X
5. Image Formation in Lenses			X			X

Among the 5 context/concepts analyzed in 10th grade textbook 2 contents in the unit were deemed to be sufficient whilst 3 contents were deemed to be insufficient. Of all the questions examined in the textbook 1 was deemed to be sufficient, 1 as partly sufficient and 2 as insufficient. In Focal Length of Spherical Mirrors unit, idealizations expected from the content are such;"it is valid in situations when incident rays are close and paraxial to optical axis and when spherical mirror's aperture radius is smaller than mirror's radius" but content is such defined; *"Rays themselves or their extensions reaching parallel to the optical axis convene right in the middle of the peak and central point and this point is named as focal point. Focal point symbol is F. Distance from the peak to the focus is defined as Focal Length and symbolized with f."*(MEB, 2019b, p.227). In the unit, content was deemed as insufficient. In 11th grade textbook 5 context/concepts were analyzed and obtained data are as illustrated in Table 3.

Table 3 Usage Levels of Idealizations in the 11th Grade Textbook

SUBJECTS/CONCEPTS	CONTENT			QUESTİONS		
	Sufficient	Partially Sufficient	İnsufficient	Sufficient	Partially Sufficient	İnsufficient
1. Free Fall Motion	X			X		
2. Hooke's Law	X					X
3. Impuls			X			X
4. Coulomb's Law		X			X	
5. Capacitance in Capacitors			X			X

Of the 5 context/concepts analyzed in 11th grade textbook 2 context/concepts in the unit were deemed to be sufficient while 2 contents deemed as insufficient. 1 question deemed as sufficient in the content was named as sufficient and 3 content questions were categorized as insufficient. One of the units categorized as sufficient in context is the unit of Free Fall Movement. In the context idealizations are such given; *"Movement that an object makes during fall is a regularly-accelerated linear motion without initial speed conducted via vertical direction and g acceleration in -y direction. Near the earth surface since gravitational acceleration is approximately 10 m/s2 result obtained via equation states that irrespective of the mass value of every object, each object left free in frictionless environment would accelerate its speed by 10 m/s every second."*(MEB, 2019c, p.68). In 12th grade textbook 5 context/concepts were analyzed and obtained data can be seen in Table 4.

Table 4 Usage Levels of Idealizations in the 12th Grade Textbook

SUBJECTS/CONCEPTS	CONTENT			QUESTİONS		
	Sufficient	Partially Sufficient	İnsufficient	Sufficient	Partially Sufficient	İnsufficient
1. Kinetic Energy of Rolling Bodies			X		X	
2. Gravitational Force	X			X		
3. Period in the Spring Pendulum			X			X
4. Period in a Simple Pendulum	X			X		
5. Path Difference in Double Slit Interference	X			X		

Of the 5 context/concepts analyzed in 12th grade textbook 3 context/concepts in the content of unit were deemed as sufficient whilst 2 contents were deemed as insufficient. 3 context/concepts deemed as sufficient in the content were also deemed as sufficient in terms of questions too. As for the questions in the other 2 contents, 1 content was deemed to be partly sufficient and 1 content as insufficient. Idealizations expected for Kinetic Energy of Rolling Objects unit is such; “it is valid in situations without sliding, absolute rolling is performed and movement-inhibitor effect of friction is omitted". Yet in the content idealizations were omitted hence the unit was deemed as insufficient. In some of the questions in the unit a few of these idealizations are placed and these questions are deemed to be partly sufficient.

In the textbooks sum of 26 context/concepts in the unit were analyzed as the content and among these contents questions of a total of 23 context/concepts were examined. Questions from Physics Science and Universe, Law of Gravity Mass units in the 9th grade textbook and Ray Approximation in the 10th grade textbook could not be detected; hence these units were excluded from the analysis. Distributions of the analyses related to the examined context/concepts in the textbooks are as shown in Table 5.

Table 5 Distributions of Idealizations in Textbooks

	CONTENT				QUESTİONS			
	Sufficient N (%)	Partially Sufficient N (%)	İnsufficient N (%)	Total	Sufficient N (%)	Partially Sufficient N (%)	İnsufficient N (%)	Total N (%)
9th Grade	1 (%9)	3 (%27)	7 (%64)	11 (%100)	-	6 (%67)	3 (%33)	9 (%100)
10th Grade	2 (%40)	-	3 (%60)	5 (%100)	1 (%25)	1 (%25)	2 (%50)	4 (%100)
11th Grade	2 (%40)	1 (%20)	2 (%40)	5 (%100)	1 (%20)	1 (%20)	3 (%60)	5 (%100)
12th Grade	3 (%60)	-	2 (%40)	5 (%100)	3 (%60)	1 (%20)	1 (%20)	5 (%100)
Grand Total	8 (%31)	4 (%15)	14 (%54)	26 (%100)	5 (%22)	9 (%39)	9 (%39)	23 (%100)

The total sum of context/concept deemed to be sufficient both in terms of content and questions is 5 whereas the number of context/concept deemed to be insufficient both in terms of content and questions is 8. Sufficient questions in the context were deemed to be insufficient and while context/concept number is 1, there are no context/concepts deemed to be sufficient among the insufficient ones in the content.

Results and Discussion

Results of this research conducted to analyze the context of Middle School Physics Textbooks with respect to the use of idealizations are as stated hereinafter;

Data obtained from the 9th grade textbook indicate that with respect to use of idealization, textbook was insufficient in content whilst partly sufficient in questions. In particular, below Physics Science and Universe unit, as physics science is introduced; definition and objective of idealization which is a vital component of physics was omitted, and in many of the units in the book emphasis on idealizations was left unaddressed and this is indeed a major deficiency of the textbook.

Data obtained from the 10th grade textbook indicate that with respect to use of idealization textbook was partly sufficient in content whilst partly insufficient in questions. One of the most striking points in textbooks is that some of the units deemed to be insufficient in content were deemed to be partly sufficient in questions and one of the most clear examples of that is Ohm Law in the 10th Grade. Expected idealizations from the content in this unit are "it is valid in alternating-current resistances and extreme levels of heat, since resistance is subject to change by temperature change of heat can be omitted" and it was detected that these idealizations were not present, hence it was insufficient. In some of the questions of units in the textbook resistance of generator and strings were omitted while in other questions internal resistance of generators was omitted. Also it was seen that in certain questions idealizations were omitted hence questions were deemed to be partly sufficient and this situation could lead the students to face chaos in problem solving.

Data obtained from the 11th grade textbook indicate that with respect to use of idealization textbook was partly sufficient in content whilst insufficient in questions. One of the most noteworthy aspects of the textbook is that at the beginning of Electric and Magnetism unit; "*Elementary particles constituting the matter are, in mathematical sense, accepted as point particle. Therefore loaded objects could be expressed as point load*." (MEB, 2019c, p. 215) thus emphasis was made on point load. A similar emphasis is detected in 12th grade

textbook Gravitational Force unit too; "*In this unit dependant variables of the gravitational force between point masses will be identified and explained via a mathematical model.*" (MEB, 2019d, p. 68). Emphasizing these statements at the start of each unit is deemed to be quite a positive asset of the book and we believe that in an attempt to grab students' attention it should be emphasized at the beginning of other units too.

Data obtained from the 12th grade textbook indicate that with respect to use of idealization textbook was partly sufficient in content and also in questions. An analysis of the textbooks from the 9th grade till 12th grade reveals that use of idealizations goes up. As the level of grade increases idealizations are mentioned more frequently. Another noteworthy result is that as grade level increased there was improvement in some of the repeated units. For instance; as Hooke's Law unit in the 11th grade textbook is examined content-relevant idealization is stated such; "*it is valid in conditions when force applied to the coil is proportional with the coil's change of place, when flexibility threshold of the coil is not overrun*". Expected idealizations are not stated in the content and in terms of content, unit is deemed to be insufficient. Hooke's Law unit in 11th grade textbook shows that in this book expected idealizations from the unit are not mentioned in the content. In terms of content the unit was deemed to be sufficient and a similar observation holds true for Law of Gravity Mass and Coulomb Law units too. We believe that in the 9th and 10th grade levels when students first encounter science of physics, introduction of idealizations is quite important for them to learn physics.

To sum up high school physics textbooks were deemed to be insufficient with respect to the use of idealizations. A similar finding is echoed in the researches by Forjan and Slisko (2014;2017) too. In their researches it was emphasized that particularly in the problems listed in textbooks idealizations were not emphasized enough. Knowing that idealizations are a major component of learning physics, we believe that this is a situation worthy of attention. Cahyadi and Butler (2004) in their research suggest that use of idealizations plays a vital role in physics teaching. Song et al., (2000) claims that with no correct approach towards idealization it would be hard for students to grasp true meanings of basic concepts, understand the meaning of equations, appreciate the need of a specific experimental procedure in researches and comprehend the difference between daily life experiments and school book experiments. As we all appreciate the role of textbooks in physics teaching it becomes evident that emphasizing idealizations sufficiently in each grade level is quite important. We cannot claim that textbooks all together omit idealizations at all times but it is vital that presented idealizations be

internalized by students and their meaning for physics be truly appreciated. Within that context, specifically in the 9th Grade Physics Science and Universe Unit it is critical to emphasize the place and value of idealizations in the nature of physics and raise awareness towards that end because we observe that even at university level students are not yet aware of the role idealizations play within the nature of physics (Şengören, Çoban & Büyükdede, 2020). In addition, idealizations such as point object, frictionless environment, resistance-free system etc. should be mentioned at the start of units in an interesting and attention-grabbing manner so as to avoid being constantly repetitive. Textbooks should help learners to realize that equations used by students in physics lessons do not necessarily represent the observations they make in daily life and that these equations represent the models developed for idealized systems. In that way textbooks could guide students to be able to hold discussions on equations.

.

Fizik Ders Kitaplarında İdealizasyonların Kullanımı

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Özet – İdealizasyonlar fiziğin doğası içerisinde oldukça önemli bir yere sahiptir. Bu araştırmada, ortaöğretim fizik ders kitaplarının içeriğini idealizasyonların kullanımı açısından incelemek amaçlanmıştır. Bu amaç doğrultusunda 9, 10, 11 ve 12. sınıf lise fizik ders kitapları incelenerek elde edilen veriler paylaşılmaktadır. Araştırmada nitel araştırma yöntemi kullanılmış ve veriler doküman inceleme tekniği ile elde edilmiştir. Araştırmanın verileri üç araştırmacı tarafından içerik analizi yöntemi ile analiz edilmiştir. Değerlendirmeler idealizasyonların baskın olarak yer alması gereken konular ile gerçekleştirilmiştir. Bu bağlamda 26 konu/kavram değerlendirilmiş ve araştırma sonucunda ders kitaplarının idealizasyonların kullanımı açısından yetersiz olduğu tespit edilmiştir. İdealizasyonların ders kitaplarında kullanımın sınıf düzeyi arttıkça daha da arttığı çalışmanın önemli sonuçlarından biridir. İdealizasyonların fizik öğrenmenin önemli bir ögesi olduğu göz önüne alındığında bu durumun üzerinde durulmasının gerekli olduğu düşünülmektedir.

Anahtar kelimeler: fizik eğitimi, idealizasyon, ders kitabı

Sorumlu yazar: Harun YILDIZ, Dokuz Eylül Üniversitesi, Buca Eğitim Fakültesi, Matematik ve Fen Bilimleri Eğitimi Bölümü

Genişletilmiş Özet

İdealizasyonların bilimin doğası içerisinde önemli bir yer kapladığı düşünüldüğünde, idealizasyonların öğrenciler tarafından öğrenilmesi ve farkındalıklarının sağlanması oldukça önemlidir. Çünkü idealleştirmenin kendisi fizik öğrenmenin temel bir öğesidir. Ulusal literatürde yer alan çalışmalar incelendiğinde ülkemizde ders kitaplarının birçok açıdan değerlendirildiği görülmektedir ancak bu çalışmalarda ders kitaplarında yer alan idealizasyonlara yönelik herhangi bir incelemeye rastlanmamıştır. Böyle bir incelemenin olmaması çalışmanın temel motivasyon kaynağını oluşturmaktadır. Bu çalışmanın amacı

ortaöğretim fizik ders kitaplarının içeriğini idealizasyonların kullanımı açısından incelemektir. Bu amaç doğrultusunda 9, 10, 11 ve 12. sınıf lise fizik ders kitapları incelenerek elde edilen veriler paylaşılmıştır.

Bu araştırmada baskın olarak nitel araştırma yöntemi kullanılmakla birlikte veriler nicel olarak da ifade edilmiştir. Araştırmanın verileri doküman inceleme tekniği ile elde edilmiştir. Araştırmada Ortaöğretim Fen Lisesi Fizik 9, 10, 11 ve 12. sınıf ders kitapları incelenerek araştırma verileri elde edilmiştir. Araştırmada elde edilen veriler içerik analizi yöntemiyle analiz edilmiştir. Bu araştırmada incelenen idealizasyonlar ünitelerdeki içerikte ve sorularda yer alan idealizasyonlar olarak iki gruba ayrılmıştır. İçerik ve sorular analiz edilirken veriler yeterli, kısmen yeterli ve yetersiz olmak üzere üç kategoriye ayrılarak değerlendirilmiştir. Veriler değerlendirilmeden önce içerik ve sorularda yer alması beklenen idealizasyonlar üç araştırmacı tarafından tartışılıp ortak bir görüş birliğine varılarak belirlenmiştir. Belirlenen idealizasyonlar içerik ve sorularda aranarak yeterli, yetersiz ve kısmen yeterliliğe yönelik veriler elde edilmiştir. Araştırmada her bir konu -fizik eğitimi bölümünde akademisyen olan bir araştırmacı ve fizik eğitimi üzerine yüksek lisansına devam eden iki öğrenci olmak üzere- üç araştırmacı tarafından tartışılmış, fikir ayrılığı durumunda ortak fikir birliğine varılana kadar tartışma devam ettirilmiş ve ortak fikir birliği sağlanmadan bir sonraki konuya geçilmemiştir. Ayrıca elde edilen veriler doğrudan alıntılarla desteklenerek ayrıntılı bir biçimde betimlenmiştir.

Veriler her bir sınıf düzeyi için ayrı ayrı tablolar halinde hazırlanmış ve sunulmuştur. 9. sınıf ders kitabında 11 konu/kavram incelenmiş ve elde edilen veriler Tablo 1.'de paylaşılmıştır. 9. sınıf ders kitabında incelenen 11 konu/kavramdan ünite içerisinde yer alan içerikte yalnızca 1 tanesi yeterli olarak değerlendirilirken 7 konu/kavram yetersiz olarak değerlendirilmiştir. Ders kitabında incelenen sorularda ise yeterli değerlendirilen konu/kavram bulunmazken 6 tanesi kısmen yeterli olarak değerlendirilmiştir. 10. sınıf ders kitabında 5 konu/kavram incelenmiş ve elde edilen veriler Tablo 2.'de paylaşılmıştır. 10. sınıf ders kitabında incelenen 5 konu/kavramdan ünite içerisinde yer alan içerikte 2 içerik yeterli olarak değerlendirilirken 3 içerik yetersiz olarak değerlendirilmiştir. Ders kitabında incelenen sorularda ise 1 yeterli, 1 kısmen yeterli ve 2 yetersiz olarak değerlendirme yapılmıştır. 11. sınıf ders kitabında 5 konu/kavram incelenmiş ve elde edilen veriler Tablo 3.'te paylaşılmıştır. 11. sınıf ders kitabında incelenen 5 konu/kavramdan ünite içerisinde yer alan içerikte 2 konu/kavram yeterli olarak değerlendirilirken 2 içerik yetersiz olarak değerlendirilmiştir. Yeterli olarak değerlendirilen içerikten 1 tanesi sorularda yeterli olarak değerlendirilirken toplamda 3 içerik sorularda yetersiz

olarak değerlendirilmiştir. 12. sınıf ders kitabında 5 konu/kavram incelenmiş ve elde edilen veriler Tablo 4.'te paylaşılmıştır. 12. sınıf ders kitabında incelenen 5 konu/kavramdan ünite içerisinde yer alan içerikte 3 konu/kavram yeterli olarak değerlendirilirken 2 içerik yetersiz olarak değerlendirilmiştir. İçerikte yeterli olarak değerlendirilen 3 konu/kavram aynı zamanda sorularda da yeterli olarak değerlendirilmiştir. Sorularda diğer 2 içerikten 1 içerik kısmen yeterli iken 1 içerik de yetersiz olarak değerlendirilmiştir. Ders kitaplarında ünite içerisinde toplam 26 konu/kavram içerik olarak değerlendirilirken bu içeriklerden toplam 23 konu/kavramın soruları değerlendirilmiştir. 9. sınıf ders kitabında yer alan Fizik Bilimi ve Evren, Kütle Çekim Yasası konuları ile 10. sınıf ders kitabında yer alan Işın Yaklaşımı konusu ile ilgili sorular bulunmadığı için bu konular değerlendirme dışında bırakılmıştır. Ders kitaplarında incelenen konu/kavramlarla ilgili yapılan değerlendirmelerin dağılımları Tablo 5.'te paylaşılmıştır. Hem içerik hem de sorularda yeterli olarak değerlendirilen konu/kavram sayısı 5 iken hem içerik hem de sorularda yetersiz olarak değerlendirilen konu/kavram sayısı 8'dir. İçerikte yeterli sorularda yetersiz olarak değerlendirilen konu/kavram sayısı 1 iken içerikte yetersiz sorularda yeterli olarak değerlendirilen konu/kavram bulunmamaktadır.

Ortaöğretim fizik ders kitaplarının içeriğini idealizasyonların kullanımı açısından incelemek amacıyla yapılan bu çalışma doğrultusunda elde edilen sonuçlar şu şekildedir; 9. sınıf ders kitabından elde edilen veriler incelendiğinde ders kitabı idealizasyonların kullanımı açısından içerikte yetersiz sorularda ise kısmen yeterli görünmektedir. Özellikle Fizik Bilimi ve Evren konu başlığı altında fizik bilimi tanıtılırken fiziğin önemli bir parçası olan idealizasyonların tanımına, amacına ve fizikte kullanımına yer verilmemiş olması, kitap içerisinde yer alan birçok konuda ise yapılması gereken idealizasyonların vurgusunun yapılmaması önemli bir eksiklik olarak görülmüştür. 10. sınıf ders kitabından elde edilen veriler incelendiğinde ders kitabı idealizasyonların kullanımı açısından içerikte kısmen yeterli sorularda ise yetersiz görünmektedir. Ders kitaplarında dikkat çeken önemli noktalardan bir tanesi de içerikte yetersiz olarak değerlendirilen bazı konuların sorularda kısmen yeterli olarak değerlendirilmiş olmasıdır. Bunun önemli örneklerinden bir tanesi de 10. Sınıfta yer alan Ohm yasası konusudur. 11. sınıf ders kitabından elde edilen veriler incelendiğinde ders kitabı idealizasyonların kullanımı açısından içerikte kısmen yeterli sorularda ise yetersiz görünmektedir. Ders kitabında dikkat çeken noktalardan bir tanesi ise Elektrik ve Manyetizma ünitesi ve Kütle Çekim Kuvveti konusu başında noktasal kütle ve noktasal parçacık vurgusunun yapılmış olmasıdır. Bu vurguların kitap içinde bölüm başlarında olması kitap açısından oldukça olumlu bulunmakta ve öğrencilerin dikkatini çekecek şekilde diğer bölüm başlarında da

vurgulanması gerektiğini düşünmekteyiz. 12. sınıf ders kitabından elde edilen veriler incelendiğinde ders kitabı idealizasyonların kullanımı açısından içerik ve sorularda kısmen yeterli görünmektedir. 9. sınıftan 12. sınıfa doğru kitaplar incelendiğinde idealizasyonların kullanım sıklığının arttığı gözlemlenmektedir. İdealizasyonlara sınıf düzeyi arttıkça daha çok yer verilmiştir. Dikkati çeken bir diğer nokta ise sınıf düzeyi arttıkça tekrar eden bazı konulardaki gelişim olmuştur.

Sonuç olarak ders kitapları idealizasyonların kullanımı açısından yetersiz olarak değerlendirilmiştir. İdealizasyonların fizik öğrenmenin önemli bir ögesi olduğu düşünüldüğünde bu durumun üzerinde durulmasının gerekli olduğu düşünülmektedir. Ders kitaplarının fizik öğretimindeki rolü düşünüldüğünde idealizasyonlara her sınıf düzeyinde yeterli ölçüde yer vermek oldukça önemlidir. Ders kitaplarında idealizasyonlardan bahsedilmediğini söyleyemeyiz ama verilen idealizasyonların öğrenci tarafından içselleştirilmesi fizik için ne anlama geldiğinin anlaşılması gerekir. Bu anlamda özellikle 9. Sınıf fizik bilimi ve evren ünitesinin fiziğin doğası içinde idealizasyonların yeri ve önemine yönelik farkındalığı yaratmak açısından önemli olduğunu düşünmekteyiz. Bunun yanında noktasal cisim, sürtünmesiz ortam, dirençsiz sistem vb. idealizasyonlar, sürekli tekrara düşmemek açısından bölüm başlarında ama dikkat ve ilgi çekici olarak verilmelidir. Ders kitapları, öğrencilerin fizik derslerinde kullandıkları denklemlerin her zaman günlük yaşamlarındaki gözlemlerini temsil etmediğini ve bu denklemlerin idealize sistemler için geliştirilen modeller olduklarını anlamalarına yardımcı olmalıdır. Böylece ders kitapları öğrencilere denklemler üzerinde tartışabilecek duruma gelmeleri için öncülük edebilir.

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Research Article

Reflections on Online Mathematics Teaching

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A changing world and developing events have resulted in the elevation of online teaching to one of the most important topics on our agenda. The effectiveness of online teaching is related to a realization of certain basic elements; the main performers of which are teachers. The transition to online education is also a new learning process for teachers. For their new learning process, their perceptions regarding the new phenomenon is important in understanding their adaptation process. This study aims to investigate 'What kinds of metaphors do teachers produce to describe online mathematics teaching?'. The study is designed as phenomenology, and metaphor analysis was used in the analysis of the data. Forty-three teachers participated in this research. The participants expressed their ideas concerning online mathematics education using metaphors. Twenty-seven different metaphors and twenty-three different reasons were created from the thoughts of the participants. The most used metaphor was 'food', and the two most used explanations were 'need to progress in a certain program' and 'lack of interaction/communication in the process'. The results of the study reveal that mathematics teachers have different perceptions in regard to emergency online education.

Keywords: Online education, online mathematics learning, metaphor analysis, pandemic.

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Introduction

Online courses have become one of the most important topics of our lives and the agenda we follow as a result of today's conditions. The teaching system, which includes learning over the Internet, is called online education (Karakaş, 2020). There are two types of online education; synchronous and asynchronous. Synchronous education is the simultaneous

interaction of the students and the teacher, while asynchronous education is called the interaction of the teacher and the student at different times (Baki, Karal, Cebi, Şılbır, & Pekşen, 2009). In this process, there are necessary materials for students and teachers to participate in education. These are the Internet, an electronic device (phone, computer, and suchlike), and an environment for study.

At the end of 2019, the Covid-19 virus spread all around the world in only a short time, changed our lifestyles, and affected education as it had in other areas. As a result of this, online education has become a concept that is now a serious item on the agenda of educators. After the first case was seen in Turkey, quarantine was implemented in a short time, and schools were initially placed on holiday. After this, face-to-face classes were suspended due to the prolongation of the process, and Information and Communication Technologies (ICT) (Bozkurt, 2015) based on the Internet, and other new technologies began started to work to provide much needed support for education. In this context, emergency online training brought about by the unexpected pandemic process has started to be implemented in Turkey, as well as throughout the rest of the world.

In the current literature, the benefits of online education, such as adaptability, active learning, and participation are emphasized, but at the same time, problems such as workload, student resistance and a decrease in students' interest in courses, as well as a lack of materials, are also discussed (Kebritchi, Lipschuetz, & Santiague, 2017). In addition to the benefits of online education, restrictions to the teacher-student relationship is another problem (Karakus, Ucuzsatar, Karacaoglu, Esendemir, & Bayraktar, 2020). For example, Elçil and Şahiner (2014) reveal that there are disconnections in teacher-student communication, as well as with university students who experience distractions and a lack of motivation during the online education process. On the other hand, Altıparmak, Kurt, and Kapıdere (2011) identify possible technological problems and mention problems such as students not being ready for programs, and financial inadequacies. Teachers, on the other hand, state that it is difficult to communicate with students remotely, in addition to the difficulty of feeling restricted by technology (Hilli, 2020). One of the issues that cause negative results, such as worry, anxiety, and stress, is the uncertainty of the situation (Küçükkömürler, 2017). Another study on the online education process with classroom teachers reveals that this situation affects students in many areas (Duban & Şen, 2020). Since students are educated at home, students do not have a certain sleep and study pattern, and some students do not have the opportunity to access education. Duban and Şen (2020) in their study, in which they state that students do not

receive characteristics such as respect and sociability that they will benefit from in a classroom environment, in online education, show that online education similarly affects all teaching fields. According to Sümer's (2016) research, reasons such as the fact that the teacher-student relationship is limited to written communication in the online education process, and the inability to make eye contact, show the interaction problem between teacher and student. In research by Tuncer and Bahadır (2017), it is stated by students that lecturers were indifferent and not sincere during the process, and that the learning environment was not friendly.

While the online training process of mathematics teachers is similar to other teachers in certain subjects, it can also differ in a number of field-specific points. Ilgaz (2014) finds online education supportive in terms of the fact that lessons can accessed later. Similarly, Karasar (2004) emphasizes that online education brings convenience as well as being supportive. A study by Gürsul and Keser (2009) shows that online training is more successful than face-to-face training in group work, contrary to previous findings in the literature. One of the most important findings of Gürsul and Keser (2009) is that there is a statistically significant difference in the success levels of groups in the face-to-face and online problem-based learning processes, mostly in favor of the online groups. For this reason, studies on online practices of mathematics teaching should be dealt with separately. A number of points may be associated with this, such as the nature of mathematics courses, practices, and student perceptions. It is frequently said that there are difficulties in the learning and teaching of mathematics in Turkey (Yenilmez & Avcu, 2009). In addition to the fact that students see mathematics as a difficult and boring subject, most students describe mathematics using negative words, such as nightmare, fear, and stress (Tahiroğlu & Çakır, 2014). In this case, it makes it difficult for students to be motivated in mathematics lessons. Certain materials or tools may be required (for example, the need to use a graphic tablet) to be able to solve questions in mathematics lessons and to reflect solutions to the students. The use of materials used in teaching mathematics is another challenging point that arises for mathematics teachers in online education. In addition, the technological readiness of teachers is one of the factors affecting this process.

The effectiveness of online teaching, whether it is an emergency or a choice in the normal teaching process, is closely-related to the realization of certain basic elements. The main performers of these basic elements are teachers. However, the transition to online education is also a new learning process for teachers. This process can be challenging and, at

the same time, developing for teachers who are responsible for going beyond routine practices, designing new practices and integrating them into lessons, and doing all of this without any preparatory process. The findings of teachers' learning in the adaptation process to new practices reveal that this is related to teachers' reflective thoughts (Toker, 2021). These findings are also valid for mathematics teachers. In this context, it is important to hear the voice of teachers, who are the main actors of online teaching, towards teaching. The research question of the study is defined as 'What kinds of metaphors do teachers produce to describe online mathematics teaching?'. The term metaphor used in the research is used to compare a phenomenon to another phenomenon through its similar characteristics. Regarding the research question, sub-questions were formed concerned with planning, resource use, material use, methods used, classroom management, evaluation, feedback, and teachers' professional development.

Conceptual Framework

Metaphors are important representative tools in revealing people's perceptions and thoughts regarding a particular phenomenon. One of the main purposes of using metaphors in qualitative research is to reveal the current situation (Fırat, Kabakçı-Yurdakul, & Ersoy, 2014). In this context, metaphors are used as a powerful data collection tool that can be used to determine perceptions and thoughts in recent studies. (Guveli, İpek, Atasoy, & Güveli, 2011). Teachers were asked to explain their thoughts with metaphors to understand more easily, classify, and draw conclusions. In the online teaching process, teachers' thoughts concerning the process are important in understanding this process. For this reason, this study aims to reveal what kind of phenomenon online mathematics teaching is, from the perspective of mathematics teachers, in light of the metaphors expressed by them.

While it is difficult to find metaphorical studies, which is the method used in this research, in online education, there are even less when it comes to the teaching of mathematics. At this point, in order to understand the process, it is important to see the point of view of the teachers, who have one of the leading roles in the process.

Method

Research Design

Online education has become a usual consequence of the pandemic today, and this shows that the entire world is united in this emergency. Therefore, the pandemic process has started a new era for all occupational groups. One of the occupational groups most affected by

this process is teaching. It is believed that the thoughts provided by the teachers who have experienced the process, to facilitate and develop this process, and to identify any deficiencies can help them achieve these goals. Therefore, the research seeks an answer the question "What kinds of metaphors do teachers produce to describe online mathematics teaching?". For this reason, the preferred design of the research was the phenomenology, which is one of the qualitative research methods (Creswell & Poth, 2018). In this study, based on the experiences of the participants, their ideas regarding a particular phenomenon were collected through metaphors. The phenomenon in this study is defined as the thoughts of teachers concerning online mathematics teaching.

Participants

Since the research aims to reveal thoughts about mathematics teaching processes, in particular, the participants targeted were classroom teachers; secondary and high school mathematics teachers who experience online teaching themselves. The data was collected in the 2020-2021 academic year, when distance education was followed during the pandemic process. Forty-three teachers participated in this research. The mean of students in the classes of the teachers participating in the research was approximately twenty-three, with the average age of the students being seventeen. The data shows that 58.1% of the teachers participating in the research did not receive any training on online education.

Data for the research was obtained from teachers who could be reached by the snowball method (Johnson, 2014). This method starts by establishing a connection with one of the units in the universe and continues by contact with another person, and then with another contact in the same way. Therefore, the sample is enlarged as a snowball effect (Gürbüz & Şahin, 2018). Participation in the research was voluntary. In the form completed by the participants, there is specific information to be used in the research, and their participation in the research shows that they consent to the use of this information. In addition, a paragraph is presented to the participants, briefly explaining the purpose of the research and informing them that the participation is voluntary, that the data obtained from the participants will not be shared with anyone, and that names will not be shared if the analyzed data is shared for scientific purposes. It was also be emphasized that participation is voluntary in the text, which includes the link of the research questionnaire to be conveyed to other teachers by the snowball method. First, the implementation of the questionnaire was started

with the teachers recognized by the researchers, and then the number of participants was increased.

Data collection

In this study, the questions created to reveal the metaphors of teachers on online education were sent to teachers. In this form, the questions were answered in ten sub-headings, such as methods, classroom management, evaluation, and feedback, allowing teachers to reflect on the subject of 'Metaphorically examining the thoughts about online mathematics teaching', These questions were prepared in the form of 'Online teaching is similar to....., because.....'. Figure 1 contains sample questions from the relevant form.

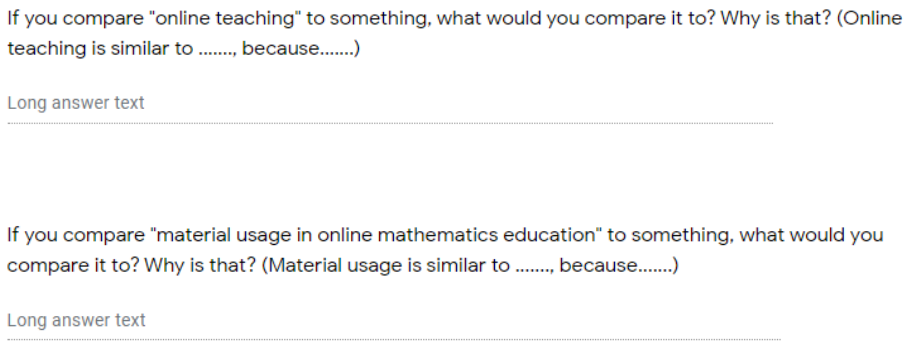

Figure 1. Sample questions from the relevant form

The form used was prepared by the researchers considering the main elements, such as planning and evaluation in the education process and sub-elements like the use of materials and feedback. After the first draft of the form used was prepared, four experts working in the field of mathematics education were consulted to obtain expert opinion. According to the opinions received, the content remained unchanged, and the form was finalized after making minor adjustments, such as adding words to increase the clarity of expressions, and adding a sample answer format to the beginning of the form to show the desired answer format. The final version of the form was applied to a teacher and a pilot application was made. At the end of the pilot application, the option not to write the answers in the questions was removed, and it became mandatory to answer all the questions.

Data Analysis

Metaphors are used to express the similarity and relationship between two elements that cannot be fully explained with basic explanations (Güneş & Fırat, 2016). For this reason, frequency tables were created by listing the metaphors used by the participants, and the data was presented by grouping them thematically. In addition to this, the aim was also to present examples of teachers' statements and data qualitatively. Ethical permission (permission numbered 04.02.2021-1110) was obtained from Human Research Ethics Committee of the university where the authors are affiliated.

Findings and Discussion

According to the results of the survey, the participants created twenty-seven different metaphors and twenty-three different reasons to describe online mathematics education as well as ten sub-questions related to planning, resource use, materials, methods, classroom management, assessment, feedback, and professional development. A total of 309 answers were given for ten questions. The metaphors of the teachers' concerning online education and their thoughts on different sub-dimensions in the online education process were examined separately.

Online Education

Out of forty-three answers to this question, forty-two valid metaphors were produced and thirty-nine valid reasons were written. Forty-two valid metaphors for this sub-question are categorized as follows: profession group (f:3); situation (f:4); emotion (f:3); living person (f:1); music (f:1); health (f:1); sports (f:5); food (f:5); equipment (f:5); process (f:4); TV (f:3); game (f:2); nature (f:2); and phenomenon (f:2), as classified in fourteen different ways. Thirty-nine valid reasons for this sub-question are classified as follows: lack of interaction/communication (f:13); novelty (f:1); the difficulty of the process (f:3); versatility (f:3); use in necessity (f:2); insufficiency (f:1); need to progress in a certain program (f:1); variety (f:2); asking for mastery (f:4); because it is from the screen/remote (f:3); not achieving the desired result (f:1); the process requires interaction (f:2); being future (f:1); being a new process (f:1); and being life itself (f:1).

The most common reason for this sub-question is a lack of interaction/communication. This reason is explained through connection with metaphors; situation (f:4), emotion (f:2), health, sports (f:2), nature, food, equipment, and phenomenon (f:1) by participants. For example, P3 describes this reason with the metaphor ‘situation’ and expresses it as follows:

"It is similar to flying a kite with a fan in the windless air, because when it is not done face-to-face, the interaction is not enough and the teaching remains artificial." P4 connects the same reason with the metaphor 'emotion' and says, *"The orchestra must have the coordination and equipment to play, direct, and sing. You need to understand quickly, understand what the other person understands, or reach the maturity and practice of communication that will explain what you do not understand."*

Online mathematics education

Out of forty-three responses to this sub-question, thirty-seven valid metaphors were produced and thirty-five valid reasons were written. Thirty-seven valid metaphors created for this sub-question are categorized as follows: fairy tale (f:1); toy (f:1); nature (f:2); action (f:3); vehicle (f:1); profession group (f:2); tool (f:2); emotion (f:3); food (f:5); process (f:2); object (f:1); activity (f:1); situation (f:6); game (f:2); sport (f:2); phenomenon (f:2); and living-animal (f:1). The thirty-five valid reasons for this sub-question are categorized as follows: the process is difficult (f:10); there is no interaction/communication (f:7); the desired result is not achieved (f:6); it is necessary to progress in a certain program (f:5); it is versatile (f:2); there is progress (f:1); uncertainty (f:1); it is from screen/remote (f:1); and unlimited (f:2).

The most expressed reason in the answers given to this question by the participants is that the process is difficult. This reason is expressed by the participants by the following metaphors; action (f:2), emotion (f:3), situation (f:2), food, sports, and living. For example, P5 expresses this reason using the metaphor of action, saying, *"It is like dressing an octopus that takes off its jacket from its arms that you always wear; it is difficult to be complete with everything."* P32 says, "It is like cooking without taste, yes, but you need to be experienced," by using a situation metaphor. P42 states, *"Online mathematics teaching is like a turtle, because writing the answers to the questions step-by-step with the help of the mouse causes a great waste of time,"* and associates this reason with a living metaphor. P4, on the other hand, uses the metaphor of nature to explain the reason 'the desired result is not achieved' by saying, *"Online mathematics education is similar to the winter sun, it illuminates but does not heat. In other words, the desired and expected results are not achieved, unfortunately, especially at primary school level."*

Planning in online education

Out of forty-two answers given to this sub-question, thirty-one valid metaphors were produced and twenty-nine valid reasons were written. Thirty-one valid metaphors created for this sub-question are categorized as follows: activity (f:5); phenomenon (f:1); situation (f:6); structure (f:1); food (f:8); tool (f:5); nature (f:1); process (f:1); living-structure (f:1); action (f:1); and emotion (f:1). The twenty-nine valid reasons for this sub-question are categorized as follows: needing to progress in a certain program (f:6); being versatile (f:2); not achieving the desired result (f:3); the process being difficult (f:4); being accessible (f:1); supportive (f:2); the process requires interaction (f:1); and it is uncertain (f:1). An answer has been put into two different categories.

The most expressed reason in the answers given to this question by the participants is the need to progress in a certain program. This reason is expressed by the participants with certain metaphors; activity (f:3), phenomenon, structure, food (f:5), equipment (f:3), nature (f:1), and action (f:1). In one answer, no metaphor is specified. For example, P7 uses the metaphor of structure to say, *"I compare this sub-question to the foundation of a building. If there is no preparation, the strength of the building you built on is questioned. The better the preparation phase, the more efficient the lesson will be."* On the other hand, P17 expresses using the activity metaphor, *"It aims to arrange the stages of preparation for the dance show, studying the movements, making the right moves with music at the right time and completing the choreography. In mathematics teaching, it will be difficult to learn without preparation, planning, and using the right method at the right time."* P5 uses the situation metaphor and connects it with the reason the process is versatile saying, *"It is like driving a car in an area where road construction works are constantly being done, you must have both B, C, D plans and know how to drive.*" However, P34 with the situation metaphor expresses, *"Planning is like life in online mathematics teaching, because you never encounter the results in your usual plans."*

Using resources (pressed, technological, and others) in online education

Out of forty-three responses to this sub-question, twenty-eight valid metaphors were produced and twenty-nine valid reasons were written. Twenty-eight valid metaphors created for this sub-question are categorized as follows: tool (f:5); phenomenon (f:2); food (f:6); movie-story character (f:2); mission (f:1); process (f:3); vehicle (f:1); activity (f:1); feeling (f:1); living-animal (f:1); action (f:2); TV (f:1); living-person (f:1); and structure (f:1). The twenty-nine valid reasons for this sub-question are categorized as follows: being accessible

(f:9); need to progress in a certain program (f:5); being supportive (f:3); asking for mastery (f:1); insufficient (f:1); novelty (f:1); using in only necessity (f:1); mandatory step (f:3); being limited (f:1); being a new process (f:1); not achieving the desired result (f:1); and difficult process (f:1). One answer was put into two different categories.

The most expressed reason in the answers given to this question by the participants is that it is accessible. This reason is expressed with the following metaphors; phenomenon (f:1), movie-story character (f:2), vehicle (f:1), food (f:2), process (f:1), tool (f:1), and living (f:1) by the participants. For example, P19 uses the food metaphor for this reason and says, *"It is like a ready meal because everything is at hand, you are just transferring."* P13 uses the movie-story character metaphor and expressed it as, *"There is a character named Mr Talented. He has a truck, all the materials for the event are easily accessible."* P7, on the other hand, expresses using resources in online education and is supportive over the structuring metaphor saying, *"It is similar to the columns we set up on the resource building in online mathematics teaching. The more columns we have, the more diverse resources we use, the stronger our building will be."* With the same feature and mission metaphor, P14 says, *"The resource in online mathematics teaching is similar to the support team of the F1 pilot, because getting support from different sources in the course makes the teacher strong and completes his deficiencies."*

Material usage in online education

Thirty-two valid metaphors were generated out of forty-three responses to this sub-question and thirty-one valid reasons were created. Thirty-two valid metaphors created for this sub-question are categorized as follows; situation (f:4); tool (f:9); living-animal (f:2); TV (f:2); process (f:1); action (f:2); activity (f:1); game (f:2); phenomenon (f:2); food (f:3); nature (f:1); living-person (f:1); movie-story character (f:1); and music (f:1). Thirty-one valid reasons for this sub-question are categorized as follows: being supportive (f:7); being versatile (f:4); providing convenience (f:3); not achieving the desired result (f:3); lack of interaction/communication (f:3); insufficient (f:3); being a new process (f:1); needing to progress in a certain program (f:3); variety (f:2); there is progress/improvement (f: 1); and being a mandatory step (f: 2). One answer was put into two different categories.

The most cited reason in the answers given to this question by the participants is that the use of materials in online mathematics teaching is supportive. Used metaphors for this reason by the participants are; situation (f:1), process (f:1), tool (f: 2), and music (f:1). No metaphor

was cited in the two answers. For example, P3 expresses using the situation metaphor saying, "*It is like filling up the vehicle's tank while driving on a long drive. Because the tank of the vehicle is full, you can drive your vehicle comfortably.*" On the other hand, P42 expresses by using the metaphor of music saying, "*Using materials in online mathematics teaching is like moving music, because the students' interest in the lesson increases with the use of materials.*" The participants stated that using material is supportive. P9 claims that material usage is versatile by using the living metaphor saying, *"Octopus. Because it is necessary to run both mouse, graphic tablet, chat screen, chat groups, and z-books at the same time."* P12 uses the TV metaphor while expressing the inadequacy of material usage saying, *"It may be watching movies from a TV that is not equipped with multidimensional movies."*

Methods in online mathematics education

Thirty-one valid metaphors were generated out of forty-three responses to this sub-question and twenty-eight valid reasons were created. Thirty-one valid metaphors created for this sub-question are categorized as follows: action (f:5); tool (f:4); game (f:3); food (f:4); institutional structure (f:2); activity (f:3); process (f:1); feeling (f:2); nature (f:1); feel (f:1); sense (f:1); living-organ (f:1); living-person (f:2); and phenomenon (f:1). Twenty-eight valid reasons for this sub-question are categorized as follows: being supportive (f:9); being a mandatory step (f:2); achieving the desired result (f:2); needing to progress in a certain program (f:4); innovation (f:1); being accessible (f:1); being insufficient (f:2); variety (f:3); the process being difficult (f:1); the process requiring interaction (f:1); no interaction/communication (f:1); not achieving the desired result (f:1); to be used in necessity (f:1); and to be a new process (f:1). Two answers were put into two different categories.

The most expressed reason for the answers given to this question by the participants is that the methods are supportive in online mathematics teaching. For this reason, the participants used the following metaphors; tools (f:2), action (f:2), activity, process, and feeling. No metaphor was stated in two answers. For example, K4 supports using the metaphor tool for this reason: *"I compared the methods to traffic lights. It would express where and when we should do what",* and K14 with the same metaphor says, *"The methods used in online mathematics teaching are similar to a road map; navigating according to the determined method will make us reach the goals we marked on the map more effectively and easily."* In addition to being supportive, K29, using the activity metaphor, states the variety of

methods in online education saying, *"Similar to painting because it can achieve different results using different techniques."* K42, on the other hand, states that it was a new process using the sense metaphor saying, *"The methods used in online mathematics teaching are like discovering new tastes, because we start to learn a new technological application every day."*

Classroom management in online education

Out of forty-three answers to this sub-question, twenty-seven valid metaphors were produced and thirty-one valid reasons were created. Twenty-seven valid metaphors created for this sub-question are categorized as follows: profession group (f:3); TV (f:1); process (f:3); structure (f:1); press (f:2); tool (f:2); living-animal (f:1); activity (f:3); situation (f:4); action (f:3); object (f:1); living-person (f:1); nature (f:1); and movie-story character (f:1). Thirty-one valid reasons for this sub-question are categorized as follows: asking for mastery (f:7); need to progress in a certain program (f:6); the process is difficult (f:6); lack of interaction/communication (f:5); because it is from screen/remote (f:3); being versatile, being supportive (f:2); being a new process (f:1); variety (f:1); and being a mandatory step (f: 1). Three responses were put into two different categories.

The most expressed reason for the answers given to this question by the participants is that classroom management demands mastery in online mathematics teaching. For this reason, the participants used the following metaphors; profession group (f:2), TV (f:1), living (f:2), and activity (f:1). In one answer, no metaphor is stated. For example, K3 uses the professional metaphor saying, *"It is like being a conductor. Because class management, which is a serious problem even in face-to-face education, requires online expertise."* K20, without using metaphors says, *"Limited, because it is difficult for the person who teaches the lesson to dominate the class. Even if the student concentrates elsewhere at that moment, it is difficult to take precautions."* K17, on the other hand, uses the activity metaphor saying, *"This is that the partners in the dance manage each other and the area they dance, while at the same time keeping the audience's attention on them. In classroom management, not only the teacher manages the classroom, but the students are actually in charge. The stage is for students, not for teachers."* They explain that classroom management demands mastery in online education. P27, on the other hand, uses the metaphor of the situation to explain that there is no interaction/communication in classroom management saying, *"Class management is like space. It is difficult to communicate with the students."*

Evaluation in online mathematics education

Out of the answers given to this sub-question, twenty-five valid metaphors were produced and twenty-one valid reasons were created. Twenty-five valid metaphors created for this sub-question are categorized as follows: food (f:3); action (f:5); tool (f:2); mathematics operation (f:2); situation (f:4); activity (f:2); object (f:1); game (f:1); sport (f:1); phenomenon (f:1); process (f:1); institutional structure (f:1); and emotion (f:1). Twenty-one valid reasons for this sub-question are categorized as follows: not achieving the desired result (f:6); uncertainty (f:5); being a difficult process (f:4); needing to progress in a certain program (f:3); insufficient (f:2); lack of interaction/communication (f:1); and achieving the desired result (f:1). One answer was put into two different categories.

The most expressed reason in the answers given to this question by the participants is that the desired result is not obtained in evaluating online mathematics education. This reason is represented by the following metaphors used by the participants; mathematics operation (f: 2), phenomenon (f:1), tool (f:1), institutional structure (f:1), and emotion (f:1). For example, P13 uses the mathematical operation metaphor stating that, "*The evaluation phase cannot be experienced sufficiently. I thought of doing a lot of work and multiplying the result obtained by 0.*" P36 uses the tool metaphor explaining that the desired result could not be achieved while assessing the situation saying, *"The lid that does not fit the pot."* K3, using the metaphor of food to explain that the process is difficult says, *"It is like losing your sense of smell and taste while thinking that you are making a very good soup, because it is difficult to evaluate that nice-looking soup that you cannot smell and taste."* While explaining the uncertainty of the process with the action metaphor K4 says, *"Evaluating is like looking inside a closed box; is there treasure hidden in it or ordinary things?"*. K16, on the other hand, uses the situation metaphor for the versatility of evaluation in online education saying, *"Evaluating online mathematics education can be like a tree climbing competition in which a monkey and a cow participate, because you may encounter unfair situations."*

Giving feedback in online mathematics education

Out of forty-three answers given to this sub-question, twenty-nine valid metaphors were produced and twenty-four valid reasons were created. Twenty-nine valid metaphors created for this sub-question are categorized as follows: situation (f:3); action (f:6); game (f:1); press (f:2); sports (f:2); food (f:5); sense (f:2); vehicle (f:1); process (f:2); activity (f:2); phenomenon (f:1); nature (f:1); and tool (f:1). Twenty-four valid reasons for this sub-question are categorized as follows: being supportive (f:7); lack of interaction/communication (f:5); not

achieving the desired result (f:4); achieving the desired result (f:2); insufficient (f:2); variety (f:1); being a mandatory step (f:2); being versatile (f:1); and requiring progress in a certain program (f:2). Two answers were put into two different categories.

The most expressed reason for the answers given to this question by the participants is that giving feedback in online mathematics teaching is supportive. The participants used the following metaphors for this reason; tool (f:1), activity (f:1), food (f:1), process (f:1), press (f:1), and action (f:2). For example, with the tool metaphor P13 says, *"Giving feedback in online mathematics teaching is like gasoline; thanks to the feedback students gain speed and become motivated."* P17 with the activity metaphor says, "*This is the applause at the end of the dance show. Applause can be given in any case, good or bad, of course. The strength of the applause and the facial expressions of the applause can be understood. The student always expects feedback. He wants to hear feedback, not only at the end of the lesson or in the homework he has done, but in every topic that he tells his teacher, every question he asks, and every subject he talks about. The most important step for the student is feedback. Giving feedback in mathematics teaching is keeping the pulse of the student."* P43 with the action metaphor says, *"Giving feedback in online mathematics teaching is similar to earning points from shopping, because students' awareness of their learning increases with the feedback they receive at regular intervals and contributes to their success."* The participants explain that giving feedback is supportive of using their sentences. K3 states the situation metaphor saying, *"It is similar to trying to enter through the window while the door is standing. Because even one glance in face-to-face teaching is superior to much online feedback."* P6, using the press metaphor *says, "Radio broadcast is a good example of online training, where one-sided narrative-based feedback is not provided. Discussing a topic by improving the conversation in the telephone conversation can also be an example of giving feedback."* They state that there is no interaction/communication in giving feedback with their sentences.

Professional development in online education

Out of forty-three answers to this sub-question, twenty-seven valid metaphors were produced and twenty-seven valid reasons were created. Twenty-seven valid metaphors created for this sub-question are categorized as follows: object (f:1); sport (f:2); situation (f:2); game (f:2); nature (f:4); process (f:5); activity (f:1); tool (f:1); profession group (f:2); food (f:1); movie-story character (f:1); living-animal (f:2); phenomenon (f:1); action (f:1); and vehicle (f:1). Twenty-seven valid reasons for this sub-question are categorized as follows: there is progress/improvement (f:11); not achieving the desired result (f:3); being a new process (f:5);

the process being difficult (f:3); achieving the desired result (f:2); asking for mastery (f:1); it will be used in necessity (f:1); and to progress in a certain program (f:1).

The most cited reason in the answers given to this question by the participants is that their professional development is in progress in online mathematics teaching. This reason is expressed with the following metaphors by the participants; nature (f:3), process (f:2), activity (f:1), occupation group (f:1), living (f:1), and vehicle (f:1). No metaphor was specified in the two answers. For example, P14 with the metaphor of nature says, *"My development in online mathematics teaching is similar to the growth phase of a sapling; as the sapling is watered, I gain experience and improve myself through reading."* P16 with the process metaphor *says, "I cannot deny the contribution of online education to my professional development, while I think that I cannot make much progress."* With the metaphor of nature P42 says, *"My development in online mathematics teaching is similar to a sapling because, with developing technology, I have to learn many programs to make the lessons more interesting. Like a sapling growing every day, my professional knowledge grows."* By establishing their sentences, these participants state that their personal development is in progress/development. P3, on the other hand, says, *"It looks like a pit where sand is constantly thrown and never fills, because I think I was never complete."* P3 emphasizes that the desired result is not achieved by constructing the sentence.

When the answers to all the questions given by the participants are examined holistically, summary information about the metaphors is presented in Table 1. The metaphors shown in the table are all of the metaphors the participants created for the ten questions in the questionnaire.

Table 1: Frequency table of the metaphors

Metaphor	Frequency (f)	Metaphor	Frequency (f)
1. Mission	1	15. Profession group	10
2. Fairytale	1	16. Feeling	12
3. Toy	1	17. Sport	12
4. Health	1	18. Nature	13
5. Mathematical operation	2	19. Phenomenon	13
6. Music	2	20. Game	13
7. Sense	3	21. Living	15
8. Institutional structure	3	22. Activity	19
9. Structure	3	23. Process	23
10.Vehicle	4	24. Action	28
11. Press-publication	4	25. Situation	33
12. Film-Tale character	5	26. Tool	36
13. Object	5	27. Food	40
14. TV	7	Total	309

As can be understood from the table, the most common metaphor is ‘food’. This metaphor, which corresponds to 13% of the metaphors, was used forty times by the participants. The second most frequently repeated metaphor is ‘tool’. It was used thirty-six times by the participants in different questions and equals 11.6% of all of the metaphors. The least used metaphors are ‘mission’, ‘fairy tale’, ‘toy’, and ‘health’. These metaphors are only used once and equal to 0.3% of the total metaphors. Table 2 presents the reasons stated by the participants regarding the metaphors they produced holistically. The explanations shown in the table are the statements created by the participants for all ten questions in the questionnaire.

Table 2: Frequency table for the reasons for metaphors

Reasons	Frequency (f)	Reasons	Frequency (f)
1. Variety	1	13. Being accessible	10
2. Because it is the future	1	14. Being a new process	10
3. Being life itself	1	15. Being a mandatory step	10
4. Unlimited	2	16. Insufficient	11
5. Providing convenience	3	17. Being versatile	13
6. Novelty	3	18. Asking for mastery	13
7. The process requires interaction	4	19. Not achieving the desired result	29
8. It will be used in necessity	5	20. Being supportive	30
9. Because it is from the screen/remote	7	21. The process is difficult	32
10. Achieving the desired result	7	22. Lack of interaction /communication	36
11. Uncertainty	8	23. Need to progress in a certain program	46
12. There is progress /improvement	8	**Total**	**295-10=285**

When the responses of the participants to all of the questions are examined, a total of 295 explanations were created. However, ten of the answers are categorized into two different categories, meaning there are 285 answers for the reasons for using metaphors in the answers. Among the 295 explanations, the most common explanation is ‘requiring progress in a certain program’, which is used forty-six times equaling 15.6% of all of the answers. It is followed by the explanation ‘lack of interaction/communication’ which was expressed thirty-six times (12.2%), ‘being a difficult process’ thirty-two times (10.8%), ‘being supportive’ thirty times (10.2%), and ‘not achieving the desired result’ twenty-nine times (9.8%). The least emphasized reasons are ‘diversity in the process’, ‘it is a future’, and ‘it is life itself’. These reasons were only stated once.

Conclusion and Suggestions

This research aims to determine what metaphors are in teachers' thoughts regarding online mathematics teaching. In the literature, general information concerning online education, which has become prominent in our lives, is in a minority of studies that include the opinions of people who are affected by online education. There is a scarcity of studies on the opinions of teachers, and the literature is extremely limited when the subject is focused on mathematics teachers. A condition of participation in the survey conducted was that the participants had personally experienced online mathematics education. The survey consisted of ten sub-questions regarding online mathematics education and planning, resource use, materials, methods, classroom management, assessment, feedback, and professional development. These survey questions require answering through a metaphor and explaining the reason for using this metaphor. Twenty-seven different metaphors and twenty-three different reasons were created by the participants. Different participants created different metaphors for the same sub-question and gave different reasons, even if they had created the same metaphor. From this, it is possible to say that it is impossible to explain online education and its sub-headings using a single metaphor, and that the same term may evoke different reasoning for different people.

According to the results, the most used metaphor is ‘eating’, with forty repetitions. The metaphor of ‘meal’ is followed by ‘tools’ with thirty-six repetitions and ‘situation’ with thirty-three repetitions. These numbers were determined from 309 responses to ten questions. The most used explanations of the reasons for the use of these metaphors are as follows: ‘need to progress in a certain program in online education’ (f:46); ‘lack of interaction/communication in the process’ (f:36); ‘difficult process’ (f:32); and ‘supportive’ (f:30). As can be seen from the explanations given for the reasons for using metaphors, the majority of the teachers participating in the research had negative views of online education, with the most important reasons being, ‘lack of interaction/communication’ (f:36), ‘the process is difficult’ (f:32), and ‘not achieving the desired result’ (f:29). Although teachers with positive attitudes are in a minority, the reasons they show are; it has been classified as ‘supportive’ (f:30), ‘accessible’ (f:10), ‘obtaining the desired result’ (f:7), and ‘facilitating’ (f:3). Apart from the positive and negative answers given by the teachers, the interesting part is that a number of the teachers looked at the process temporarily and said that this process was a mandatory step, or that it would only be used in necessity. Certain teachers had

difficulty in adapting to the process even over time, and could not integrate online education into the normal teaching process.

Tuncer and Bahadır's (2017) study evaluates the indifference and insincerity of instructors, saying that this process is considered to be a cold environment by the students and that face-to-face education is preferred. They also emphasize that online education is supportive as it allows learning in the environment and review when desired. In a study by Karakuş, Ucuzsatar, Karacaoğlu, Esendemir, and Bayraktar (2020) a restriction is noted in the relationship between teacher-student in the online education process, and that the relationship between student-student and student-teacher is not the same as in face-to-face education. In addition, in research conducted by Sümer (2016), students support the explanation that there is no interaction/communication in the process, which was repeated thirty-six times during the research, for reasons such as providing the interaction in the online course in written form and not making eye contact with the teacher.

Gürsul and Keser (2009), in their study with forty-two students, argue that contrary to the findings of the research, online education is more successful than face-to-face education in group work. Corner (2020), on the other hand, talks about students turning off their cameras and only listening to the lesson, making classroom management more difficult and affecting teachers' well-being. This research shows the difficulty of the process in general. Ilgaz (2014) finds that the fact that lessons are recorded and accessible afterwards is helpful for students who missed the course content while taking notes in face-to-face lessons and argue that this is supportive in terms of education. Karasar (2004) similarly argues that online education brings convenience and supports education. Although metaphors containing negative thoughts are prevalent in this study, metaphors involving positive perspectives also overlap with the findings of these studies.

The results of this research can be used in the organization of in-service seminars given to teachers, the preparation of content, and the creation of models for online mathematics education, as they will provide clues concerning teachers' thoughts on the process, deficiencies of the process and how it can be improved. In addition, this research can direct researchers to more detailed research on the subject; for example, 'How were different grade levels affected by this process?'. Another benefit of the study for researchers is that it allows comparison of the thoughts on online teaching shown in this research with thoughts on non-online face-to-face lessons.

In addition to researchers, it can also offer teachers the opportunity to repeat the process for themselves and to look at their teaching practices in light of their thinking. This type of practice can also provide opportunities to improve their teaching practices indirectly. There are a number of studies regarding the online teaching process of teachers in the field, the pandemic process, an epidemic or online education. It is clear that much more work is needed on the quality of the education received, the deficiencies of the education and measures that can be taken in this regard.

Çevrimiçi Matematik Öğretimi Üzerine Yansıtıcı Düşünceler

Özet:

Değişen dünya ve gelişen olaylar ile birlikte çevrim içi öğretim gündemimizin en önemli başlıklarından biri haline gelmiştir. Çevrim içi öğretimin etkililiği başlıca gerçekleştiricisi öğretmenler olan bazı temel unsurların gerçekleşmesi ile ilişkilidir. Çevrim içi eğitime geçiş süreci öğretmenler için de yeni bir öğrenme sürecidir. Öğretmenlerin yeni uygulamalara uyum sürecinde kendi öğrenmesiyle ilgili bulgular bunun öğretmenlerin yansıtıcı düşünceleri ile ilişkili olduğunu ortaya koymaktadır. Bu sebeple, bu araştırmanın sorusu "Öğretmenler, çevrim içi matematik öğretimine yönelik ne tür metaforlar üretmektedir?" şeklindedir. Araştırmanın deseni olgu bilim desenidir. Verilerin analizinde metafor analizi kullanılmıştır. Bu araştırmaya 43 öğretmen katılmıştır. Katılımcılar, çevrimiçi matematik eğitimi ile ilgili fikirlerini metaforlar kullanarak yansıtmışlardır. Katılımcıların düşüncelerinden 27 farklı metafor ve 23 farklı neden oluşturulmuştur, en çok kullanılan metafor "yemek" metaforu, en çok kullanılan iki açıklama ise "belirli bir programda ilerleme ihtiyacı" ve "süreçte etkileşim/iletişim yokluğu" olmuştur. Araştırma sonucunda öğretmenlerin çevrimiçi eğitim hakkında çoğunlukla olumsuz düşündükleri belirlenmiştir.

Anahtar kelimeler: Çevrim içi eğitim, çevrim içi matematik öğrenimi, metafor analizi, pandemi.

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Research Article

Students' Algebra Achievement, Algebraic Thinking and Views in the Case of Using Algebra Tiles in Groups

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Abstract – The study investigated how using algebra tiles in group work affected students' algebra achievement, algebraic thinking and views about using algebra tiles. 40 sixth grade students in the same school participated in a pretest-posttest control group design study. Students in the experimental group (EG) used algebra tiles in groups and those in the control group (CG) continued with their regular instruction. Prior Algebra Knowledge Test and Algebra Achievement Test were implemented to both groups as pretest and posttest. EG students expressed their views in the Views about Algebra Tiles Questionnaire. Although students' performances did not differ in the statistical analysis in both tests, qualitative analysis of the responses revealed that algebra tiles had positive effect on EG students' algebraic thinking. EG students indicated that using algebra tiles in group work supported their learning, they made them understand the concepts meaningfully, and the lessons were more enjoyable.

Key words: algebra achievement, algebra tiles, algebraic thinking, group work, middle school students

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Introduction

Algebra appears less concrete than arithmetic to the students because it requires thinking about sets of numbers rather than only a few numbers (Palabıyık & Akkuş, 2011). It is considered as remembering a set of rules to apply while operating with letters and numerals by students (Kaput, 1995) because algebra teaching in middle schools emphasizes procedures that involve rules and steps separated from other mathematical concepts and real life of students

(Kaput, 1999). Therefore, students have difficulties in understanding multiple meanings of letters and the underlying logic, and making transition from arithmetic to algebra while learning algebra and developing algebraic thinking (Jupri et al., 2015; MacGregor, 2004).

Algebraic thinking is one's potential to reveal the relationship between the variables in one's representations of quantitative situations (Driscoll, 1999). It is employing representations that illustrate quantitative relationships (Kieran, 1996). Improvement of algebraic thinking results in understanding algebra meaningfully rather than focusing only on procedures (Windsor, 2010). Presenting elementary and middle school students with situations that incorporate relationships in contexts improves their algebraic thinking (Lawrence & Hennessy, 2002). Manipulatives can be used for meaningful and effective algebra learning process to eliminate students' difficulties and to develop students' algebraic thinking (Akkuş, 2004; Chappell & Strutchens, 2001; Larbi & Okyere, 2016). Students have higher algebraic abilities, such as representing algebraic expressions and interpreting them, and making connections between algebraic concepts, when manipulatives are used (Chappell & Strutchens, 2001). Particularly, using manipulatives enables middle school students to make meaningful connections in algebraic thinking (Chappell & Strutchens, 2001).

Algebraic thinking is promoted when students are provided with the opportunities to convey their mathematical ideas in a classroom context that values and encourages collaborative learning (Windsor, 2010). Group work enhances students' algebra learning and increases their self-efficacy in algebra (Fletcher, 2008). Moreover, group work has the potential to foster positive dispositions towards mathematics, students' procedural fluency, and the development of their mathematical reasoning skills (Jansen, 2012). Students can notice what their peers struggle to capture, help them understand better, and also eliminate misunderstandings while learning a new concept in a group (Webb & Farivar, 1994). Furthermore, explaining to peers allows students to develop a deep understanding by identifying knowledge gaps and filling those gaps (Fuchs et al., 1997).

Algebra tiles, which are one of the manipulatives that are used in teaching algebra, help students see the relationship between algebraic and geometric concepts (Leitze & Kitt, 2000). Students can make the transition from concrete to symbolic representations of algebraic concepts with the help of algebra tiles (Fennema, 1972). Use of algebra tiles eliminates students' mistakes and confusion between expressions such as 2x and 2+x (Picciotto & Wah, 1993). Furthermore, algebra tiles provide visual and hands-on approach for the newly-introduced concepts. Students can reach the algebraic rules from their own experiences with

the help of algebra tiles (Okpube & Anugwo, 2016). One specific importance of algebra tiles is that they can be easily prepared by teachers by cutting the cardboards (Karakırık & Aydın, 2011). In this respect, it is important to investigate the effects of algebra tiles since they are easily created, replicated and used by the teachers cheaply when the resources are not sufficient. Examining the effects of manipulatives, specifically algebra tiles, is important in students' initial encounter with the algebraic concepts because students' learning can be supported by using manipulatives when students learn abstract concepts for the first time (Akkaya, 2006).

Research on the use of algebra tiles in teaching and learning of algebra have mostly investigated teaching solving linear equations in one variable to middle school students with algebra tiles (Magruder, 2012; Saraswati et al., 2016), a system of two linear equations to senior high school students by using algebra tiles (Akpalu et al., 2018), factoring algebraic expressions to high school students with algebra tiles (Larbi & Okyere, 2016; Schlosser, 2010; Sharp, 1995; Thornton, 1995), polynomial multiplication by using algebra tiles (Goins, 2001; Johnson, 1993; Ünlüer & Kurtuluş, 2021; Wingett, 2019), distributive property to expand algebraic expressions (Larbi & Okyere, 2016); solving quadratic equations by completing a square (Vinogradova, 2007) and algebraic expressions to students with learning disability through algebra tiles (Castro, 2017). These studies have found that middle school students reflected on their actions while solving linear equations with the help of algebra tiles (Magruder, 2012) and reached the solution of linear equation in one variable easily (Saraswati et al., 2016); high school students conceptually understood a system of two linear equations (Akpalu et al., 2018), learned factoring and distributive property meaningfully (Larbi & Okyere, 2016), and could make geometric connection to factoring polynomials when algebra tiles were used (Schlosser, 2010). In addition, high school students stated meaningful learning of factoring with ease (Sharp, 1995), had understood the concepts much better (Thornton, 1995) and could provide better explanation of polynomial multiplication process with the help of algebra tiles (Goins, 2001). Furthermore, students who have failed in algebra before performed better when they used algebra tiles (Wingett, 2019) and algebra tiles made a difference in the post-test scores of students with learning disabilities in a positive manner (Castro, 2017). Similarly, middle school students could easily model algebraic expressions (Ünlüer & Kurtuluş, 2021) and algebra tiles helped students build connections between algebraic and geometric concepts (Vinogradova, 2007). Using algebra tiles supported even teachers' understanding of polynomial multiplication (Johnson, 1993).

On the other hand, some research studies conducted in Turkey did not specifically examine the use of algebra tiles but the effects of various manipulatives including algebra tiles used together to teach algebra (e.g., Akyüz & Hangül, 2013; Gürbüz & Toprak, 2014; Işık & Çağdaşer, 2009; Koğ & Başer, 2012; Palabıyık & Akkuş, 2011; Türksever, 2019; Yıldız, 2012). While these studies generally reported the positive effects of manipulatives in students' learning of algebra, the studies in which algebra tiles were used did not focus on students' development of algebraic thinking when they met algebra concepts for the first time.

Gathering students' views has always been important in educational research because those views show us how they perceive teachers' efforts and learning the content. Students' positive and negative views about using manipulatives in learning mathematics help researchers have better interpretations of their views and opinions (Enki, 2014) and teachers to make sense of their learning with manipulatives (Yıldız, 2012). Students' negative views about using manipulatives that arise from seeing mathematics as a body of algorithms and rules that should be followed (Hinzman, 1997) and students' perceptions of the activities including manipulatives in which they engage might have an effect on the way teachers teach (Thompson & Lambdin, 1994).

Working in small groups in the classroom improved middle school students' algebra achievement and students expressed their satisfaction with being a part of the group work (Balt, 2017). Being engaged in group work enabled students improve their conceptual understanding in algebra (Jones, 2008) and promoted improvement of their algebra learning and their self-efficacy (Fletcher. 2008). Hinzman (1997) found that hands on manipulatives and group activities were useful in enhancement of middle school students' performance in algebraic concepts. Moreover, students stated that they enjoyed the use of manipulatives in activities while learning algebraic concepts.

Understanding the effects of using algebra tiles in group work on students' algebra achievement and algebraic thinking is important because algebra tiles have the potential to help students to internalize algebraic ideas when they first meet them. They are easy to produce for teachers, even for students. Therefore, they can provide a convenient material for teaching and learning algebra, especially when resources are scarce. Using algebra tiles in group work may provide students an idea-rich environment for learning the basic algebra concepts, which affects their future mathematics performance (Wang & Goldschmidt, 2003). In this sense, it is also important to explore students' views about using algebra tiles because their views can help teachers and researchers understand the useful features of these manipulatives for students'

learning of algebra and development of algebraic thinking. Despite the above presented literature, there seems to be lack of studies on students' learning of algebra by using the algebra tiles in group work when they are introduced the algebra concepts for the first time. Thus, it is this study may contribute to the literature by providing knowledge on students' algebra achievement when they use algebra tiles in groups.

The present study investigated the effects of using algebra tiles in group work on sixth grade students' algebra achievement, algebraic thinking and views about using algebra tiles when they first met algebra concepts. For this purpose, following research questions were formulated:

1) Do 6th grade students who use algebra tiles in group work significantly outperform those who do not use algebra tiles in the algebra achievement test?
2) How does students' algebraic thinking differ for those who use algebra tiles in group work and who do not use in the algebra achievement test?
3) What views do 6th grade students develop about using algebra tiles in group work in the mathematics lessons?

In the study, the term "algebra achievement" was used to address achievement scores of the 6th grade students in the algebra achievement test that was developed by the researchers and that included questions about algebraic concepts based on the 6th grade objectives. "Algebraic thinking" includes recognizing and analyzing numerical and geometric patterns and expressing them mathematically in word or symbols, representing relationships, making generalizations about the mathematical relationships, and thinking with unknown quantities (NCTM, 2000). Students' algebraic thinking was investigated in this study by deeply analyzing their responses to all questions in the algebra achievement test. In this study, views refer to the 6th grade students' opinions, beliefs and feelings about using algebra tiles in group work in mathematics lessons and investigated by an open-ended questionnaire. Detailed information about mentioned tests is provided below.

Method

The study is a mixed-method study employing both quantitative and qualitative methods. A pretest-posttest control group design was chosen in order to investigate the effects of using algebra tiles in groups on 6th grade students' algebra achievement and algebraic thinking. Experimental group (EG) students learned initial algebra concepts by using algebra tiles in groups while control group (CG) students learned through regular instruction. Both EG and CG

students' responses in the Prior Algebra Knowledge Test (PAKT) and Algebra Achievement Test (AAT) were examined in detail and experimental group students' views were explored through the Views about Algebra Tiles Questionnaire (VATQ) which was a qualitative survey.

The Curriculum Context in Relation to the Study

At the time of the study, there was a change in the middle school mathematics curriculum in Turkey. The new (2018) curriculum had just been initiated in the middle schools starting from the 5th grade. Students in the 6th grade were learning mathematics based on the previous (2013) curriculum. Algebra topics were introduced in the 6th grade in both curricula (MEB, 2013; 2018). Table 1 shows the objectives related to algebraic expressions at the 6th grade level in 2013 curriculum (MEB, 2013) and the corresponding grade level of the same objective in 2018 curriculum (MEB, 2018).

Table 1. Objectives related to algebraic expressions in the 6th grade in 2013 curriculum and 2018 curriculum

Objectives	Students should be able to…	2013 Curriculum	2018 Curriculum
O1.	Write a phrase as an algebraic expression and write a phrase for a given algebraic expression.	6th grade	6th grade
O2.	Evaluate an algebraic expression for different values of variable.	6th grade	6th grade
O3.	Express the meaning of simple algebraic expressions.	6th grade	6th grade
O4.	Make addition and subtraction in algebraic expressions.	6th grade	7th grade
O5.	Multiply an algebraic expression with a natural number.	6th grade	7th grade

As can be observed in Table 1, O4 and O5 moved to the 7th grade level in the recent curriculum change although they were covered in the 6th grade at the time of the study. This presented an obstacle for the study in terms of its significance and the implications of the results for teaching mathematics and curriculum. However, the study addressed both the curriculum objectives and students' algebraic thinking, which was an overarching construct based on students' existing knowledge and skills both in other concepts and in algebra as explained below in AAT. Consequently, objectives O1 and O2 were considered as the prerequisite algebra knowledge in this study for both EG and CG. Algebra tiles were introduced and used in the EG while covering O3, O4, and O5, while CG continued with the teacher's regular instruction. This

provided a research base to compare both curricula and inform the algebra teaching practices in the 2018 curriculum.

Participants and the School Context

Participants of the study consisted of 40 sixth grade students (age 11-12) in two 6th grade classrooms taught by the same teacher in a public school in one of the cities in Turkey, selected based on the convenience of the first author (hereafter, the researcher). One class was randomly assigned as the EG and the other was assigned as the CG. Students in both classes had similar mathematics achievement according to the school-based mathematics examinations. Students in both CG and EG did not learn any algebraic concept until the 6th grade. Table 2 shows the number of students who took pretest and posttest in EG and CG.

Table 2. The number of students who took pretest and posttest in EG and CG

Groups	Pretest	Posttest	Pretest ∩ Posttest
Experimental	23	23	22
Control	21	20	18
Total	44	43	40

The school was an inner-city school where students from middle socioeconomic status families attended, as indicated by the classroom teacher. Students in both groups have used counters and fraction tiles as materials but they have never used algebra tiles before. In addition, students have not worked in a group in the mathematics lessons.

Data Collection Tools

Prior Algebra Knowledge Test (PAKT), Algebra Achievement Test (AAT) and Views about Algebra Tiles Questionnaire (VATQ) were used to collect data for the study. PAKT, AAT, and lesson plans were prepared according to the 2013 curriculum. O1 and O2 (see Table 1) were the objectives where algebra tiles were not used in teaching. Therefore, these two objectives were used as a base for students' existing algebra knowledge to see if EG and CG groups were at the same achievement level before the implementation started. Then, algebra tiles were used by the students in groups in EG while the regular instruction continued in CG.

Prior Algebra Knowledge Test (PAKT): PAKT consisted of 4 essay type questions with subquestions (15 questions in total) and developed by the researchers to see if EG and CG students had differences in their existing algebra knowledge before the treatment. Both EG and CG students were introduced with algebra topics for the first time in the 6th grade. The treatment in the EG in this study started after the students learned to (i) write a phrase as an algebraic

expression and write an algebraic expression as a phrase (O1) and (ii) evaluate an algebraic expression for different values of variables (O2). Therefore, these two objectives were covered in the pretest to see if students in both groups had similar achievement in basic algebraic concepts. PAKT was implemented to both EG and CG students as a pretest in 40 minutes. The 6th grade objectives covered in the PAKT and sample questions for each objective are presented in Table 3.

Table 3. The 6th grade objectives (MEB, 2013) covered in the PAKT and sample questions for each objective

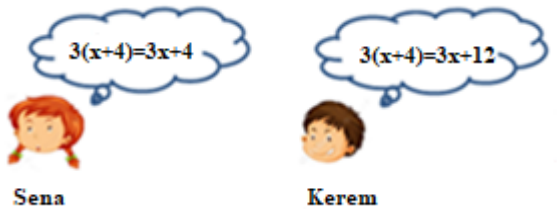
Objectives	Sample Questions
Write a phrase as an algebraic expression and write a phrase for a given algebraic expression.	Write each phrase as an algebraic expression. • 3 less than twice a number of candies in the jar • 2 less than a number plus twice the same number • The amount of remaining time of the exam when 15 minutes of the time completed • If the sum of two numbers is 80 and one of the numbers is m, the other number is Write a phrase for each algebraic expression given below. 5(c-2) 7k-6 (m+1)/2 x/2+5
Evaluate an algebraic expression for different values of variable.	Evaluate each algebraic expression given below for a given value of variables. $\frac{2(n-3)}{5}$ $for\ n = 13$ $\frac{3x+4}{2}$ $for\ x = 6$

Algebra Achievement Test (AAT): AAT included 11 essay type questions with subquestions (35 questions in total) and developed to examine students' algebra achievement and algebraic thinking. Two questions in the test were taken from "Chelsea Mathematics Diagnostic Tests-Algebra" developed by Hart et al. (1985) and adapted to Turkish by Altun (2005). These questions were modified by the researchers. Other questions were developed by the researchers according to the literature and objectives in the curriculum. The test was used to reveal possible differences in EG and CG students' algebra achievement and algebraic thinking based on the use of algebra tiles. It was administered to EG and CG students as a posttest after the treatment allowing 40 minutes. The objectives covered in the AAT, sample

questions for each objective, and sample questions about algebraic thinking are given in Table 4.

In addition to questions related to objectives O3, O4, and O5 in the curriculum (see Table 1), there were questions in the AAT that were developed to address students' algebraic thinking in a different way based on their existing mathematics knowledge and skills including the 6th grade algebra objectives. They were related to finding the perimeter of a geometric figure in terms of algebraic expressions, writing given algebraic expressions as multiplication of a natural number and an algebraic expression, comparing algebraic expressions, and finding the length of one side of a geometric figure in terms of algebraic expressions. These questions were based on a combination of students' existing knowledge and skills in geometry, multiplication, comparison of quantities, and recently learned algebraic concepts.

Table 4. The 6th grade objectives (MEB, 2013) covered in the AAT, sample questions for each objective, and sample questions about algebraic thinking

Objectives	Sample Questions
Express the meaning of simple algebraic expressions.	Determine whether given representations are correct or incorrect and rewrite incorrect representations as correct representations. ….. $y + y + 1 = 3y$ ….. $x + x - 1 = -1 + 2x$ ….. $\frac{a}{2} + \frac{a}{2} = 2a$ ….. $5 - c - c + c = 5 - 3c$
Make addition and subtraction in algebraic expressions.	Perform operations for the algebraic expressions given below. (4x–5) + (–2x+3) (x+3) – (–2x – 1)
Multiply an algebraic expression with a natural number.	 Sena and Kerem think the equivalent algebraic expression of 3(x+4) as shown in the picture. Explain which representation is correct.
Find the perimeter of a geometric figure in terms of algebraic expressions.	Assume that one part of the regular polygon, whose the length of one side is 4 unit and number of the side is unknown, is covered by paper. 

	Find the perimeter of the polygon in terms of algebraic expression.
Compare algebraic expressions.	When you compare 3n and (n+3) algebraic expressions for different values of n, which algebraic expression is greater? Explain.

Both PAKT and AAT, and the rubrics which were prepared by the researchers and used to evaluate and score students' responses in the tests (explained below) were reviewed for validity by two mathematics education researchers, one of whom has an experience in teaching middle school mathematics more than 10 years. They claimed that the questions in these instruments reflected the objectives and the goals of the instruments, as well as the rubrics. Then, PAKT was piloted with 55 7th grade students and AAT was piloted with 52 7th grade students in a non-participant middle school in the same city that the study was conducted. One question was removed from the PAKT because none of the students could write the general rule of sequence algebraically. After the question was removed, the last version of PAKT was presented to the same mathematics education researchers for the final review. The test was ready to administer to the students after their final approval. PAKT had 0.73 and AAT had 0.62 reliability coefficients calculated by Kuder-Richardson (KR-21) formula, which indicated that both tests were reliable (Hinton et al., 2014).

Views about Algebra Tiles Questionnaire (VATQ): VATQ consisted of 5 open-ended questions and developed by the researchers in order to gather students' views about using algebra tiles in group work. Questions were reviewed by mathematics teachers and two mathematics education researchers for validity of the questionnaire. There was no pilot study for VTQA but two 6th grade students who were not in the EG and CG were asked to read the questions and comment on their clarity. VTQA was implemented only to EG students after the treatment and was completed in 20-30 minutes.

Procedure and Treatment

The study was conducted in the two 6th grade classes of one mathematics teacher after the necessary ethical and formal procedures were completed. The teacher was trained by the researcher before the implementation about how to use algebra tiles. Then, the lesson plans of the EG were prepared by the researchers and reviewed by the teacher and the researcher together. The teacher used her own lesson plans for the CG, thereby continuing her regular instruction. She taught the algebra topics in both EG and CG classrooms.

Lessons plans of the EG were prepared according to 5E instructional model including engagement, exploration, explanation, elaboration, and evaluation phases. This model enables students to reconstruct initial concepts through self-reflection and continuous interaction with social and physical environment and they build a more grounded conceptual understanding based on their interpretations of the concepts (Bybee, 1997). The 5E model suited the purposes of the study because it provided a structure for students' use of algebra tiles while collaborating with their peers. Throughout the treatment, three objectives (O3, O4, and O5), were covered in both EG and CG in 7 class hours by the mathematics teacher. PAKT was implemented to both EG and CG before the treatment. When the treatment ended, AAT was implemented to both EG and CG. Additionally, views of EG students were explored by VATQ after the treatment.

Experimental group (EG) treatment: EG lessons employed questioning, discussion, group work, and individual work including algebra tiles. For all of the three objectives, the sequence of engagement, exploration, explanation, elaboration and evaluation phases were followed. In the engagement phase, at the beginning of the lessons, for the first objective, the teacher introduced the algebra tiles to the students. For the second objective, she asked the concept of zero pair in algebra tiles in order to enable students to connect their existing knowledge to the new concepts. For the third objective, the teacher presented students with real life problems in order to puzzle and motivate them for the lesson. Other phases were similar to each other for the three objectives as described below.

In the exploration phase, after the students modelled algebraic expressions and operations with algebraic expressions with the help of algebra tiles in groups of 2-4 students, they showed the same operations by drawing pictures that represent algebra tiles and wrote their work with algebraic notations. In the explanation phase, the teacher went through the process that students involved in the exploration part and made necessary explanations. In the elaboration phase, she got the algebra tiles back from the students, presented activity sheets to the students and asked them to complete the items individually without using algebra tiles. Thus, the students could apply what they have learned. In the evaluation phase, at the end of the lessons, the teacher presented exit cards to the students and asked them to give back to her while leaving the classroom after completing the tasks in exit cards. During the instructions in EG, the researcher did not participate and only observed the class to make sure that treatment was being implemented as in the lesson plans. Table 5 summarizes the treatment in EG.

Table 5. The summary of the treatment in EG

Phase	Explanation
Engagement Phase	Introducing algebra tiles

	Asking the concept of zero pair Presenting real life problems
Exploration Phase	Discovering the rules in operations with algebraic expressions by using algebra tiles as concrete manipulative in groups of 2-4 students
Explanation Phase	Teacher's reviews and explanations about the process
Elaboration Phase	Completing the items in the activity sheet individually without using algebra tiles
Evaluation Phase	Completing the tasks in exit cards

Control group (CG) treatment: Algebra tiles were not used in CG and students had regular instruction where questioning, drill and practice, and individual work took place. The teacher explained the concepts on the board during which she asked some questions to the students. For instance, while teaching subtraction in algebraic expressions, she asked "How do you make subtraction in integers?" to connect subtraction in algebraic expressions and subtraction in integers. After she explained the concepts, she solved some related problems on the board. She then asked the students to solve the problems that she wrote on the board individually. For each problem, one student came to the board to show his/her solution. At the end of the lessons, homework related to the concepts was given to the students. The researcher also observed the CG class to document how the regular instruction was implemented. Students in CG did not work in groups, and they did not work with manipulatives. However, after the treatment ended, activities in the EG were also conducted in CG by using algebra tiles.

Data Analysis

In order to analyze students' answers in PAKT and AAT a rubric for each of the instruments were prepared by the researcher and reviewed by the mathematics teachers and the mathematics education researchers who were involved in the instrument construction process. Students' correct answers were coded as 1 and their incorrect answers were coded as 0 according to the rubrics, and total score from the tests were calculated for all students. To answer the first research question, means and standards deviations of PAKT and AAT of EG and CG were calculated. Table 6 shows the result of Shapiro-Wilk Test conducted to check normality assumption for PAKT. Since the significance values for both groups violated the normal distribution assumption, Mann-Whitney U test was conducted to determine if there was a statistically significant difference between the EG and CG in terms of prerequisite knowledge before the treatment in PAKT.

Table 6. Result of Shapiro-Wilk Test for PAKT

	Statistic	df	Sig.
Experimental Group	0.888	23	0.014
Control Group	0.881	21	0.015

Table 7 presents the result of Shapiro-Wilk test for AAT. Since normality assumption was ensured, independent samples t-test was conducted to compare the scores of EG and CG in AAT after the treatment.

Table 7. Result of Shapiro-Wilk Test for AAT

	Statistic	df	Sig.
Experimental Group	0.977	23	0.858
Control Group	0.930	23	0.154

In order to investigate the second research question, students' responses in AAT were analyzed in-depth and their mistakes, misconceptions and alternative solutions were determined. For the third research question, students' responses in VATQ were read several times carefully and codes representing meaning units and possible upper-level categories that encompassed these codes and represented the data set were identified by the researcher, with examples from data for the codes. Then, both authors discussed these codes, upper-level codes, and code-coded data pairs and finalized the names of the codes. The researcher used these codes to label the responses in VATQ, brought them under the upper-level categories, and discussed the findings with the second author. The upper-level categories were finalized after this discussion. Intercoder reliability measure suggested by Miles and Huberman (1994) was used to calculate the agreement and it was found 92.3%.

Results

In this section, the results of the descriptive and inferential statistics analysis for PAKT and AAT and findings of VATQ will be presented respectively.

Students' Prior Algebra Knowledge

PAKT was administered to 23 students in EG and 21 students in CG as a pretest before the treatment. Descriptive statistics of PAKT scores for both groups is given in Table 6.

Table 6. Descriptive statistics of PAKT scores for EG and CG

	Experimental Group	Control Group
N	23	21

Minimum	0	0
Maximum	15	15
Mean	8.61	6.95
Standard Deviation	5.42	5.56

Table 6 shows that EG students' mean score (M=8.61, SD=5.42) was higher than CG students' mean score in PAKT (M=6.95, SD=5.56). In order to determine whether there was a significant mean difference between the groups before the treatment, Mann-Whitney U Test was performed since normality assumption for independent t-test could not be ensured. The result of Mann Whitney U test for PAKT is presented in Table 7.

Table 7. Result of Mann-Whitney U Test for PAKT

	Mann-Whitney U	Sig.
PAKT	205.500	0.395

$p>0.05$

Table 7 shows that there was no statistically significant mean difference between the groups before the treatment (U=205.500, $p>0.05$). Thus, based on the statistical results, it can be said that EG and CG students had equal prior algebra knowledge.

Students' Algebra Achievement After the Treatment

AAT was implemented to 23 students in EG and 20 students in CG as a posttest after the treatment. Descriptive statistics of AAT scores for both groups is given in Table 8.

Table 8. Descriptive statistics of AAT scores for EG and CG

	Experimental Group	Control Group
N	23	20
Minimum	1	0
Maximum	34	32
Mean	19.65	14.85
Standard Deviation	8.51	10.32

As seen from Table 8, EG students' mean score (M=19.65, SD=8.51) was higher than CG students' mean score in AAT (M=14.85, SD=10.32). In order to investigate the first research question, independent samples t-test was conducted as the data set was suitable for the analysis. Table 9 shows independent samples t-test results of AAT.

Table 9. Results of independent samples t-test for AAT

	Experimental Group		Control Group		t Value	df	p
AAT	Mean	SD	Mean	SD	1.67	41	.10
	19.65	8.51	14.85	10.32			

p>0.05

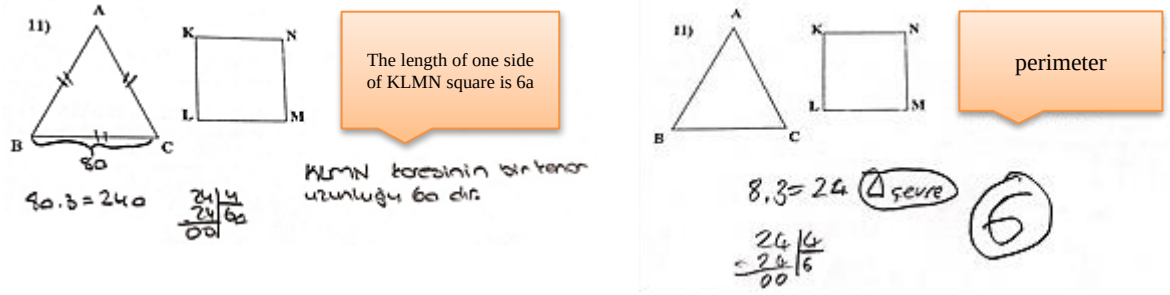
There was no statistically significant mean difference between the groups after the treatment (t(41)=1.67, p= .10). These results indicated that using algebra tiles in group work did not lead to significantly better results in terms of students' algebra knowledge and algebraic thinking than regular instruction.

Differences in Algebraic Thinking

In order to investigate the second research question, EG and CG students' responses to each question in AAT were analyzed in detail. The detailed analysis of the responses revealed that EG students provided more correct answers than CG students for the questions related to the following objectives: determining variable, term, constant term, coefficients and sum of coefficients of given algebraic expressions; performing addition and subtraction with the given algebraic expressions; writing given algebraic expressions as multiplication of a natural number and an algebraic expression; and finding the length of one side of a geometric figure in terms of algebraic expressions. Representative responses of EG and CG students to the related questions are given in Table 10.

Table 10. Representative responses of EG and CG students to the questions in which EG students performed better

One EG student's response	One CG student's response
Perform operations for the algebraic expressions given below.	
i) (4x–5) + (–2x+3) = 2x–2 ii) (x+3) – (–2x – 1) (x+3) + (+2x+1) = 3x +4	i) (4x–5) + (–2x+3) = 4x – 2 ii) (x+3) – (–2x – 1) = –1x +2
Write each algebraic expression given below as multiplication of a natural number and an algebraic expression.	
• 6x + 8 2(3x+4) = 6x+8 • 9 – 3x 3(3–x) = 9–3x • –2x – 10 2(–x–5) = –2x–10	• 6x + 8 6(x+8) • 9 – 3x 3(9–x) • –2x – 10 2(–x–10)

ABC equilateral triangle and KLMN square have equal perimeters. If the length of one side of the triangle is 8a, find the length of one side of the square.


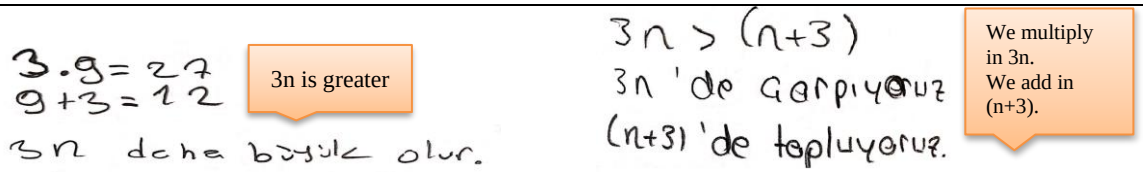
The examples in Table 10 revealed that exploring how to perform operations with algebra tiles in group work helped EG students make addition and subtraction with the given algebraic expressions meaningfully. CG students had difficulties in adding and subtracting variables and in subtracting the negative variable as in the representative response. Moreover, some CG students made operations between unlike terms. When students were asked to write given algebraic expressions as multiplication of a natural number and an algebraic expression, EG students performed considerably better than CG students. Most of the CG students multiplied the number outside the parenthesis by only x inside the parenthesis as in the representative response. These representative responses illustrated that EG students were able to connect their new learning of the algebra concepts with their existing knowledge and skills of arithmetic better than CG students. In the question that asked students to find the length of one side of a geometric figure in terms of algebraic expressions, most of the EG students were able to give the correct answer. However, most of the CG students ignored the variable and wrote only 6 as the answer instead of 6a as in the representative response.

On the other hand, both EG and CG students did not perform well in answering some of the questions, those especially related to finding the perimeter of a geometric figure in terms of algebraic expressions and explaining which algebraic expression is greater. Representative responses of EG and CG students to the related questions are given in Table 11.

Table 11. Representative responses of EG and CG students to the question in which they did not perform well

One EG student's response	One CG student's response
Assume that one part of the regular polygon, whose the length of one side is 4 unit and number of the side is unknown, is covered by paper. Find the perimeter of the polygon in terms of algebraic expression.	

When you compare 3n and (n+3) algebraic expressions for different values of n, which algebraic expression is greater? Explain.

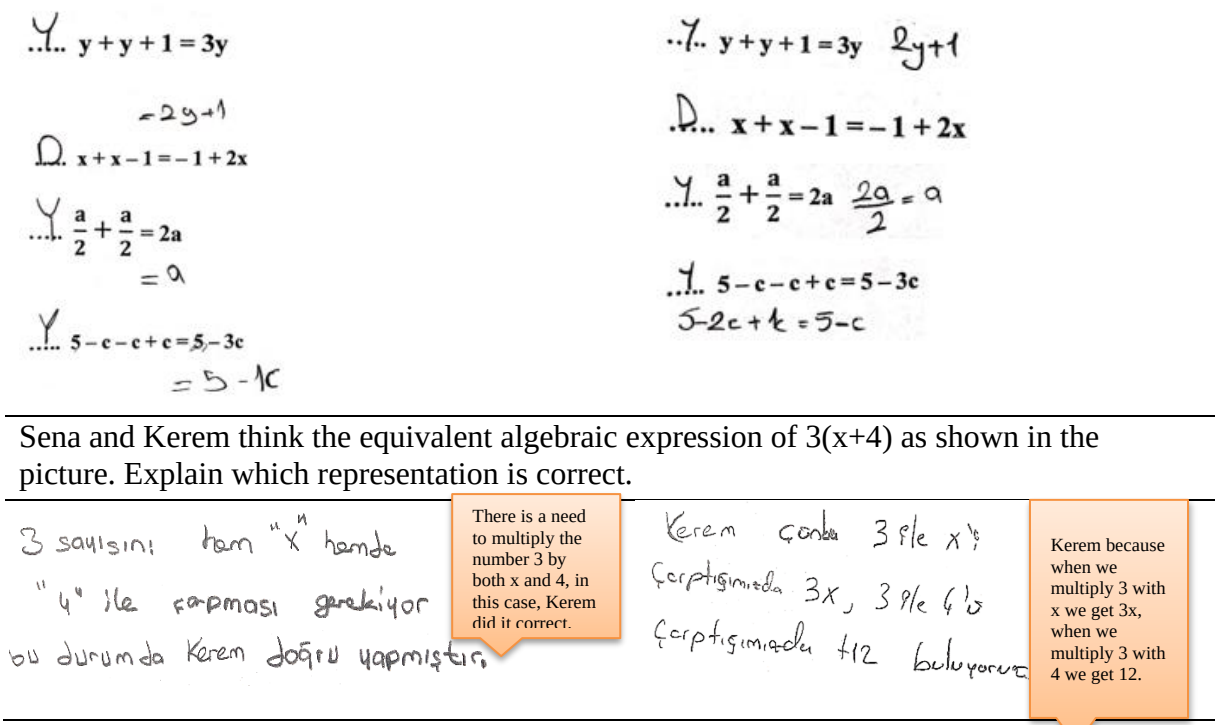


As it is seen from the representative responses, while finding the perimeter of a geometric figure whose number of the side is unknown, some students in both EG and CG added 4 and variable rather than multiplying. Also, some students wrote 32 by adding the visible eight sides of the polygon. In the question that asked students to explain which algebraic expression was greater, students generally tended to evaluate algebraic expressions for only one value and decide that one was greater than other according to this evaluation. Also, some students thought that 3n was greater (because of including multiplication operation in it) than n+ 3 which includes addition operation.

In addition, in two questions related to the representation of algebraic expressions, most of the both EG and CG students could determine whether given representations were correct or incorrect and could explain which representation was correct by using multiplication of a natural number and an algebraic expression. As a different solution than other students, it was seen that one EG student showed the correct representation by assigning an arbitrary value to the x and comparing Sena's and Kerem's responses. Representative responses of EG and CG students to the related questions are given in Table 12.

Table 12. Representative responses of EG and CG students to the question in which they performed well

One EG student's response	One CG student's response
Determine whether given representations are correct (D) or incorrect (Y) and rewrite incorrect representations as correct representations.	



Sena and Kerem think the equivalent algebraic expression of 3(x+4) as shown in the picture. Explain which representation is correct.

Students' Views about Using Algebra Tiles in Group Work

In order to investigate the third research question, EG students' responses to the questions in VATQ were examined and three major categories were identified as using algebra tiles, group work, and enjoyment. Sub-categories and examples related to these categories are presented in Table 13.

Table 13. Categories, sub-categories and examples obtained from VATQ

Category	Sub-category	Example
Using algebra tiles	Effective understanding of algebra	Algebra tiles clarified the concept better and helped me learn the concept better.
		When I saw the operation on the board, I did not understand what to do. With the help of algebra tiles, I understood and comprehended the concept better.
		Algebra tiles enabled me to remember the concept easily.
		Algebra tiles enabled me to perform complicated operation easily.
Group work	Learning easier	With my group mates, we concentrated more and [completed the task] easier altogether. Additionally, I helped my group mates for their understandings.
		Group work helped me understand things that I did not understand before.
		Group work made understanding easier for all of us.

Enjoyment	Enjoying the lesson	By using algebra tiles, we both made activity and had fun. I learned with fun, I did not get bored.

Findings showed that both algebra tiles and group work aspects of the EG courses were enjoyable for the students. There were responses combining both aspects of the EG lessons. Some students remarked on using algebra tiles in group work in the way that using them together eased their understanding. The following excerpt illustrates this:

"In group work, students who understood explained to those who did not understand. Before the group work, we were confused about what to do. We had some questions such as "How will we do?" in our minds. However, when we used algebra tiles, we understood immediately."

Enjoyment appeared in data also in relation to using algebra tiles and working in groups. Some students made positive comments on the lessons where algebra tiles were used as illustrated below:

"While using algebra tiles, we did not only have fun, but we also comprehended topic. I have already liked mathematics, now, I began to like much more."

Discussion and Conclusion

The analyses documented above indicated that although there was no statistically significant mean difference between the groups, EG had a higher mean score than CG in AAT. It can be said that using algebra tiles in group work might have some effect on difference in scores. This result is consistent with the result of previous studies which reported similar findings for different grade levels and algebraic concepts (Castro, 2017; Schlosser, 2010; Sharp, 1995; Wingett, 2019). The difference could be the result of students' increased motivation to respond to the questions due to their use of algebra tiles. The non-significant result could be related to allocating only 7 class hours according to the curriculum to teach algebra concepts with algebra tiles. It was not possible to extend the time for the implementation because of the curriculum requirements. Otherwise, when students are engaged with algebra tiles longer, their learning is significantly positively affected (Larbi & Okyere, 2016). In addition, EG students stated that they have only used counters and fraction tiles as manipulatives in the mathematics lesson before. They used algebra tiles for the first time in this study. This non-significant result might be due to students' limited exposure to manipulatives. If these students had used more

manipulatives in mathematics lessons, it would be possible that they would benefit more from the treatment. It is argued that students perform better when they use multiple materials while learning algebra (Koğ & Başer, 2012). Therefore, for meaningful learning and better algebraic thinking, instruction should involve more manipulatives.

In terms of algebraic thinking, there were qualitative differences in students' responses in approximately half of the questions in AAT favouring EG. Use of algebra tiles in group work in lessons could lead to this qualitative difference between EG and CG students. EG students performed better in analysing the given algebraic expressions and determining their parts; performing operations in algebraic expressions meaningfully; writing given algebraic expressions as multiplication of a natural number and an algebraic expression and finding the length of one side of a geometric figure in terms of algebraic expressions. It can be said that interaction with algebra tiles in group work in the form of concrete manipulatives has some positive effect on students' algebraic thinking (as indicated by the mean scores) in the present study confirming the findings where middle school students established meaningful connections in algebraic thinking by using manipulatives (Chappell & Strutchens, 2001).

The use of algebra tiles did not make a difference in EG students' responses to the questions that included both algebra and geometry concepts. Students' low performance in these questions can be due to the lack of their prior knowledge in geometry concepts. In addition, both EG and CG students might not be familiar with these kinds of questions, which could result in students' low performance. This might, in a limited sense, also reveal that when the students were asked to combine their knowledge and skills of different concepts to solve a question, they might not always perform well. However, this is rather an inference and should be investigated in further studies. As a result, it can be concluded that using algebra tiles in group work had limited but qualitatively positive effect on the students' algebraic thinking.

Students are reported to have positive views and state meaningful learning outcomes when they use algebra tiles (Schlosser, 2010; Sharp, 1995; Thornton, 1995). Similarly, in this study, although statistically significant difference could not be found between the groups, EG students stated that they learned and understood algebraic expressions better and faster with the help of algebra tiles in their responses in VATQ. Findings showed that some students were aware that algebra tiles helped them build conceptual connections, which helped them understand the concepts better.

EG students were exposed to group work while exploring the concepts with algebra tiles. However, this was the first time for the students working in a group in the mathematics lesson

as the teacher indicated. Although group work has positive effects on students' learning (Koblitz & Wison, 2014), these effects might not be seen because of the limited exposure to group work in this study. Students in EG asserted that group work made their understanding easier confirming previous studies (Balt, 2017). Group work facilitates students' noticing of other group members' understanding, and enables students to help their friends and deepen their own knowledge by explaining the concept (Webb & Farivar, 1994). This was the case in the present study and some students mentioned that they helped their group mates for their understanding in the group work. EG students also expressed enjoyment for working with algebra tiles in group work, which has been reported elsewhere (Jansen, 2012; Koçak et al., 2009; Mulryan, 1994; Sofroniou & Konstantinos, 2016).

We would like to make cautious speculations about the relationship between the nature of the implementation and the findings here. The major input in teaching algebra concepts in this study was the algebra tiles whereas the group work provided an idea-rich context for students to make sense of the algebraic concepts. This might reveal questions about what really affected EG students' responses in AAT. The findings seemed to be due to the combined effect of the algebra tiles and group work. However, the group work was not designed to be structured during the implementation. Therefore, while we indicate that the findings could be attributed to the combined effect, we also address that algebra tiles might have more influence on the findings in this combination. Yet, there is a need to investigate both the combined and individual effects of the group work and algebra tiles.

There was a change in the curriculum at the time of the study and the 6^{th} grade students in the following year did not learn about addition and subtraction of algebraic expression, and multiplication of an algebraic explanation with a natural number. A follow-up study could be to conduct a similar study in the 7^{th} grade and see if there will be differences, which would provide curriculum developers with a feedback for the changes in the grade level of related objectives. Curriculum changes take place quite frequently in Turkey, which brings difficulties for the researchers who investigate teaching at schools in terms of justifying the significance of their ongoing studies and recent findings. This study emphasized both the objectives in the curriculum and a combination of students' existing knowledge and skills with their recent algebra knowledge and skills, and addressed them as algebraic thinking. Working with such focus is valuable because it provides an evaluation of and feedback for the current curriculum to the teachers and curriculum developers; and justify the findings of the study regardless of the changes. This study provided some findings for to what extent students could combine their

existing knowledge with a new knowledge for the teachers. We suggest that further studies based on teaching in classrooms in frequently changing education systems could focus on more overarching constructs.

It should be kept in mind that the findings were limited to the conveniently selected schools and the teacher, and students who participated in the study. The implementation was limited by the designated lesson hour for the topic in the national curriculum. Further studies should consider these limitations. It can be recommended that future studies would include one group using algebra tiles in group work, one group using algebra tiles without group work, and one group without using algebra tiles and group work to increase the generalizability and to determine the effectiveness of algebra tiles with or without group work. Furthermore, interviews can be conducted with the students to examine their algebraic thinking and views in-depth.

In this study, we tried to address that the initial algebra topics could be taught by the algebra tiles, which are easy to produce within a limited time frame available for these topics in the curriculum. Our findings indicated that using algebra tiles in group work even for a short time has some promising effects on students who learn algebra for the first time. The students also mentioned that they liked using algebra tiles while learning algebraic expressions and were happy to work in groups while using the algebra tiles. Therefore, we recommend that teachers integrate algebra tiles to the mathematics lessons in the beginning of the algebraic concepts to enhance students' algebraic thinking and achievement. Familiarity of the students with the group work might increase the effectiveness of using the algebra tiles.

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Grup Çalışmasında Cebir Karoları Kullanılması Durumu: Öğrencilerin Cebir Başarısı, Cebirsel Düşünmeleri ve Görüşleri

Özet:

Bu çalışmada grup çalışmalarında cebir karosu kullanımının öğrencilerin cebir başarısını, cebirsel düşünmelerini ve cebir karosu kullanımına ilişkin görüşlerini nasıl etkilediği incelenmiştir. Çalışma 40 altıncı sınıf öğrencisinin katıldığı öntest-sontest kontrol gruplu deneysel desen ile gerçekleştirilmiştir. Deney grubu öğrencileri gruplar halinde cebir karolarını somut materyal olarak kullanırken, kontrol grubu öğrencileri herhangi bir somut materyal kullanmamış, öğretmen olağan dersini yapmıştır. Her iki gruba da Cebir Ön Bilgi Testi öntest olarak ve Cebir Başarı Testi sontest olarak uygulanmıştır. Deney grubu öğrencileri Cebir Karosu Kullanımına İlişkin Öğrenci Görüş Formu ile görüşlerini belirtmişlerdir. İstatistiksel analizler her iki testte de öğrencilerin performansları arasında anlamlı bir fark göstermemesine rağmen, nitel analizler cebir karoları kullanımının deney grubu öğrencilerinin cebirsel düşünmeleri üzerinde olumlu bir etkisi olduğunu ortaya koymuştur. Ayrıca, deney grubu öğrencileri grup çalışmalarında cebir karoları kullanımının öğrenmelerini desteklediğini, kavramları anlamlı bir şekilde anlamalarını sağladığını ve dersleri daha eğlenceli hale getirdiğini ifade etmişlerdir.

Anahtar kelimeler: cebir başarısı, Cebir karoları, cebirsel düşünme, grup çalışması, orta okul öğrencileri, öğrenci görüşleri

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Research Article

An instrumental genesis perspective on the students' using spreadsheet for the interest concept and calculations

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Abstract – Spreadsheets are used in mathematics education because the software has the potential to organize data as well as examine the relationship between variables. Studies on the concept of interest show that students have difficulties in interpreting the effects of variables in interest formulas. This study aims to examine students' use of spreadsheets in terms of instrumental genesis in tasks that deal with the mathematical structure of the concept of interest. The research was carried out with eight students of the course of finance mathematics at a state university. Data obtained through screen recordings, clinical interviews, and observation notes were analyzed through thematic analysis. The results of the study show that the students could see the relationship between simple and compound interest through the sequential operations in spreadsheets, they can interpret the changes in values by estimating through multiple manipulations, and they understand the necessity of entering cell addresses.

Key words: interest, instrumental genesis, spreadsheets, instrumentation, instrumentalization

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Introduction

The use of technology is one of the main research topics in the field of mathematics education (Miles, 2021). National Council of Teachers of Mathematics [NCTM] states that the learning environment should be designed to create a positive effect of technology use on learning (NCTM, 2015). Similarly, Van De Walle, et. al. (2015), emphasizes that the relationship between the tool and mathematical concepts should be set up for effective learning (Nobre et al., 2012; Van De Walle et al., 2015). Spreadsheets can be defined as a tool used in

teaching and learning environments as a common technology that is easy to access from different devices (Bernard & Senjayawati, 2019).

Spreadsheets are software that is frequently used in daily life, designed to organize, use and present data in tables. Spreadsheet are software that helps in tracing algebraic relationships between numeric data, with cell addresses and features such as cell formatting and creating formulas. In addition, it leads multiple data to be created and dynamic (Drier, 2001). Spreadsheets as one of the software used in mathematics teaching, is expressed as an effective learning material in NCTM standards (NCTM, 2015). Spreadsheets provide reasoning and practicing skills about concepts (Haspekian, 2014; Park et al., 2013). It is stated that it provides conceptual transitions in mathematics, which is a cumulative discipline, facilitates the calculation of multiple data, and reveals the relationship between variables in dynamic data groups (Abramovich, 2018; Mays, 2015). Spreadsheets have an intense relationship with mathematical concepts, especially financial operations, as well as reading data over tables and graphs. Accordingly, financial operations, in which percentage representations are used on the spreadsheet, can be considered as a research topic in mathematics education.

Percentage and interest calculations are the concepts handled in various levels of mathematics education. They are also included in curriculums (MEB, 2013; Pournara, 2013; Sugden et al., 2015; YÖK, 2020). In the literature, it is seen that students have some difficulties related to the concept of interest. According to the literature, the difficulties and misconceptions about simple and compound interest are briefly summarized in Table 1.

Table 1. Misconceptions and difficulties on the concept of interest

Mathematical structure	The inability to understand that simple interest is a linear function while compound interest is an exponential function
Calculating	Disregarding the increase of sequential principals in the transition from simple to compound interest
	Inability to calculate interest to intended values
	The inability to synchronize time
	Conversion mistakes on ratios
	The inability to reflect the relationships between ratio-percentage to calculations
Interpreting	Disregarding abnormal and unreal results and values
	The inability to compare the result of simple and compound interest calculations
	The inability to interpret the effects of variables on results

In studies in which percentage, rate, and interest types are handled together, there are some difficulties such as; the confusion between the calculations of interest types, the inability to perform meaningful calculations (Sugden & Miller, 2011), the inability to explain the interest calculations based on variables (Bakker et.al, 2006; Hoyles et.al, 2010; Hubbard et al., 2016) the inability to establish and interpret the relationship (Pournara, 2013). Besides, in the studies on the concept of interest, difficulties related to the variables of interest calculations are handled

as well. The maintain difficulties are such as; the difference in the number of periods and time synchronization of simple and compound interest calculations (Feng & Kwan, 2015), the incorrect use of interest rates in calculations (Chong, et al., 2015), the inability to detect abnormal values due to not following current interest parameters (Sugden & Miller, 2011), the inability to compare the differences of the parameters of the interest types (Marley-Payne & Dituri, 2019). This study aims to examine a learning process designed to handle interest calculations on the spreadsheet in terms of the instrumental genesis approach.

Theoretical Framework: Instrumental Genesis

Instrumental genesis theory is a framework in terms of examining the teaching process using the spreadsheet in the study. Instrumental genesis examines the relationship between the tool and the learning process, the techniques developed by the learners in the use of tools, and their conceptual development (Trouche, 2004). It is considered as the transformation from an artefact (tool) into an instrument. Instrumental genesis is handled in the following dimensions: instrumentalization and instrumentation. While an *artifact i*s a material or abstract structure likely to be used for a given task; the *instrument* is a subjective process developed by the learner with the help of this tool. Besides, a schema is a solution created with an instrument (Drijvers & Trouche, 2008). While *instrumentalization* refers to the usage schemes that contribute to the transformation of the tool into an instrument, *instrumentation* emphasizes the conceptual schemes designed during the task (Özdemir Erdoğan, 2016). For example, spreadsheet, as an office program, can be a tool that is to be turned into an instrument using for generating solutions for financial calculations through conceptual schemes in terms of its functions and properties (Figure 1).

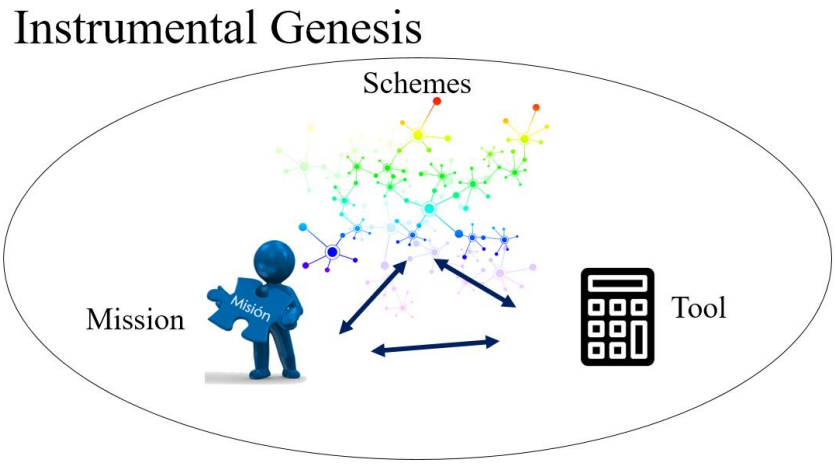


Figure 1. Transformation of a tool into an instrument (adapted from Drijvers & Trouche, 2008)

The *schemes* are formed by personalizing the features of the tool and can be revealed with the techniques presented by the learners (Drijvers et.al, 2013). Learners can make the same tool

into a different instrument in terms of their knowledge (Drijvers & Trouche, 2008). It is expected that the schemes that lead to the transformation of the tool into an instrument include solutions for the use of the tool and the mathematical background on which it is based (Özdemir Erdoğan, 2016). These schemes can be traced through instrumentalization and instrumentation.

While instrumentalization is users to personalize the tool and determine the mental paths that lead to the solution, instrumentation is the handling of the mathematical base of these paths and the relationships between the paths on the tool (Trouche, 2018). Instrumentation is a hybrid process that learners develop through the relationships between task and tool, which should be handled with instrumentalization beyond a mathematical development. (Trouche, 2018). It is emphasized to determine the conceptual components of the task and the personalized features used in the tool to examine the processes of instrumentalization and instrumentation (Gueudet & Trouche, 2011).

The Environment

Students of the Department of Banking and Finance, which is one of the programs carried out in vocational schools providing associate degree education in Turkey, work in financial institutions such as banks and insurance companies after their two-year education. Companies provide in-service training to their new employees that model their working processes. It is stated that the most important reason for this is the necessity of improving the competencies of the students in the field (Güvenç & Yücebalkan, 2017). People who work in the field of finance make almost all of their calculations with technological software. The schools offer courses that improve these aspects of students as well. Percentage and interest calculations are two main concepts frequently used in this department. Many calculations such as interest types, rates, loans presented in the product range of the banking are related to these concepts. In addition, the employees in the business should make correct calculations besides focusing on skills such as designing the calculations according to the customer's request at the optimum level, estimating and interpreting the changes based on the manipulations of different variables such as time, ratio, and principal amounts. The used technologies can make interpretation skills faster and more efficient as well as ease of calculation.

Purpose and research questions

This study aims to examine a learning process designed to handle interest calculations on the spreadsheet in terms of the instrumental genesis approach.

In this context, answers to the following research questions are handled:

1. How do students use spreadsheets functions and features in interest calculations?

2. What is the contribution of the use of spreadsheets to the students' development of the concept of interest?

Method

In this study, the case study method, which is one of the qualitative research approaches, was adopted. Case study is a method that answers the questions of why and how by examining in detail a situation, lesson or an activity (Yıldırım & Şimşek, 2008). Case study concerns with the process rather than the outcomes, the context of the case rather than the specific factors, and figuring out the facts rather than verifying them (Merriam & Grenier, 2019). Case study method was used for the study since it was aimed to examine the students' processes of converting the spreadsheet from a tool to an instrument.

Participants

The study was carried out with a group of 8 students among 89 who took the course of finance mathematics in the Department of Banking and Finance at a state university in the Western Mediterranean. In the study, the appropriate sampling method was used to reflect the environment taking into account the dispersion of their cognitive level and genders (Lehner, 1992). Akın, Ceylin, Didem, Doğuş, Hatice, Nurdan, Sema and Şengül, nicknames of the voluntary participants in the study. The students were familiar with the spreadsheet as an office program from their vocational courses, however, they used it the first time for the course of finance mathematics.

Data collection

In the study, four tasks were carried out in the spreadsheets. It was tried to obtain data that would reveal the skills and thoughts of the students in the process (Merriam & Grenier, 2019). Data collection tools of the study are; (1) screen recordings of students, (2) audio recordings of clinical interviews, and (3) observation notes taken by the researchers. Screen recordings were used as primary data collection tools to monitor students' skills in the tasks. The relationships between students' actions and thoughts were tried to be revealed through clinical interviews conducted during the tasks. The data were supported by researcher observation notes. It is aimed to increase the validity and reliability of the research data by using more than one data collection tool (Yıldırım & Şimşek, 2008). The Observation notes were taken in a structured form outlined in Table 6. This form was created on the main lines of instrumentalization and instrumentation, taking into account the dynamics of both instrumental genesis and the concept of interest. Researchers are also observers.

Process

(1) Preparation of the tasks: In the department of banking and finance, the concept of interest is handled in the fall semester of the first year within the course of finance mathematics. In the course, students use paper-pencil and functional calculators. Within the study, this concept is discussed in the Information Technology (IT) environment. The tasks were prepared in the spreadsheets taking into account the skills expressed in the literature along with the outcomes determined by the institution for the course (Hoyles, 2018; Pournara, 2013).

Accordingly, the tasks were built on four basic outcomes and instructions was presented to the students for each outcome.

Outcomes:

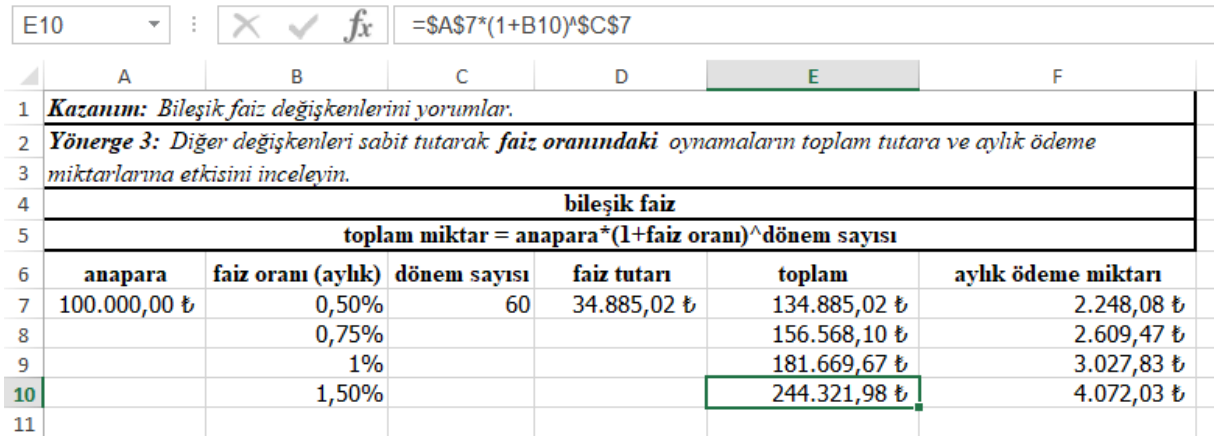
O1. Make simple interest and compound interest calculations with pencil-paper, calculator and spreadsheets.

O2. Provide transitions from simple interest to compound interest.

O3. Interpret variables of compound interest.

O4. Prepare compound interest applications on spreadsheets as well as monitor variable changes.

The tasks were prepared on the spreadsheet shown in Figure 2 and presented to the students as an Excel file.



E10 | =$A$7*(1+B10)^$C$7

	A	B	C	D	E	F
1	***Kazanım:*** *Bileşik faiz değişkenlerini yorumlar.*					
2	***Yönerge 3:*** *Diğer değişkenleri sabit tutarak* ***faiz oranındaki*** *oynamaların toplam tutara ve aylık ödeme*					
3	*miktarlarına etkisini inceleyin.*					
4	**bileşik faiz**					
5	**toplam miktar = anapara*(1+faiz oranı)^dönem sayısı**					
6	**anapara**	**faiz oranı (aylık)**	**dönem sayısı**	**faiz tutarı**	**toplam**	**aylık ödeme miktarı**
7	100.000,00 ₺	0,50%	60	34.885,02 ₺	134.885,02 ₺	2.248,08 ₺
8		0,75%			156.568,10 ₺	2.609,47 ₺
9		1%			181.669,67 ₺	3.027,83 ₺
10		1,50%			244.321,98 ₺	4.072,03 ₺
11						

Figure 2. An example from worksheets, Task 3

(2) Implementation steps: The implementation was carried out as an extracurricular activity, focusing on one of the outcomes for each week. Students performed these tasks using Excel 2013 on their equivalent computers. Table 2 indicates the calendar of the implementation during five weeks organized as two parts of 45 minutes each week.

Table 2. The Implementation Calendar

	Process notes
Week 0 (introducing spreadsheets)	• Deal with and try spreadsheet functions and features required for finance mathematics.
Week 1 (Outcome 1)	• Calculate simple interest and compound interest transactions on spreadsheets. • Check the calculations on the spreadsheets using a calculator and paper-pencil.
Week 2 (Outcome 2)	• Perform the transitions from simple to compound interest. • Trace the changes in multiple interest calculations using dynamics of spreadsheets
Week 3	• Interpreting the variables of compound interest.

(Outcome 3)	
Week 4 (Outcome 4)	• Prepare compound interest practices on spreadsheets and monitor variable changes

As seen in Table 2, before the tasks, a short training was given to the students on the features of spreadsheets that they will benefit from in interest calculations. Then, in the first week, the students were asked to transfer the interest calculations they made in a paper-and-pencil environment to spreadsheet. In this task, the students were not guided about the features they should use. In the second task, it was aimed to examine the relationships between compound and simple interest calculations and the effects of the parameters. For this, students were provided with support where necessary by reflecting the teacher's worksheets. In the 3rd and 4th tasks focusing interpreting, it was tried to reflect the students' thoughts and images of the worksheets to be discussed in the classroom environment. Meanwhile, the researchers kept the communication in the classroom on the one hand, took observation notes and recorded the digital data at the end of the tasks.

Data Analysis

Thematic analysis was carried out in the study for data from screen recordings, clinical interviews and observation notes. The thematic analysis of the research was handled in two parts according to the instrumentalization and instrumentation that were dimensions of the instrumental genesis approach. Five themes given in Table 3 were created in terms of functions and features of spreadsheets, five themes of Ainley et al. (2005) given in Table 4 are related to the conceptual process. These analysis themes reveal the subjects' schemes defined within the framework of the instrumental genesis approach.

Table 3. The Instrumentalization Process

Themes	Tasks	Focal themes
1. Creating a formula - Create a formula using cell addresses - Perform function inputs from correct cells.	Task 1:	1,2,3
2. Using cell addresses - Provides dynamism of both cells and calculations.	Task 2:	1,2,3,4,5
3. Formatting Cells - Organize a readable working sheet with edits.	Task 3:	1,2,3,4,5
4. Fixing - Uses constant ($) where necessary for drags.	Task 4:	1,2,3,4,5
5. Dragging - Use drag based on formulas, suitable for the pattern of given numbers instead of manual entries. - Use dragging in multi-manipulations. - Realize that dragging aims to do and trace maximum calculations as well as minimum manual entry.		

The analysis according to the themes obtained were carried out by the researchers together. When necessary, audio recordings and screenshots were re-examined, compared with the notes taken by the researchers, it was checked whether the data supported each other and data loss was tried to be kept to a minimum.

Table 4. The instrumentation process

Themes	Tasks	Focal themes
1. Constructing algebraic structures - Perform simple and compound interest calculations by creating formulas.	Task 1:	1,2,3
2. Explaining why - Explain the created formulas and spreadsheets properties under their mathematical background	Task 2:	1,2,3,4
3. Explaining the rule or relationship - Explain the relationship between interest calculations and their results. - Explain the effect of interest variables on results. - Estimate results according to interest rate variables. - Manipulate interest variables according to focal results.	Task 3:	1,2,3,4
4. Generalizing the process to many examples - Perform manipulations over the system established on spreadsheets.	Task 4:	1,2,3,4,5
5. Finding the unknown - Reach conclusions about the effects of the variables of simple and compound interest.		

Findings

In the first week of the research, the functions, formulas and other specified features of spreadsheets were introduced to the students in particular for the concept of interest. Although it was observed that the students were motivated, they had limited skills on the concept of interest, especially in the spreadsheets environment. The findings are handled under the sub-headings of each outcome in parallel with the implementation process for each week.

Calculate simple interest and compound interest on spreadsheets

In this first step, in which simple and compound interest calculations are expected to be made in the spreadsheets, students are reminded of simple and compound interest formulas. The first task is limited to creating cell address-based formulas and formatting them. It is observed that students who use calculators in previous lessons tend to manual inputs instead of creating formulas or using cell addresses for calculation (Figure 3).

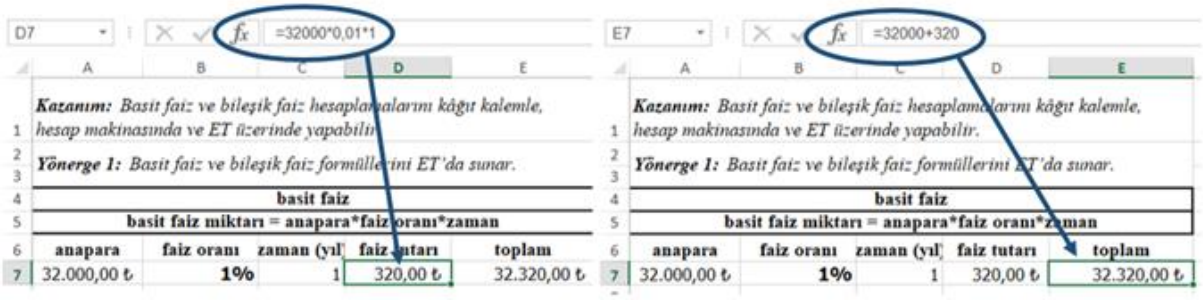


Figure 3. An example from Manuel inputs by Didem

The researcher did not intervene in this situation directly, the researcher oriented students to reasonable solutions. Formulating dependent variables such as the interest amount (I), the total amount (S) depended on the cell addresses was the focal target during the first lesson (Figure 4).

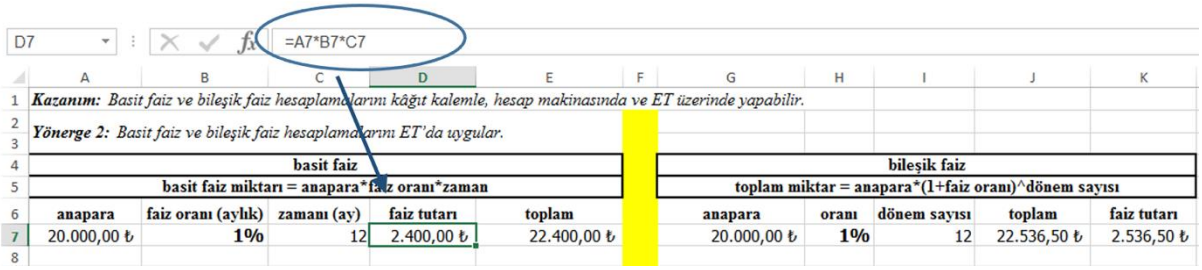


Figure 4. An example for using cell address from a simple interest calculation by Şengül

The researcher supported students in formatting cells and formulas in the first week such as cell formatting and formula formation for using currency and financial values, by the researcher. In this process, the researcher gave instructions by showing the necessary technical steps on his own screen in a way that all students could see. These features were used by all students before the end of the first week. The researcher observed that the students preferred cell addresses instead of manual inputs after a few practices. Didem and Akın's statements shed light on their experiences on using cell addresses.

Didem: All my calculations would be correct if I created the cells correctly.

Akın: I wrote formulas in places (cells) where there are formulas, but I did not understand where else to write them.

While Didem describes the positive effect of usıng cell addresses on the accuracy of calculations, Akın tries to create schemes about which cells and variables should be used for cell addresses. It is seen that students have difficulty in using commas and dots while they can

easily perform currency formatting. Students stated that their previous spreadsheets and calculator experiences might have caused.

Doğuş: I already do this in the course of accounting. In fact, I have now emplaced it to quick access.

Akın: We were doing the opposite (using periods and commas) on the calculator. I could confuse frequently if I'm not careful.

Ceylin: Well, it gives an error when I put a dot! Why?

Ceylin falls with errors because she tries to write the dots for thousands that the spreadsheet separates automatically at the end of the calculations. It is monitored that the students do not have any difficulty in transferring the calculations of interest to the spreadsheets. All students write correct interest calculations besides, Nurdan and Sema successfully entered the formula based on cell address for the interest amount in compound interest calculations without any guidance (Figure 5).

$$I = P\ x\ r\ x\ t \qquad S = P\ x\ (1+r)^{n*} \qquad I = S - P$$

$$I \rightarrow\ = A7 * B7\ x\ C7/12 \qquad S \rightarrow\ = G7\ x(1+H7)\text{^}I7 \qquad I \rightarrow\ = J7 - G7$$

J7 =G7*(1+H7)^I7

	A	B	C	D	E	F	G	H	I	J	K
1	***Kazanım:*** *Basit faiz ve bileşik faiz hesaplamalarını kâğıt kalemle, hesap makinasında ve ET üzerinde yapabilir.*										
2	***Yönerge 2:*** *Basit faiz ve bileşik faiz hesaplamalarını ET'da uygular.*										
3											
4	**basit faiz**						**bileşik faiz**				
5	**basit faiz miktarı = anapara*faiz oranı*zaman**						**toplam miktar = anapara*(1+faiz oranı)^dönem sayısı**				
6	**anapara**	**faiz oranı (aylık)**	**zamanı (ay)**	**faiz tutarı**	**toplam**		**anapara**	**oranı**	**dönem sayısı**	**toplam**	**faiz tutarı**
7	20.000,00 ₺	**1%**	12	2.400,00 ₺	22.400,00 ₺		20.000,00 ₺	**1%**	12	22.536,50 ₺	2.536,50 ₺
8											

Figure 5. An example of using cell address for compound interest calculation by Nurdan

In Task 1, it is seen that the students have difficulties in writing the interest rate in the correct digit. Şengül, Nurdan, and Sema are able to write correctly, while five students (63%) have difficulty both in writing the interest rate, which was given ready-to-use as 0.95%, and using the percentage feature (Figure 6).

* P: Principal (initial value), r: Interest rate n: number of period of interest S: Total amount t: time (as years) I: Interest amount

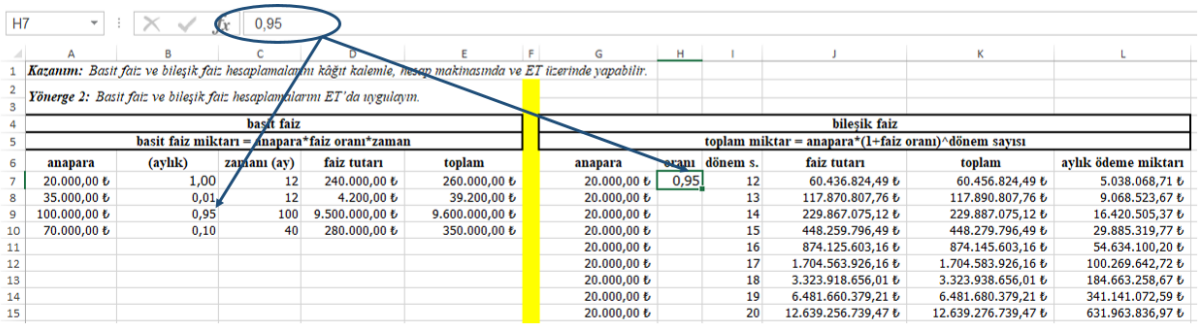


Figure 6. An example for using the wrong percentage for interest rate by Akın

In Task 1, it is observed that the students check the calculations by calculators they are used to. It is seen that this checking is not only for the results but also for the formulas that the students write cell addresses.

Sema: I am not sure if I write the percentage correctly, but my result shows that it is correct.

The transition from simple interest to compound interest

Students begin by creating a template for simple interest calculations and formatting cells in their worksheets. Then the students do the first-month calculation by entering data into the cells, they sustain the calculations sequentially by using dragging. In this task for Outcome 2, firstly, the equality of simple and compound interest calculations over the first month is handled. In the first step of Task 2, it is observed that half of the students (Hatice, Didem, Akın and Doğuş) entered the interest rate as numerical (manual) in the formula instead of cell addresses. In the task, the same interest rate is used for all calculations so the difference in entry data does not affect the results. But Didem realizes this situation at the end of the calculations (Figure 7).

Didem: I drag it, type the rate (interest rate) normally (manually), but it is fine. Probably, because it is not changed (the rate).

$$S\rightarrow \quad = A5 + D5 \qquad\qquad S\rightarrow \quad = B5 * (1 + C51)\text{^}D12$$

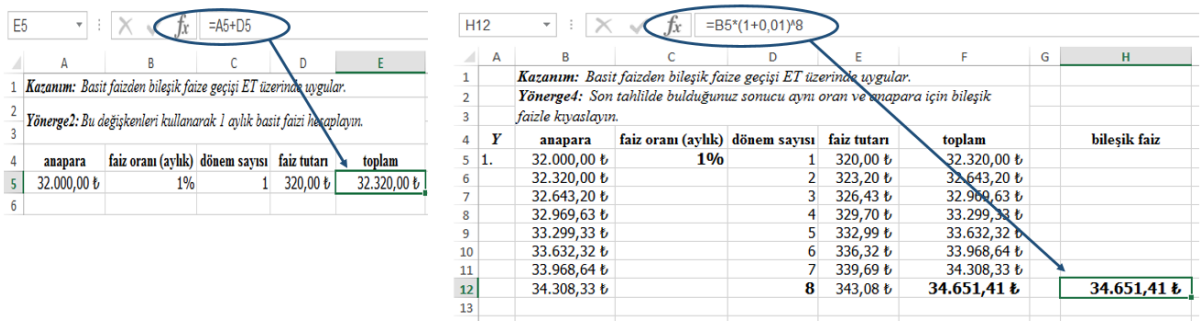


Figure 7. An example for using or not using cell addresses by Nurdan and Doğuş

Figure 8 shows the effect of fixing cells on the results in writing the targeted formula. Failure using fixing causes not occur the results or incorrect results in sub-rows. While Hatice forgets to use fixing, Ceylin and Şengül created the same formula for each row by manually updating the cell addresses according to the row, without using the fixing feature.

$$I\rightarrow \quad = B5 + E5 \qquad\qquad I\rightarrow \quad = B12 * \$C\$5 * \$D\$5$$

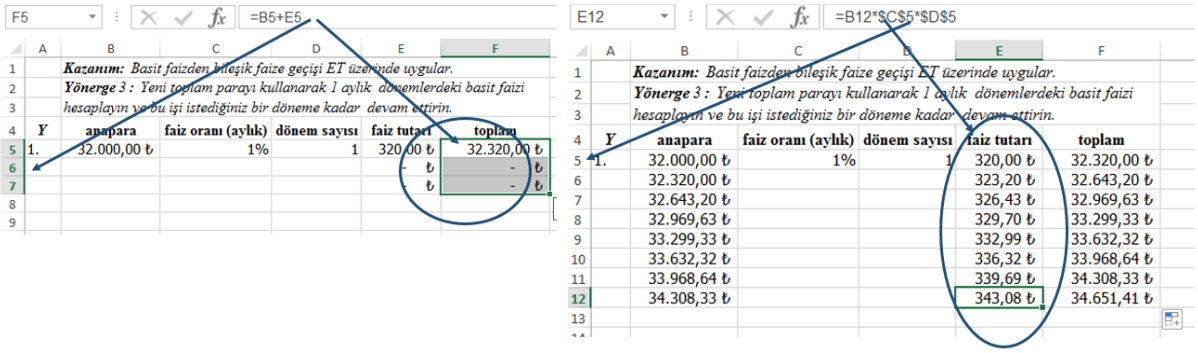


Figure 8. An example for using or not using cell addresses by Hatice and Sema

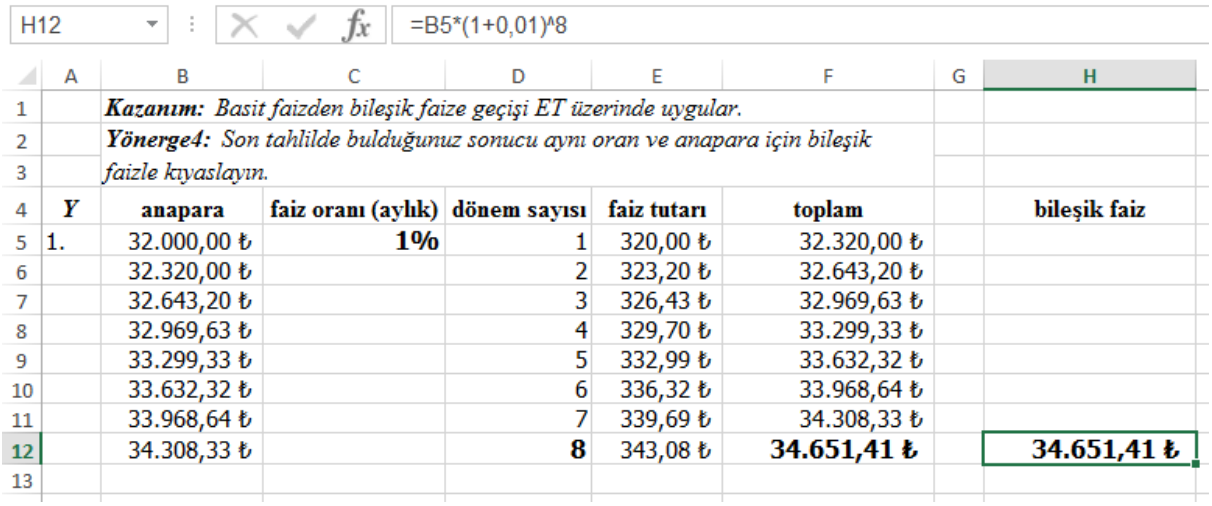
In the third week, it is desired to indicate the equality of consecutive simple interest calculations to compound interest by using the fixing and dragging. In this process, while the students use the mentioned features of the spreadsheets in the first week, Şengül achieve the correct results by using the copy-pasting that she is familiar in her Office experiences. Ceylin rewrites the same values for each line. Although Hatice use the drag feature, she could not reach the correct result due to the error she makes on creating the formula.

Şengül: I may get confused about where to put the $ in fixing, but I can finish the process by copy-pasting without needing dragging.

This task is designed for students to make sense of the relationship between simple and compound interest. The relationship between these concepts is not established over linear and exponential functions, taking into account the mathematics level of the students. Instead, it is enabled them to deduce that compound interest calculations consist of a combination of simple interest calculations by spreadsheets, calculators and paper-pencil on teacher instructions on the board (Figure 9).

Although the students accept that consecutive simple interest calculations and compound interest are equal, it is seen that they could not establish a relationship between the formulas. All of the students complete the task using cell addresses in the formulas and could generalize their calculations. Hatice and Nurdan's thoughts on Task 3 shed light on their worksheets including simple and compound interest calculations.

$$S\rightarrow \quad = B5 * (1 + \$C\$5)\text{^}D12$$



H12 =B5*(1+0,01)^8

	A	B	C	D	E	F	G	H
1		***Kazanım:*** *Basit faizden bileşik faize geçişi ET üzerinde uygular.*						
2		***Yönerge4:*** *Son tahlilde bulduğunuz sonucu aynı oran ve anapara için bileşik*						
3		*faizle kıyaslayın.*						
4	***Y***	**anapara**	**faiz oranı (aylık)**	**dönem sayısı**	**faiz tutarı**	**toplam**		**bileşik faiz**
5	1.	32.000,00 ₺	**1%**	1	320,00 ₺	32.320,00 ₺		
6		32.320,00 ₺		2	323,20 ₺	32.643,20 ₺		
7		32.643,20 ₺		3	326,43 ₺	32.969,63 ₺		
8		32.969,63 ₺		4	329,70 ₺	33.299,33 ₺		
9		33.299,33 ₺		5	332,99 ₺	33.632,32 ₺		
10		33.632,32 ₺		6	336,32 ₺	33.968,64 ₺		
11		33.968,64 ₺		7	339,69 ₺	34.308,33 ₺		
12		34.308,33 ₺		**8**	343,08 ₺	**34.651,41 ₺**		**34.651,41 ₺**
13								

Figure 9. Comparison of consecutive simple and compound interest results by Didem

Nurdan: Compound interest is equal to successive calculations (on simple interest) but I cannot explain it by formula. … I realize that compound interest calculations would be higher. Because although there is a calculation (in simple interest calculations), in the compound interest calculations, there are calculations as much as the number of periods.

Hatice: I have not known where the formula came from, I couldn't understand it now either. But dragging (successive calculations) makes it clear what compound interest is. …I understand that money (capital) is reworked every month (period) in compound interest. This causes the last money (total amount) to rise.

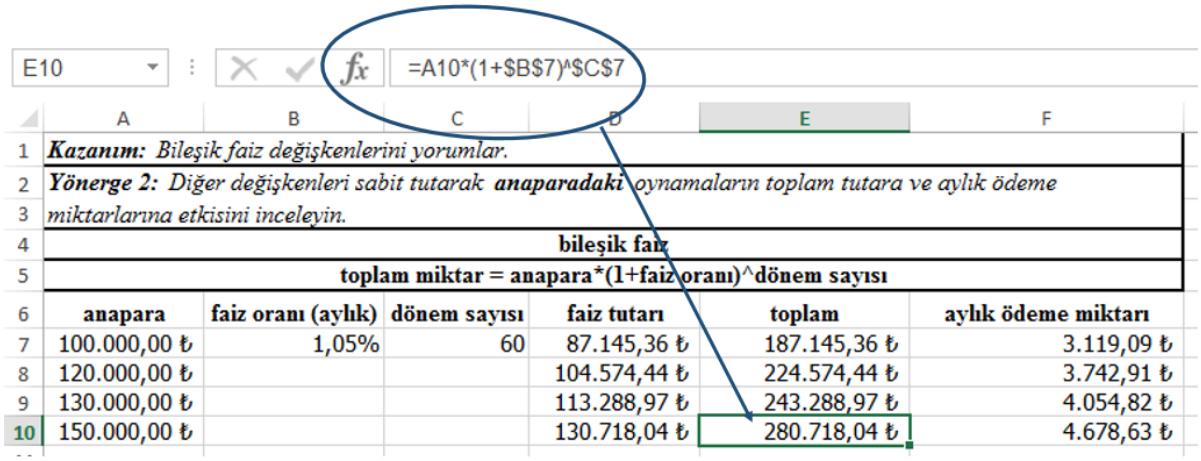
Interpreting compound interest variables

In Task 3, the students are first asked whether they followed the current interest rates and other variables (for example, what would be the current interest rates for a loan of 100000 TL and the total amount of a 10-year loan?). It is observed that the students do not have sufficient information or experiences on them. A couple of students could not perceive unsuitable (too high) values in their compound interest calculations. During the task, the current interest rates are indicated on the websites of several banks and discussed with the students. After this process, students are asked to provide manipulation of compound interest variables (principal, interest rate, and time) with appropriate dragging operations. In this way, the effects of the variables are examined. Examples of worksheets created by students in this process are presented in Figures 10-12.

$$M = S/n^{\dagger}$$

$S\rightarrow$ $= A10 * (1 + \$B\$7)\text{^}\$C\$7$ $M\rightarrow$ $= E7/\$C\$7$

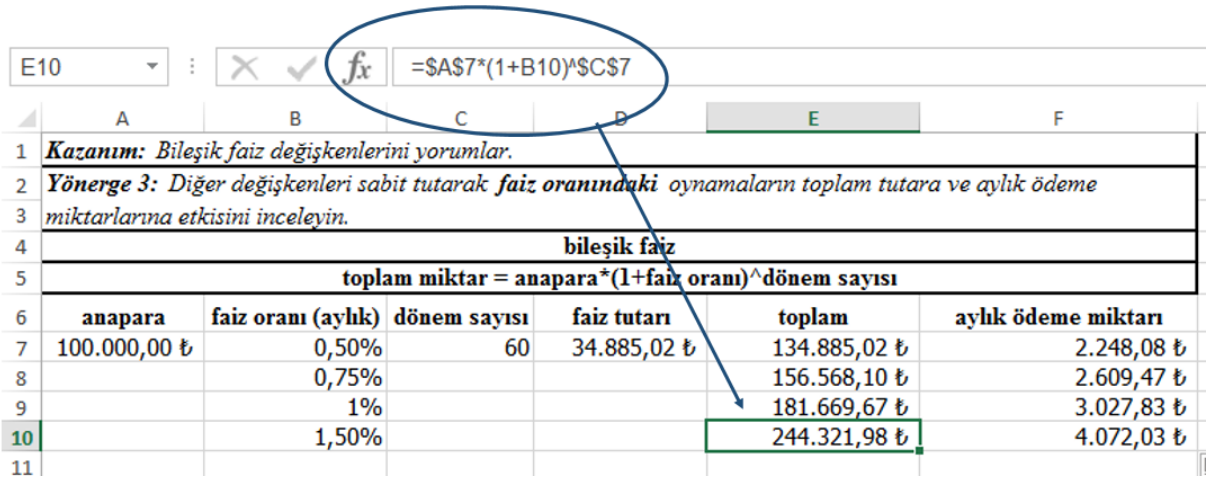
† M: Monthly payment



	A	B	C	D	E	F
1	***Kazanım:*** *Bileşik faiz değişkenlerini yorumlar.*					
2	***Yönerge 2:*** *Diğer değişkenleri sabit tutarak* ***anaparadaki*** *oynamaların toplam tutara ve aylık ödeme*					
3	*miktarlarına etkisini inceleyin.*					
4	**bileşik faiz**					
5	**toplam miktar = anapara*(1+faiz oranı)^dönem sayısı**					
6	**anapara**	**faiz oranı (aylık)**	**dönem sayısı**	**faiz tutarı**	**toplam**	**aylık ödeme miktarı**
7	100.000,00 ₺	1,05%	60	87.145,36 ₺	187.145,36 ₺	3.119,09 ₺
8	120.000,00 ₺			104.574,44 ₺	224.574,44 ₺	3.742,91 ₺
9	130.000,00 ₺			113.288,97 ₺	243.288,97 ₺	4.054,82 ₺
10	150.000,00 ₺			130.718,04 ₺	280.718,04 ₺	4.678,63 ₺

Figure 10. The effect of changing of interest rate on compound interest results by Ceylin

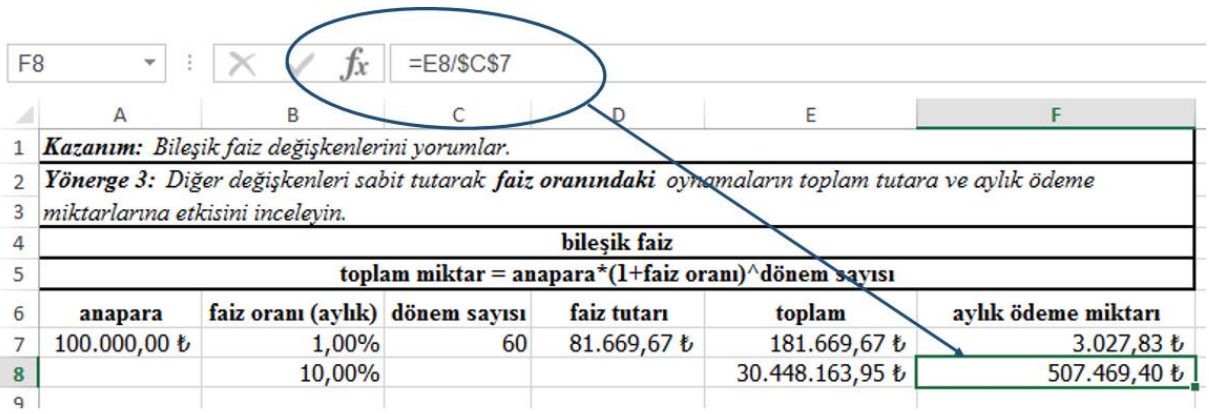
$$S\rightarrow \ = \$A\$10 * (1 + B10)\text{^}\$C\$7$$



	A	B	C	D	E	F
1	***Kazanım:*** *Bileşik faiz değişkenlerini yorumlar.*					
2	***Yönerge 3:*** *Diğer değişkenleri sabit tutarak* ***faiz oranındaki*** *oynamaların toplam tutara ve aylık ödeme*					
3	*miktarlarına etkisini inceleyin.*					
4	**bileşik faiz**					
5	**toplam miktar = anapara*(1+faiz oranı)^dönem sayısı**					
6	**anapara**	**faiz oranı (aylık)**	**dönem sayısı**	**faiz tutarı**	**toplam**	**aylık ödeme miktarı**
7	100.000,00 ₺	0,50%	60	34.885,02 ₺	134.885,02 ₺	2.248,08 ₺
8		0,75%			156.568,10 ₺	2.609,47 ₺
9		1%			181.669,67 ₺	3.027,83 ₺
10		1,50%			244.321,98 ₺	4.072,03 ₺
11						

Figure 11. The effect of changing of interest rate on compound interest results by Didem

$$M\rightarrow \ = E8/\$C\$7$$



	A	B	C	D	E	F
1	***Kazanım:*** *Bileşik faiz değişkenlerini yorumlar.*					
2	***Yönerge 3:*** *Diğer değişkenleri sabit tutarak* ***faiz oranındaki*** *oynamaların toplam tutara ve aylık ödeme*					
3	*miktarlarına etkisini inceleyin.*					
4	**bileşik faiz**					
5	**toplam miktar = anapara*(1+faiz oranı)^dönem sayısı**					
6	**anapara**	**faiz oranı (aylık)**	**dönem sayısı**	**faiz tutarı**	**toplam**	**aylık ödeme miktarı**
7	100.000,00 ₺	1,00%	60	81.669,67 ₺	181.669,67 ₺	3.027,83 ₺
8		10,00%			30.448.163,95 ₺	507.469,40 ₺
9						

Figure 12. The effect of changing periods on compound interest results by Nurdan

In this process, the students realize that the increase of the principal is reflected in the total amount, interest amount, and monthly payments. While they understand that rising the number of periods increases the total amount, they have difficulty in making sense of the decrease in monthly payments. A couple of quotes from students' interviews explain this situation.

Şengül: It's a bit complicated! We cannot predict exactly which one (variable) will affect how. There are already so many cells (variables) that it seems difficult to set them all and determine the total amount or monthly payment.

Akın: …but how do we know, teacher, does it increase or decrease (the total amount)? I think when the principal and interest rate increase payment (total) increases, but if the number of periods increases, I don't understand how total payment decreases!

Ceylin: I tried 0.5% (interest rate), it comes out 134000 (total amount), I write 1% and it comes out 181000. Isn't that too much, sir?

Didem: How big is the difference between 1% and 10%? Which rate is close to the rate of the banks?

One reason why students have difficulty interpreting the variables in compound interest calculations is a large number of variables. This situation is reflected in Şengül's statement. In addition, after the total amount is found, other results such as monthly payment play a role in decision-making for loans. From this point of view, it is seen that the students could refer a mathematical meaning to the manipulations of one variable by fixing the others, but they could not make the correct calculations for intended results. For example, a monthly payment of 2000 TL is requested for a loan but the manipulations for this adjustment cannot be formulated. Nevertheless, considering the statements of Ceylin and Didem, it is seen that the effects of the interest rates on the results cause surprise.

It is determined that a few problems continue in the use of spreadsheets during the implementation of the task. It is observed that Hatice's mistakes in formatting cells, dragging, and fixing lead to incalculable situations rather than wrong results (Figure 13). However, Hatice realizes her mistakes and makes the necessary arrangements.

Hatice: Sure! I forget to fix it while dragging. …yes, I guess I do not convert it to TL (meaning formatting cells for currency), that's why.

$$M\rightarrow \ = E8/C8$$

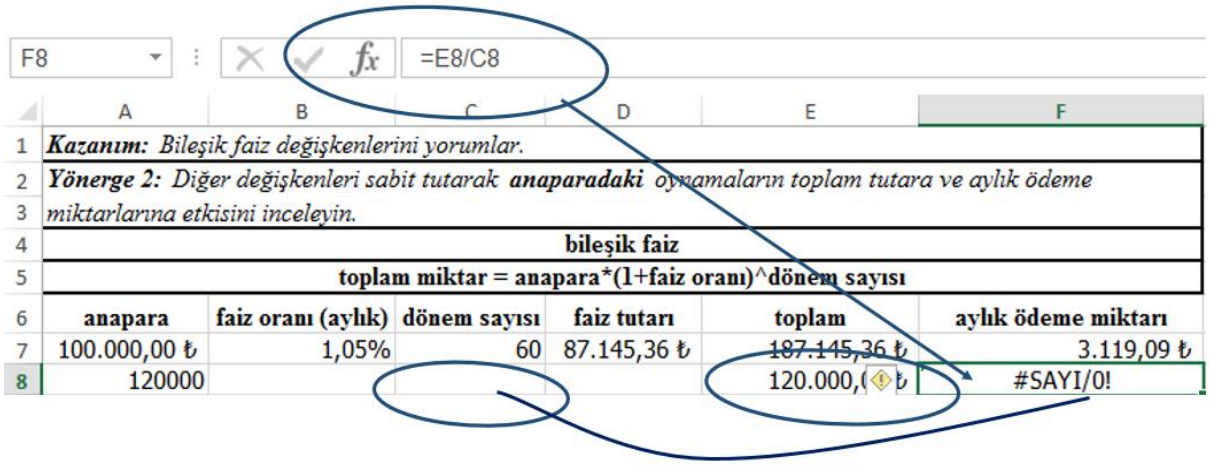


Figure 13. Realizing the mathematical mistakes by Hatice

However, Doğuş, who completes his calculations with formulas using cell addresses, obtains a big large value that is not suitable for the problem situation due to the mistake he makes regarding the writing of the interest rate (typing10.5% instead of 1.05%). In the interview, it is seen that Doğuş does not pay attention to this value and does not feel the need to verify the results.

Doğuş: What kind of mistake? (he does not think the results are abnormal). .. but I do not make any mistakes, I write the same in calculations.

…hmm! Of course, the monthly payment would not be 500,000 TL! Do I make a mistake in the formula?

..no, I do not notice that (he's talking about the mistake on the interest rate)

Preparing practices on compound interest on spreadsheets and monitoring variable changes

In Task 4, the last part of the study, students are asked to build up intended calculations on compound interest by the variables. In the regulations, it is requested that the results be harmonized with current values and the policies followed by the banks using the =if function. The policies are limited to the number of periods and the related changes in the interest rate. When the students need support regarding the use of= if function, the researcher guides them by sharing his screen. In Task 4, first, the effect of the number of periods and changing of interest rate in the compound interest calculations are handled. Hatice selects the wrong cell besides does mistakes on fixing. Sema reflects the interest policy manually on her worksheet without using =if function. Even then, Sema makes appropriate analyses and states that the increase of the number of periods reduces the monthly payment amount while increasing the total amount too much. Figure 14 shows that Doğuş limits the number of periods to 120 months and performs changes on the number of periods and interest rates in his worksheet. It is observed that Doğuş, Nurdan, Sema and Didem pay attention to both the interest policies and regarding

the change of interest rates over the duration of time. According to Doğuş's statements, it can be seen that he improves to both building up effective worksheets by functions and features of spreadsheets and interpreting the variables of interest.

Sema: It is too long (typing =if function). I would definitely do it wrong.

High-interest rates increase everything (the total amount and monthly payment amount) so the number of periods should be as short as possible.

…of course, it increases a little bit (he talks about the increase in monthly payments when the period is shortened). But as I said, it depends on the interest rate.

Doğuş: Now, when I write the formula (= if) as you do, I bring dynamism to the interest rate. I do not need to change it manually.

Yeah. I saw it in a bank's calculation engine. I got it from there. the interest rate can be 120 months maximal (number of periods).

Extending the duration increases both the interest rate and the total (amount).

$$r\rightarrow\ = if(C12 < 36; "\%0{,}75"; if(C12 < 60; "\%0{,}95"; if(C12 < 120; "\%1{,}1"; "uncountable")))$$

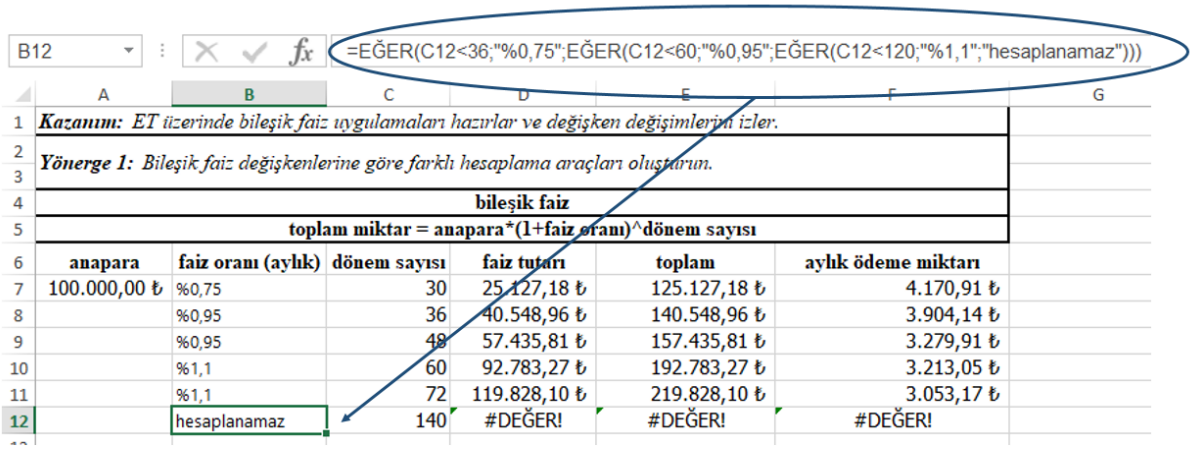
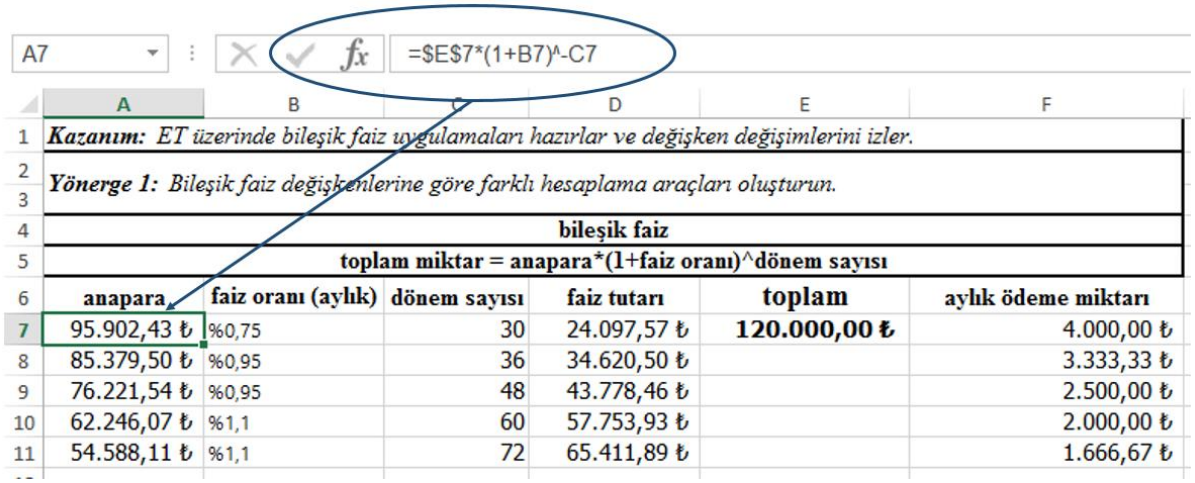


Figure 14. Typing =if function for current interest rate policies by Doğuş

Considering the interest rates in Figure 14, Doğuş develops an understanding of the impact of changes in interest rates. While Doğuş is able not to notice the abnormal values in Task 3, he can interpret the effect of the 0.05% change in the interest rate on the total amount in Task 4. The researcher stated that the strategy that non-target variables are kept constant may be useful for examining the effect of target variables. Figure 15 shows Nurdan's strategy of fixing the total money. Nurdan develops a suitable formulation by removing the principal from the compound interest formula. According to the formula, the principal and monthly payment amounts change regarding the total amount.

$$P = S * (1 + r)\text{^}(-n)$$

$$P\rightarrow \ = \$E\$7 * (1 + B7)\wedge - C7$$



	A	B	C	D	E	F
1	***Kazanım:*** *ET üzerinde bileşik faiz uygulamaları hazırlar ve değişken değişimlerini izler.*					
2	***Yönerge 1:*** *Bileşik faiz değişkenlerine göre farklı hesaplama araçları oluşturun.*					
3						
4	**bileşik faiz**					
5	**toplam miktar = anapara*(1+faiz oranı)^dönem sayısı**					
6	**anapara**	**faiz oranı (aylık)**	**dönem sayısı**	**faiz tutarı**	**toplam**	**aylık ödeme miktarı**
7	95.902,43 ₺	%0,75	30	24.097,57 ₺	**120.000,00 ₺**	4.000,00 ₺
8	85.379,50 ₺	%0,95	36	34.620,50 ₺		3.333,33 ₺
9	76.221,54 ₺	%0,95	48	43.778,46 ₺		2.500,00 ₺
10	62.246,07 ₺	%1,1	60	57.753,93 ₺		2.000,00 ₺
11	54.588,11 ₺	%1,1	72	65.411,89 ₺		1.666,67 ₺

Figure 15. Keeping the total amount constant in compound interest calculations by Nurdan

Nurdan: The total amount does not change, but the principal decreases when the monthly payment amount decreases. I would not because the interest rate is higher.

Considering Nurdan's explanations, it is seen that she can interpret the results of the changes through correct calculations as well as explain the intended changes of the variables. Sema, the other student who could keep the total amount constant, keep the monthly payment amount constant to 2000 TL as well. She also follows the changes of the principals, interest amounts and total amount in the manipulations she carried out in accordance with the interest policies (Figure 16).

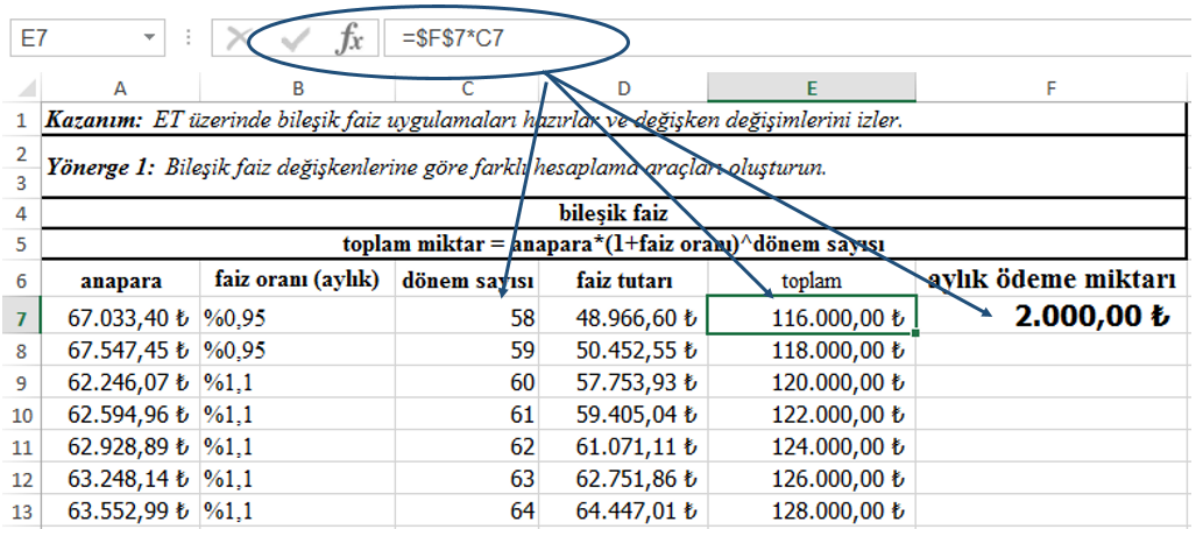
Sema: I keep the monthly payment constant, for this, I use the total money divided by the number of periods. Of course, firstly, I find the formula for the total amount then I drag the number of periods. Then I drag the sum and interest amount. I did so.

In other words, both (principal and total amount) are always increasing, I don't understand how they affect the monthly payment.

.

Sema explains how she uses the formulas on the spreadsheet besides, she expresses the mathematical structure of them. But it is seen that Sema has difficulty in explaining the relationship among monthly payment, total amount and principal. Nurdan, Doğuş and Didem could not create a formula to keep the monthly payment amount constant, but to find the closest calculations to constant monthly payment (2000 TL), they manipulate the values of principals and periods together. One of them, Nurdan's worksheet for this task is indicated in Figure 17.

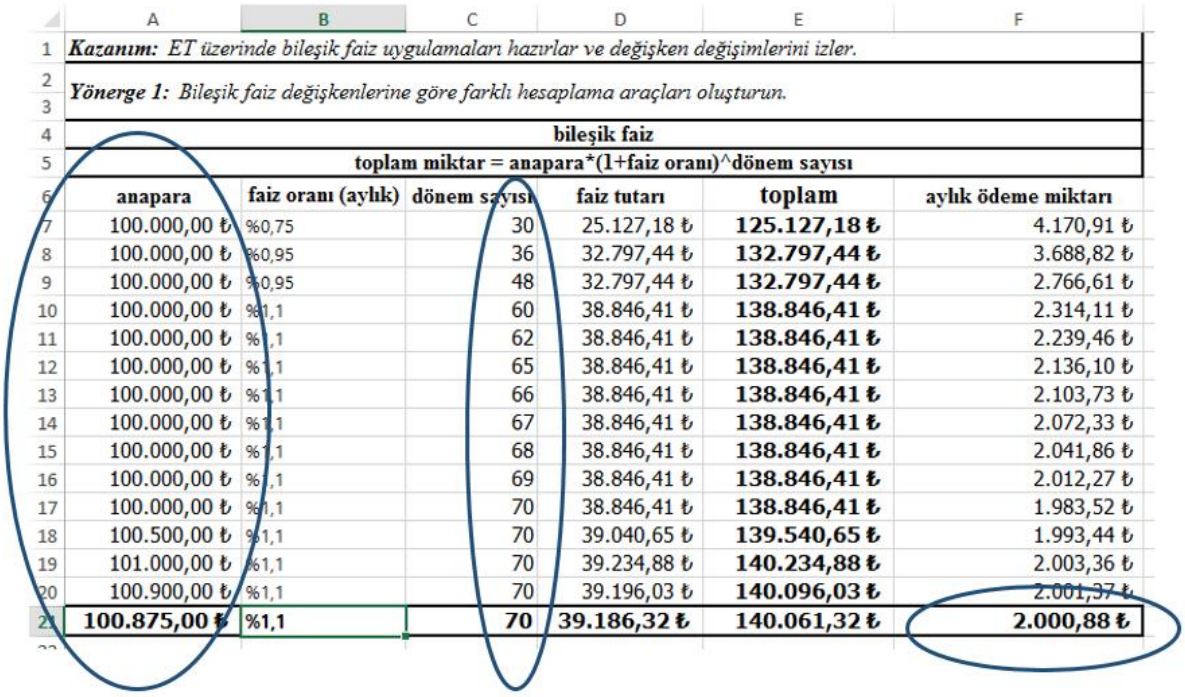
$$P\rightarrow \ = E6 * (1 + B6)\wedge - C6 \qquad I\rightarrow \ = E6 - A6 \qquad S\rightarrow \ = \$F\$6 * C6$$



E7 | =$F$7*C7

	A	B	C	D	E	F
1	***Kazanım:*** *ET üzerinde bileşik faiz uygulamaları hazırlar ve değişken değişimlerini izler.*					
2	***Yönerge 1:*** *Bileşik faiz değişkenlerine göre farklı hesaplama araçları oluşturun.*					
3						
4	**bileşik faiz**					
5	**toplam miktar = anapara*(1+faiz oranı)^dönem sayısı**					
6	**anapara**	**faiz oranı (aylık)**	**dönem sayısı**	**faiz tutarı**	toplam	**aylık ödeme miktarı**
7	67.033,40 ₺	%0,95	58	48.966,60 ₺	116.000,00 ₺	**2.000,00 ₺**
8	67.547,45 ₺	%0,95	59	50.452,55 ₺	118.000,00 ₺	
9	62.246,07 ₺	%1,1	60	57.753,93 ₺	120.000,00 ₺	
10	62.594,96 ₺	%1,1	61	59.405,04 ₺	122.000,00 ₺	
11	62.928,89 ₺	%1,1	62	61.071,11 ₺	124.000,00 ₺	
12	63.248,14 ₺	%1,1	63	62.751,86 ₺	126.000,00 ₺	
13	63.552,99 ₺	%1,1	64	64.447,01 ₺	128.000,00 ₺	

Figure 16. Keeping the total amount constant in compound interest calculations by Nurdan



	A	B	C	D	E	F
1	***Kazanım:*** *ET üzerinde bileşik faiz uygulamaları hazırlar ve değişken değişimlerini izler.*					
2	***Yönerge 1:*** *Bileşik faiz değişkenlerine göre farklı hesaplama araçları oluşturun.*					
3						
4	**bileşik faiz**					
5	**toplam miktar = anapara*(1+faiz oranı)^dönem sayısı**					
6	**anapara**	**faiz oranı (aylık)**	**dönem sayısı**	**faiz tutarı**	**toplam**	**aylık ödeme miktarı**
7	100.000,00 ₺	%0,75	30	25.127,18 ₺	**125.127,18 ₺**	4.170,91 ₺
8	100.000,00 ₺	%0,95	36	32.797,44 ₺	**132.797,44 ₺**	3.688,82 ₺
9	100.000,00 ₺	%0,95	48	32.797,44 ₺	**132.797,44 ₺**	2.766,61 ₺
10	100.000,00 ₺	%1,1	60	38.846,41 ₺	**138.846,41 ₺**	2.314,11 ₺
11	100.000,00 ₺	%1,1	62	38.846,41 ₺	**138.846,41 ₺**	2.239,46 ₺
12	100.000,00 ₺	%1,1	65	38.846,41 ₺	**138.846,41 ₺**	2.136,10 ₺
13	100.000,00 ₺	%1,1	66	38.846,41 ₺	**138.846,41 ₺**	2.103,73 ₺
14	100.000,00 ₺	%1,1	67	38.846,41 ₺	**138.846,41 ₺**	2.072,33 ₺
15	100.000,00 ₺	%1,1	68	38.846,41 ₺	**138.846,41 ₺**	2.041,86 ₺
16	100.000,00 ₺	%1,1	69	38.846,41 ₺	**138.846,41 ₺**	2.012,27 ₺
17	100.000,00 ₺	%1,1	70	38.846,41 ₺	**138.846,41 ₺**	1.983,52 ₺
18	100.500,00 ₺	%1,1	70	39.040,65 ₺	**139.540,65 ₺**	1.993,44 ₺
19	101.000,00 ₺	%1,1	70	39.234,88 ₺	**140.234,88 ₺**	2.003,36 ₺
20	100.900,00 ₺	%1,1	70	39.196,03 ₺	**140.096,03 ₺**	2.001,37 ₺
21	**100.875,00 ₺**	**%1,1**	**70**	**39.186,32 ₺**	**140.061,32 ₺**	**2.000,88 ₺**

Figure 17. Manipulations on principal and periods for target monthly payment by Nurdan

In the second part of Task 4, an interview is held with the students on the case of a loan. In these interviews, the students are asked to prepare a worksheet where they could manipulate the variables in order to make a proposal suitable for the client's (researcher plays this role) wishes and present these proposals to him.

In the case designed as a vehicle loan, it is observed that Doğuş, Nurdan and Sema are able to perform manipulations intended for the monthly payment. Half of the students (Didem, Nurdan, Sema and Doğuş), are successful in the formulas in which =if is used on the interest policy. Didem's calculations based on this case are shown in Figure 18.

The Case study: *Mr. Aslan, who wants to take a vehicle loan of 40000 TL, comes to the bank for an interview. Help the customer to make a decision by calculating the credit expectations of the customer, taking into account the interest policies.*

Didem: *Mr. Aslan, as you see, when we increase the number of periods, both the interest rate and your monthly payments increase.*

Mr. Aslan: *:I think the amount of interest is increasing, not the monthly payments.*

Didem: Yes, I'm sorry. However, you will pay more total money out of this way.

Mr. Aslan: But the monthly payment is the most important thing for us because I need to control my budget. My payment should not exceed 2000 TL.

Didem: Then 26 months is suitable for you. But again, I recommend you to consider 23 months because the interest rate increase after 24. months. There is an excess of around 122 TL, does it force you?

Mr. Aslan: I think it would be more appropriate as well, thank you..

F11 =E11/C11

	A	B	C	D	E	F
1	***Kazanım:*** *ET üzerinde bileşik faiz uygulamaları hazırlar ve değişken değişimlerini izler.*					
2	***Yönerge 2:*** *Temsili bir müşteri ile gerçekleştireceğiniz bir örnek olay sunun.*					
3	***Örnek olay: 40000*** *tl araç kredi çekmek isteyen Fahrettin bey bankaya görüşmeye gelmiştir. faiz politikalarını dikkate alarak müşterinin kredi beklentilerini hesaplayarak karar vermesine yardımcı olunuz.*					
4						
5	**anapara**	**faiz oranı (aylık)**	**dönem sayısı**	**faiz tutarı**	**toplam**	**aylık ödeme miktarı**
6	40,000.00 ₺	%0,87	18	6,749.43 ₺	46,749.43 ₺	2,597.19 ₺
7		%0,87	19	7,156.16 ₺	47,156.16 ₺	2,481.90 ₺
8		%0,87	20	7,566.41 ₺	47,566.41 ₺	2,378.32 ₺
9		%0,87	21	7,980.24 ₺	47,980.24 ₺	2,284.77 ₺
10		%0,87	22	8,397.67 ₺	48,397.67 ₺	2,199.89 ₺
11		%0,87	23	8,818.73 ₺	48,818.73 ₺	2,122.55 ₺
12		%1	24	10,789.39 ₺	50,789.39 ₺	2,116.22 ₺
13		%1	25	11,297.28 ₺	51,297.28 ₺	2,051.89 ₺
14		%1	26	11,810.25 ₺	51,810.25 ₺	1,992.70 ₺
15		%1	27	12,328.36 ₺	52,328.36 ₺	1,938.09 ₺
16		%1	28	12,851.64 ₺	52,851.64 ₺	1,887.56 ₺
17		%1	29	13,380.16 ₺	53,380.16 ₺	1,840.70 ₺
18		%1	30	13,913.96 ₺	53,913.96 ₺	1,797.13 ₺

Figure 18. Manipulations according to costumer's wishes by Didem

Considering the interview, Didem constantly warns the customer about the interest rate although the priority of the customer is the monthly payment amount. Didem efforts to do appropriate payment plans, instead of keeping the monthly payment amount constant. Although one of the reasons is the changing after 24. months, it is seen that Didem could not formulate a constant monthly payment, 2000 TL. The researcher in the role of Mr. Aslan reminds the monthly payment does not increase. Despite that, Didem enquires whether increasing the monthly payments is affordable or not when the number of periods is shortened. In this way,

she tries to take the customer's priority towards her known calculations. Accordingly, although Didem could not keep the monthly payment constant, she could manipulate and interpret different variables such as monthly payment, interest amount and interest rate.

An overview of the process of building an instrument from spreadsheets

The processes revealed by the students for the four outcomes are analyzed throughout the research. These processes observed in the dimensions of instrumentalization and instrumentation are indicated in Table 6.

Examining Table 6, it is seen that the students do not have difficulties in the processes of instrumentalization. In general, students can create appropriate formulas for simple and compound interest calculations. However, it is seen that there are mistakes in writing =if in Task 4. It is observed that some students prefer to enter the interest rate manually instead of cell addresses. Nevertheless, dragging is accepted by the students for manipulations, it is seen that there are students to turn to use features that they feel more comfortable with, such as editing the cell address for each row, copy-pasting instead of fixing.

Table 6. Students' schemes identified on the process

		Outcomes	Akın	Ceylin	Didem	Doğuş	Hatice	Nurdan	Sema	Şengül
Instrumentalization	1.Formulating	1	√	√	√	√	x	√	√	√
		2	√	√	√	√	√	√	√	√
		3	√	√	√	√	√	√	√	√
		4	x	x	x	√	x	√	x	√
	2.Entering cell addresses	1	√	√	√	x	x	√	√	√
		2	x	√	x	x	x	√	√	√
		3	√	√	√	√	√	√	√	√
		4	√	√	√	√	√	√	√	√
	3.Formatting cells	1	√	x	√	√	x	√	√	√
		2	√	√	√	√	√	√	√	√
		3	√	√	√	√	x	√	√	√
		4	√	√	√	√	√	√	√	√
	4.Fixing	1	N	N	N	N	N	N	N	N
		2	√	x	√	√	x	√	√	x
		3	√	x	√	√	x	√	√	x
		4	√	x	√	√	x	√	√	x
	5.Dragging	1	N	N	N	N	N	N	N	N
		2	√	√	√	√	√	√	√	√
		3	√	√	√	√	x	√	√	√
		4	√	√	√	√	x	√	√	√
Instrumentation	1.Constructing algebraic structures	1	√	√	√	√	√	√	√	√
		2	√	√	√	√	x	√	√	√
		3	√	√	√	√	√	√	√	√
		4	√	√	√	√	√	√	√	√
	2.Explaining why	1	√	√	√	√	√	√	√	√
		2	√	√	√	√	√	√	√	√
		3	x	√	√	x	x	√	√	√
		4	x	√	√	√	x	√	√	√
	3.Explaining the rule or relationship	1	√	√	√	√	√	√	√	√
		2	x	x	x	x	x	x	x	x
		3	x	x	x	x	x	x	x	x
		4	x	√	√	√	x	√	√	√
		1	√	√	√	√	x	√	√	√
		2	√	√	√	√	x	√	√	√

4.Generalizing the process to many examples	3	√	√	√	√	√	√	√	√
	4	√	√	√	√	√	√	√	√
5.Finding the unknown	1	√	√	√	√	√	√	√	√
	2	√	√	√	√	x	√	√	√
	3	x	x	√	√	x	√	√	√
	4	x	x	√	x	x	√	√	√

√: Performing, x: Not performing, N: The task does not include the process

It is seen that students can construct the algebraic structure and explain their calculations based on the spreadsheets for simple and compound interest. Although they make sense to trace of constructing compound interest onto consecutive simple interest calculations in spreadsheets, they could neither establish meaningful relationships between them nor understand the changing the mathematical structures. Another prominent point in the Tasks is that students who can create formulas using the cell addresses during the formulation phase are also successful in generalizations. When students examine the effect of the variables on the calculations, few students could formula for each variable. Instead, they try multi manipulations including one more than variables for intended results.

Instrumentalization	Ceylin:	Honestly, spreadsheets are useful more than calculators, especially in multi-manipulations ..in what way? You can see them all together, it is not happening on the calculator. ...I had a hard time creating the penny (Kr). Writing the percentage made my job easier. I am getting tired of typing parentheses in the calculator.
	Şengül:	…it is easy to use spreadsheets to do more calculations.
	Nurdan:	…visuality is well. I could see all the calculations.
	Akın:	…we did a lot of calculations from simple to compound (interest). If we do this with a calculator, it would take half an hour. And we definitely make mistakes so many in the calculations.
	Sema:	Creating a currency from financial and entering a percentage (formatting cells) made the calculations readable. We could see where the money is and what the rate is. When we write in the notebook, it is confusing because I take irregular notes.
	Didem:	I entered the percentage incorrectly, but I didn't realize it until the total amount was high. If we hadn't turned the money from the financial (formatting cells), I still wouldn't know. In order to understand the calculations, we must have habits in spreadsheets, we need to know how the rules (formulas) are written. Now I feel like I have memorized the rules (formulas) a little bit.
Instrume	Hatice:	I thought that all calculations (banking transactions) were done with simple interest.

Doğuş: While reaching the compound from simple interest, I thought that the result would not be the same. I was surprised when it came out equal. If I didn't see this, I would say they were unrelated things.
…I found that (abnormal) amount but I wouldn't have understood it if you hadn't told me.
…I think that the expectation of the customer is more important than other variables. The interest rate seems to be effective, but the rate cannot be changed at will. I understand that customers pay more attention to the principal and the monthly payment.

Sema: These calculations helped me to understand the range of the real interest rates.
…In my worksheet, the effect of the rate was greater. In my opinion, the rates are asked firstly when taking out a loan which is the reason.

Ceylin: I did the dragging correctly. I have created the formulas correctly. But I don't know if the results are right or wrong.
I can decide more easily when I see all the calculations because I have done them together. Thus I can balance the interest rate and the number of periods more easily.

Nurdan: I couldn't make a full comparison of which variable is more effective. But when I tried the 1% to 10% rate, it seemed to me that the interest rate was more effective. I thought that all calculations (banking transactions) were done with simple interest.

Examining the students' explanations on the use of spreadsheets, The use of cell addresses in formulas and the ability to perform many calculations without blocking other calculations are expressed as an important convenience that increases visibility and editing. Similarly, it is stated that the dynamism in the worksheets by creating appropriate formulas based on the cell address reduces mistakes. The students stated that the worksheets created on the spreadsheets offer a readable structure if they are arranged in an accordance format.

Regarding the handling of the concept of interest in spreadsheets; the students express that they have gained awareness within the concepts of simple and compound interest. The students state that the relationship between simple and compound interest can be seen thanks to sequential calculations in spreadsheets. In addition, it is stated that abnormal numbers in the calculations can be noticed with spreadsheets features such as formatting cells, besides the current values becoming meaningful with the created formulas. Moreover, it is stated that multiple manipulations are an important factor in examining the effects of the variables handled in interest calculations so that students can process the calculations in the intended direction.

Conclusions and Suggestions

In the study, the instrumental processes in Spreadsheets for students are examined through tasks prepared for the concept of interest which is one of the topics that students have difficulty with. Instead of formula-based learning using paper-pencil, the study is designed on the tasks for a conceptual development regarding the changes in variables on spreadsheets

regarding the students' mathematics levels. Performing tasks on spreadsheets allows multiple manipulations and tracing of them. Considering the expressing the students who have done the same calculations on paper-pencil and calculator before; it can be stated that spreadsheets offer possibilities regarding the multiple calculations, it allows to see numerous calculations at the same time as well as it has more readable worksheets by formatting cells (Sugden & Miller, 2011).

In order to carry out the manipulations, the necessity of cell addresses is adopted by the students so that entering cell addresses is preferred consciously instead of manual entries. In this way, it is stated that the calculations performed by paper-pencil and calculators are dynamized in spreadsheets. However, it is observed that some mistakes using schemes in spreadsheets such as not using/misusing fixing and dragging. This issue causes some students to use the time ineffective as well as to be unable to monitor variable changes.

It is seen that students who lay themselves paths by their reasoning skills during the instrumental transformation in spreadsheets enrich their instrumentalization processes. Accordingly, instrumentalization refers to a process based on conceptual structure rather than just the use of the tool (Drier, 2001). Besides, checking the results in the monitoring of the variable changes let the students get an idea about the adjustment of the created formulas. This shows that the instrumentalization processes emerging in the study are fed by the instrumentation processes (Özdemir Erdoğan, 2016).

The results obtained indicate that the instrumentalization processes are necessary but not sufficient for the instrumentation processes. It is seen that the correct formulas and calculations in spreadsheets are not reflected in the conceptual developments of all students. The fact that a couple of students who use handle correct calculations and formulas cannot interpret the relationships between variables correctly and notice abnormal values can be expressed for this.

It is seen that the students have no difficulty in constructing the algebraic structure of simple and compound interest formulas in spreadsheets. Considering the examinations on simple and compound interest variables, it is seen that some students have difficulties in using the interest rate, similar to the literature (Chong et al., 2015). For example, when writing 0.0189 as a decimal instead of 1.89%, there are mistakes in both the number of digits and the place of use of the dot. However, it is observed that some students develop the ways using spreadsheets features such as formatting cells for the correct interest rate to provide convenience in calculations.

Students in general generally make sense of the compound interest as a result of sequential simple interest calculations. In contrast to the study of Marley-Payne & Dituri, (2019) the students can compare compound and simple interest results. it is thought that spreadsheets leads the conceptual development of the students in this direction by indicating

sequential calculations together (NCTM, 2015). The reflection of the fact that compound interest is a consequence of sequential simple interest has similarities with the literature (Abramovich, 2018; Haspekian, 2014; Park et al., 2013). In examining the effects of the variables on the results, it can be said that the students can interpret linear relationships, for example, the reflection of the increase in the principal on the interest amount and the total amount. Nevertheless, they have difficulties with non-linear exponential changes, for example, the increase in the number of periods reduces the monthly payment amounts. Moreover, the spreadsheet environment has the potential with multi-manipulations to turn into an effective tool by the students in examining and comparing the effects of the variables. Students can monitor the change of values, direct the manipulations and interpret the results by estimating through multiple manipulations and by making numerous practices in calculations (Hubbard, et al., 2016; Pournara, 2013).

The expectation from people who work in the banking and insurance market is that they can manipulate the variables used in the calculations according to customers' expectations. Regarding this, it is thought that the tasks contribute students to developing their reasoning skills. The use of current values in calculations leads to raising students' awareness of the concept of interest on calculations and interpretations of the concept. In addition, in terms of mathematics education, the use of spreadsheets as a useful learning tool to determine and examine variables in other mathematical concepts is considered important for students' conceptual development and increasing their skills in using technology.

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Research Article

Öğrencilerin Faiz Kavramı ve Hesaplarında Elektronik Tablo Kullanımlarına Enstrümantal Oluşum Açısından Bir Bakış

Özet:

Elektronik tablolar verilerin düzenlenmesi, sunulması ve gerekli hesaplamaların yapılmasında, veri gruplarında değişkenler arasındaki ilişkinin incelenmesinde sunduğu dinamik potansiyel sayesinde matematik eğitimi alanında da kullanılan ofis programlarıdır. Araştırmalar öğrencilerin faiz çeşitleri arasındaki bağlantı, faiz formüllerindeki değişkenlerin etkisinin belirlenmesinde zorluklar yaşadıklarını göstermektedir. Bu çalışmanın amacı da elektronik tablo ortamında öğrencilerin matematiksel yapısını anlamakta zorlandıkları faiz kavramının ele alındığı etkinliklerde öğrencilerin elektronik tablo kullanımlarını enstrümantal oluşum açısından incelemektir. Enstrümantal oluşum, öğrencilerin araç kullanımları ile kavramsal öğrenmeleri arasındaki etkileşimi ortaya koyan, teknolojik ortamlarda gerçekleştirilen karmaşık öğrenme süreçlerinin analizini sağlayan teorik bir yaklaşımdır. Araştırma bir devlet üniversitesinde finans matematiği dersini alan sekiz öğrenciyle gerçekleştirilmiştir. Ekran kayıtları, klinik görüşmeler ve gözlem notlarıyla elde edilen verilerin tematik analizi yapılmıştır. Araştırma sonuçları öğrencilerin elektronik tablonun ardışık işlemleri sunma potansiyeliyle basit ve bileşik faiz arasındaki ilişkiyi görebildikleri, çoklu manipülasyonlar yoluyla tahmin yöntemi üzerinden değerlerin değişimlerini yorumlayabildikleri, bu manipülasyonların gerçekleştirilebilmesinde hücre adreslerine dayalı veri girişinin gerekliliğini benimsediklerini göstermektedir.

Anahtar kelimeler: faiz, enstrümantal oluşum, elektronik tablo, enstrümantasyon, enstrümantalizasyon

Geniş Özet

Giriş

Teknoloji kullanımının öğrenmeye pozitif etkisinin oluşturulabilmesi için öğrenme ortamının uygun tasarımı ve araç ile matematiksel kavramların ilişkisinin doğru kurgulanması gerekmektedir (NCTM 2015; Van De Walle vd., 2015). Elektronik tablo (ET) verilerin tablolar halinde düzenlenmesi, kullanılması ve sunulması için tasarlanmış, öğretim ortamlarında sıkça yararlanılan bir yazılımdır. ET, hücre adresleri, hücre biçimlendirme ve formül oluşturma gibi özellikleri ile sayısal veriler arasında cebirsel ilişkilerin izlenmesinde katkısı ile muhakeme yeteneği ve uygulama becerisi kazandıran etkili bir öğrenme materyalidir (Drier, 2001; Haspekian, 2014; NCTM, 2015; Park vd., 2013). Yığılmalı bir bilim dalı olan matematikte kavramsal geçişlerin sağlanmasında, çoklu verilerin hesaplanmasında kolaylık sağladığı, dinamik veri gruplarında değişkenler arasındaki ilişkiyi ortaya çıkardığı belirtilmektedir (Abramovich, 2018; Mays, 2015).

Yüzde ve faiz hesaplamaları matematik öğretiminin çeşitli kademelerinde, öğretim programlarında yer verilen kavramlardan biridir (Paurnara, 2013; Sugden vd., 2015). Literatürde öğrencilerin faiz kavramı ve hesaplamaları ile ilgili bazı zorluklar ile karşılaştıkları görülmektedir. Yüzde, oran ve faiz çeşitlerinin birlikte ele alındığı çalışmalarda; faiz

hesaplarının karıştırılması ve anlamlı işlemler gerçekleştirilememesi (Sugden & Miller, 2011), yapılan faiz hesaplamalarının değişkenlere bağlı açıklanamaması (Bakker vd., 2006; Hoyles vd., 2010; Hubbard vd., 2016) faiz çeşitleri arasındaki ilişkinin kurulamaması ve yorumlanamaması (Pournara, 2013), basit ve bileşik faiz işlemlerinin zaman senkronizasyonunun yapılmaması (Feng & Kwan, 2015), faiz oranlarının hesaplamalarda hatalı kullanılması (Chong vd., 2015), güncel faiz parametrelerinin takip edilmemesinden kaynaklı anormal değerlerin fark edilememesi (Marley-Payne & Dituri, 2019; Sugden & Miller, 2011) bu zorlukların başlıcaları olarak ifade edilebilir.

Teorik Çerçeve: Enstrümantal Oluşum

Araştırmada ET'den yararlanılan öğretim sürecinin incelenmesi açısından enstrümantal oluşum teorisi temel alınmıştır. *Enstrümantal oluşum,* araç ile öğrenme süreci arasındaki ilişkiyi, öğrenenlerin araç kullanımında geliştirdikleri teknikleri ve kavramsal gelişimlerini inceler (Trouche, 2004). Enstrümantal oluşum *enstrümantalizasyon ve enstrümantasyon olmak üzere iki* boyut üzerinden ele alınır. *Enstrümantalizasyon,* kullanıcıların aracı kişiselleştirerek çözüme götüren zihinsel yollar belirlemeleri iken, *enstrümantasyon,* bu yolların matematiksel altyapılarını ve bunun enstrüman oluşumu ile ilişkisinin ele alınmasıdır (Trouche, 2018). *Enstrümantasyon* öğrenenlerin görev-araç ilişkisi üzerinden geliştirdikleri, matematiksel bir gelişimin ötesinde enstrümantalizasyon ile birlikte değerlendirilmesi gereken hibrid bir süreçtir (Trouche, 2018).

Bankacılık ve finans bölümü öğrencilerine işe başlama yıllarında istihdam edildikleri şirketler tarafından çalışma süreçlerini modelleyen hizmet içi eğitimler verilmektedir. Bunun en önemli sebebi olarak öğrencilerin alan üzerinde yeterliklerinin geliştirilmesi gerekliliği dile getirilmektedir (Güvenç & Yücebalkan, 2017). Yüzde ve faiz hesaplamaları bölüm öğrencilerinin sık kullandıkları kavramlardandır. Bankacılık sektörünün ürün yelpazesinde sunulan faiz türevleri, vade oranları, kredi hesaplamaları gibi birçok işlem bu kavramlarla ilişkilidir. Sektör çalışanlarında ilgili hesaplamalarını doğru yapmalarının yanında, bu hesaplamaları müşteri isteğine göre tasarlamak ve zaman, oran, sermaye gibi farklı değişkenlerin manipülasyonunda ortaya çıkabilecek değişimleri önceden sezmek, yorumlamak, bu durumu uygun şekilde izah etmek, kurum-müşteri beklentilerini optimum seviyede karşılamak gibi becerilere ağırlık verilmektedir.

Çalışmanın amacı

Bu çalışmanın amacı faiz işlemlerini ele almak için tasarlanan bir öğrenme ortamında öğrencilerin ET kullanımlarının enstrümantal oluşum açısından incelenmesidir. Bu kapsamda aşağıdaki araştırma sorularına cevap aranmaktadır:

1. Öğrencilerin faiz işlemlerinde ET fonksiyon ve özelliklerini kullanımları nasıldır?
2. ET kullanımının öğrencilerin faiz kavramı gelişimine katkısı nedir?

Yöntem

Bu çalışmada nitel araştırma yaklaşımlarından biri olan durum çalışması yöntemi benimsenmiştir. Durum çalışması, bir durumu, dersi veya bir etkinliği ayrıntılı olarak inceleyerek neden ve nasıl sorularına cevap veren bir yöntemdir (Yıldırım & Şimşek, 2008). Durum çalışması, sonuçlardan ziyade süreçle, gerçekleri doğrulamak yerine vakanın bağlamıyla ve keşfetmekle ilgilenir (Merriam & Grenier, 2019). Öğrencilerin ET'yi bir araçtan enstrümana dönüştürme süreçlerinin incelenmesi amaçlandığından çalışmada durum çalışması yöntemi kullanılmıştır.

Katılımcılar: Araştırma, Batı Akdeniz'de bulunan bir devlet üniversitesinde önlisans düzeyinde Bankacılık ve Finans bölümünde 1. Sınıf finans matematiği dersini alan 89 öğrenci arasından 8 kişilik bir çalışma grubu ile gerçekleştirilmiştir. Araştırmada bilişsel düzey ve cinsiyet dağılımı dikkate alınarak çevreyi yansıtmak için uygun örnekleme yöntemi kullanılmıştır (Lehner, 1992). Çalışmaya katılım gönüllülük esasına dayalı olarak yapılmıştır. Öğrenciler mesleki dersleri kapsamında bir ofis programı olarak elektronik tabloyu tanımakla birlikte finans matematiği dersi kapsamında ilk kez kullanmışlardır.

Veri toplama araçları: Araştırmada ET ortamında dört etkinlik yapılmış, gerçekleştirilen etkinliklerin ürünleri ile öğrencilerin süreç içerisindeki becerileri ve düşüncelerini ortaya koyacak dokümanlar elde edilmeye çalışılmıştır (Merriam & Grenier, 2019). Araştırmanın veri toplama araçları; (1) öğrencilerin etkinliklerine dair ekran kayıtları, (2) klinik görüşmelerin ses kayıtları ve (3) araştırmacının tuttuğu gözlem notlarıdır. Birden fazla veri toplama aracı kullanarak araştırmanın verilerine dair geçerlilik güvenirliğinin artırılması hedeflenmiştir (Yıldırım & Şimşek, 2008).

Araştırma Süreci: Etkinlikler elektronik tablo ortamında finans matematiği dersi kapsamında kurum tarafından belirlenmiş ders içeriklerinde yer alan kazanımlar ile birlikte literatürde ifade edilmiş becerileri de dikkate alarak hazırlanmıştır (Hoyles, 2018; Paunara, 2013). Buna göre

etkinlikler dört temel kazanım üzerine inşa edilmiş ve her bir kazanım için öğrencilere bir yönerge sunulmuştur.

Kazanımlar : (K1). Basit faiz ve bileşik faiz hesaplamalarını kâğıt kalemle, hesap makinasında ve ET üzerinde yapabilir, (K2). Basit faizden bileşik faize geçişleri sağlayabilir, (K3). Bileşik faiz değişkenlerini yorumlayabilir, (K4). ET üzerinde bileşik faiz uygulamaları hazırlar ve değişken değişimlerini izleyebilir.

Öğrenciler aynı donanımlara sahip bilgisayarlar üzerinde Excel 2013 kullanarak bu etkinlikleri gerçekleştirmiştir. Beş haftalık uygulama süreci her hafta 45'er dakikadan iki seans şeklinde düzenlenmiştir.

Verilerin analizi: Çalışmada ekran kayıtları, klinik görüşmeler ve gözlem notlarından elde edilen veriler için tematik analiz yapılmıştır. Araştırmanın tematik analizi, enstrümantal oluşum yaklaşımının boyutları olan enstrümantalizasyon ve enstrümantasyona göre iki bölümde ele alınmıştır. Temalar elektronik tabloların işlevleri ve özellikleri açısından, Ainley vd. (2005 çalışmasından alınmıştır (Ainley vd., 2005). Bu analiz temaları, katılımcıların enstrümantal oluşum yaklaşımı çerçevesinde tanımlanan şemalarını ortaya koymaktadır. Elde edilen temalara göre analizler araştırmacılar tarafından birlikte yapılmıştır. Gerektiğinde ses kayıtları ve ekran görüntüleri yeniden incelenmiş, araştırmacılar tarafından alınan notlarla karşılaştırılarak verilerin birbirini destekleyip desteklemediği kontrol edilmiş ve veri kaybı minimumda tutulmaya çalışılmıştır.

Enstrümantalizasyon Süreçleri

1. Formül oluşturma: -Hücre adreslerini kullanarak formül oluşturur, fonksiyon girişlerini doğru hücrelerden gerçekleştirir.
2. Hücre adresi kullanımı: -Hücrelerin ve hesaplamaların dinamikliğini sağlar.
3. Hücre biçimlendirme: -Para birimi vb. düzenlemelerle okunabilir bir sayfa hazırlar.
4. Sabitleme: -Sürüklemeler için gerekli yerlerde sabit ($) kullanır.
5. Sürükleme: -Verilen sayıların örüntüsüne uygun, formüllere dayalı sürükleme özelliğini kullanır, manuel girişleri kullanmaz, çoklu manipülasyonda sürüklemeyi kullanır. Bu özelliğin amacının minimum manuel giriş ile maximum işlem hacmini amaçladığını fark eder.

Enstrümantasyon Süreçleri

1. Cebirsel yapıyı inşa edebilme: -Formül oluşturarak basit ve bileşik faiz işlemlerini gerçekleştirir.
2. Nasıl yaptığını açıklayabilme: -Oluşturulan formülleri ve ET özelliklerini matematiksel altyapıya uygun şeklide açıklar.
3. Kuralı ya da ilişkiyi açıklayabilme: -Faiz işlemleri ve sonuçları arasındaki ilişkiyi açıklayabilir, faiz değişkenlerinin sonuçlara etkisini açıklayabilir, faiz değişkenlerine göre sonuçları tahmin edebilir, faiz değişkenlerini istenen sonuçlara göre manipüle edebilir.
4. Yapılan işlemi farklı örneklere genelleyebilme: -ET üzerinde kurduğu sistem üzerinden manipülasyonlar gerçekleştirebilir.
5. Bilinmeyeni bulabilme: -Basit ve bileşik faiz değişkenlerine dair sonuçlara ulaşabilir.

Bulgular

Öğrencilerin araştırmaya konu edilen dört kazanım için ortaya koyduğu beceriler araştırma boyunca analiz edilmiştir. Bulgularda, öğrencilerin enstrümantalizasyon süreçlerinde zorlanmadıkları görülmektedir. Öğrenciler genel olarak basit ve bileşik faiz işlemleri için uygun formülleri oluşturabilmiştir. Ancak Etkinlik 4'te *=Eğer (if)* kodunu yazmada hatalar oluştuğu görülmektedir. Hücre adresine dayalı giriş yapmak yerine bazı öğrencilerin faiz oranını manuel girmeyi tercih ettikleri gözlenmiştir. Sürükleme, manipülasyonlar için öğrencilerden kabul görürken, bazı öğrencilerin hücre sabitleme yerine her satır için hücre adresini düzenleme ya da kopyala-yapıştır gibi kendilerini daha rahat hissettikleri kullanımlara yöneldiği görülmektedir.

Öğrencilerin basit ve bileşik faiz için ET ortamına dayalı olarak cebirsel yapıyı inşa edebildikleri ve yaptıkları işlemi açıklayabildikleri görülmektedir. Bileşik faizin ardışık basit faizlerden oluşmasına dair ET üzerinde geliştirilen izleme anlamlı gelse de iki faiz formülü arasındaki matematiksel yapı değişikliğinin ve ilişkisinin açıklanamadığı görülmektedir. Etkinliklerde öne çıkan diğer bir nokta ise formülleştirme aşamasında hücre adresini kullanarak formül oluşturabilen öğrencilerin genellemelerde de başarılı olduğu yönündedir. Faiz işlemlerinde değişkenlerin değerleri bulunurken o değişkene özgü bir formül oluşturabilme becerisi sınırlı kalmış, daha çok çoklu manipülasyonlar yoluyla deneyerek istenilen sonuca ulaşıldığı gözlenmiştir.

Öğrencilerin faiz işlemleri için ET kullanımına yönelik açıklamaları incelendiğinde; formüllerde hücre adresi kullanımı ve çok sayıda hesaplamanın diğer hesaplamaları engellemeden yapılabilmesi, görülebilirliği ve düzenlenebilirliği artıran önemli bir kolaylık

olarak ifade edilmektedir. Buna paralel olarak ET üzerinde hücre adresine dayalı uygun formül oluşturularak hazırlanacak sayfalarda oluşan dinamikliğin hata riskini azalttığı dile getirilmiştir. Öğrenciler açıklamalarında, ET üzerinde oluşturulan çalışma sayfalarının konunun formatına uygun düzenlemesi halinde okunabilir bir yapı sunduğunu ifade etmişlerdir.

Faiz konusunun ET'de ele alınmasına yönelik yapılan değerlendirmelerde ise; öğrenciler basit ve bileşik faiz kavramları çerçevesinde farkındalık kazandıklarını dile getirmektedir. Öğrenciler basit ve bileşik faiz işlemleri arasındaki ilişkinin ET'de yürütülen ardışık işlemler sayesinde görülebildiğini ifade etmişlerdir. Bununla birlikte hesaplamalarda ortaya çıkan anormal değerlerin hücre biçimlendirme gibi ET özellikleri ile fark edilebildiği, güncel değerlerin oluşturulan formüllerle anlamlı hale geldiği dile getirilmiştir. Diğer taraftan faiz işlemlerinde ele alınan değişkenlerin etkilerinin incelenmesinde çoklu manipülasyonun önemli bir faktör olduğu, bu sayede istenilen yönde hesaplamaların yapılabilirliği çalışmanın öğrencilere kazandırdığı bir beceri olarak ifade edilmiştir.

Sonuç ve Tartışma

Bu çalışmada öğrencilerin zorlandıkları konulardan biri olan faiz işlemleri ile ilgili olarak hazırlanan etkinlikler aracılığıyla ET'nin öğrenciler için enstrümantal dönüşümü incelenmiştir. Hazırlanan etkinlikler formüle dayalı bir öğrenme yerine, öğrencilerin matematik düzeyleri de dikkate alınarak, değişken değişimlerinin ET üzerinde izlenmesine dayanan bir kavramsal gelişime zemin hazırlamıştır. Etkinliklerin ET üzerinde gerçekleştirilmesi öğrencilerin çoklu manipülasyonlarına imkan vermektedir. Araştırmada ET'nin çoklu hesaplamalar yapma açısından sunduğu imkanların dile getirildiği; ET'nin yapılan işlemleri aynı anda görülebilir kıldığı ve hücre biçimlendirme ve çalışma sayfası formatı yoluyla okunabilir bir yapı sunduğuna vurgu yapıldığı görülmektedir. Bu manipülasyonların gerçekleştirilebilmesinde hücre adreslerine dayalı veri girişinin gerekliliği öğrenciler tarafından benimsenmiş, sayısal veri girişleri yerine hücre adresine dayalı veri girişleri bilinçli şekilde tercih edilmiştir. Bu sayede gerçekleştirilen işlemlerin ET ortamında dinamikleştirildiği ifade edilmiştir. Bununla birlikte öğrencilerin ET kullanım şemalarındaki farklılıkların çoklu manipülasyonların sürdürülmesinde sorunlar oluşturduğu görülmüştür. Bu durumun bazı öğrencilerin, zaman ve işlem tasarrufu yapamamalarına, değişken değişimleri izleyememelerine neden olduğu gözlenmiştir. ET'nin enstrümantal dönüşüm sırasında muhakeme becerilerini kullanan öğrencilerin ise ortaya koyduğu alternatif çözüm yolları ile enstrümantalizasyon süreçlerini zenginleştirdiği görülmektir. Buna göre enstrümantalizasyon salt aracın kullanımından ziyade kavramsal temellere dayalı bir süreci ifade etmektedir (Drier, 2001). Buna benzer şeklide,

değişken değişimlerinin izlenmesinde değişkenlerin sonuçlarının kontrol edilmesi, oluşturulan formüllerin doğruluğu hakkında da öğrencilere fikir vermiştir. Bu durum çalışmada ortaya çıkan enstrümantalizasyon süreçlerinin enstrümantasyon süreçlerinden beslendiğini göstermektedir (Özdemir Erdoğan, 2016).

Enstrümantasyon süreci için de enstrümantalizasyon sürecinin gerçekleşmesinin gerekli ama yeterli olmadığını gösteren sonuçlara da ulaşılmıştır. ET'de doğru formül ve işlemlerin tüm öğrencilerin kavramsal gelişimine yansımadığı görülmektedir. Doğru işlem ve formül kullanan bazı öğrencilerin değişkenler arasındaki ilişkileri doğru yorumlayamaması ve anormal değerleri fark edememeleri buna dayanak olarak ifade edilebilir.

Araştırmada öğrencilerin ET üzerinde basit ve bileşik faiz formüllerinin cebirsel yapısını inşa etmede zorlanmadıkları görülmektedir. Basit ve bileşik faiz değişkenlerine yönelik incelemeler dikkate alındığında ise bazı öğrencilerin literatüre benzer şekilde faiz oranını kullanmakta zorlandıkları görülmektedir (Chong vd., 2015). Bununla birlikte bazı öğrencilerin faiz oranının doğru kullanımı için hücre biçimlendirme gibi ET özeliklerini kullanarak geliştirdikleri yolların hesaplamalarda kolaylık sağladığı görülmüştür.

Öğrenciler genel olarak ardışık basit faiz işlemlerinin bir sonucu olarak bileşik faiz sonuçlarını değerlendirebilmektedir. Yine bileşik faiz sonuçları ile basit faiz sonuçları Marley-Payne & Dituri, (2019) çalışmasının aksine karşılaştırılabilmektedir. ET ardışık işlemleri birlikte gösterebilme özelliği ile öğrencilerin bu yöndeki kavramsal gelişimlerinde rol oynamıştır (NCTM, 2015). ET üzerinde sunulan bileşik faizin ardışık basit faiz işlemlerinden oluşmasına yönelik sürecin kavramlar arası geçişlere yol açması bu yöndeki literatür ile benzerlikler taşımaktadır (Abramovich, 2018; Haspekian, 2014; Park vd., 2013). Değişkenlerin sonuçlara etkisinin incelenmesinde öğrencilerin doğrusal ilişkileri yorumlamakta, örneğin anapara artışının faiz miktarı ve toplam tutara yansıması, zorlanmadıkları ancak doğrusal olmayan üstel değişimleri, örneğin dönem sayısının artmasının aylık ödeme tutarlarını azaltması, yorumlamakta zorlandıkları ve anlamlandıramadıkları gözlenmektedir. Bununla birlikte değişkenlerin etkisinin incelenmesinde ve karşılaştırılmasında öğrenciler tarafından ET'nin çoklu manipülasyon potansiyeli etkin bir araca dönüştürülmüştür (Sugden & Miller, 2011). Öğrenciler çoklu manipülasyonlar yoluyla ve hesaplamalarda çok sayıda denemenin yapılmasıyla tahmin yöntemi üzerinden değerlerin değişimini izleyebilmekte, manipülasyonları yönlendirebilmekte ve sonuçları yorumlayabilmektedir (Hubbard vd., 2016; Pournara, 2013).

Bankacılık ve sigortacılık sektöründe çalışanlardan beklenti, hesaplamada kullanılan değişkenlerin müşteri beklentilerine göre manipüle edilebilmesidir. Bu itibarla etkinliklerde yer verilen görevlerin öğrencilerin bu yöndeki gelişimlerine katkı sunduğu düşünülmektedir. Yapılan işlemlerde güncel değerlerin kullanılması faiz kavramı, hesaplamaları ve yorumlamalarına dönük öğrencilere bilinç kazandırırken kurumsal beklentileri de karşılamaya dönük önemli bir adım olarak görülmektedir.

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Research Article

Thematic Analysis of Postgraduate Theses on Mathematics Literacy in the Field of Mathematics Education in Turkey

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Abstract – The aim of this study is to reveal the characteristics of the postgraduate thesis on the subject of mathematical literacy in Turkey according to various criteria. The criteria examined in line with the purpose of the study; The type and publication year of the postgraduate theses, the university in which it was made, its subject, keywords, sample type and sample numbers, research method and research design, data collection tools, main results and main suggestions were determined. Thematic analysis, one of the qualitative research approaches, was used in the study. The sample of the research consists of 74 postgraduate theses on mathematical literacy in the field of education registered on the official website of the National Theses Center of the Council of Higher Education between 2003-2020. This study differs from other articles and theses on the examination of postgraduate theses on mathematical literacy in terms of the variety of the criteria discussed.

Key words: Mathematical literacy, thematic analysis, mathematics education, postgraduate thesis

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Introduction

The concept of literacy in PISA; is defined as students using their knowledge in daily life, making logical inferences, interpreting problems related to various situations and making inferences from what they have learned to solve (EARGED, 2010). The international student assessment program PISA focuses on the use of learned mathematics in our lives. The part of

PISA that is related to mathematics is called mathematical literacy (Altun et al., 2018). Mathematical Literacy (ML) is defined as one's capacity to use the steps of formulating, applying and interpreting mathematics in various situations we encounter in our lives (Organisation for Economic Co-Operation and Development [OECD], 2016). Real context problems in mathematics are handled according to the competencies, which are the dimensions of constructing (formulating) mathematical problems, solving (executing) mathematical problems with mathematical knowledge, operations and reasoning, and deciding (interpretation/evaluation) that the result is suitable for real life (OECD, 2013). ML has come to the fore as the disconnect between school mathematics and life has increased, and its aim is to integrate knowledge with skill and to enable it to be used (Altun, 2020).

Considering the relationship between ML and school mathematics, it was necessary to examine the ML achievement reported in the Ministry of National Education (MoNE) resources. Our country participated in PISA exams for the first time in 2003. Looking at the success ranking by country in the PISA evaluation, it is seen that Turkey's ML success ranking is in the lower ranks. According to the results of the PISA 2015 application, Turkey ranks 50th among 72 countries with an average score of 420 in terms of mathematics achievement. In 2015, the rate of students in the lower level increased in Turkey, while the ratio of students in the upper level decreased (MoNE, 2016). Turkey ranks 42nd among 79 countries with an average score of 454 in the PISA 2018 survey. The fact that the average mathematics score, which was calculated as 420 in PISA 2015 application, increased to 454 in 2018 is an indication that Turkey has increased its performance (MoNE, 2019). However, although it has increased, it can be said that this ranking is not sufficient.

These results show that studies need to be increased so that mathematics education in Turkey can reach a better point. In particular, identifying and developing problems can be realized with more comprehensive and in-depth studies in mathematics education. Increasing the number of studies examining the tendencies and orientations of theses in the field of mathematics education in the literature is important in terms of directing new studies. In the literature, there are studies to determine the tendencies of postgraduate theses on different subjects in mathematics education in Turkey. Such as; mathematics curriculum (Yenilmez & Sölpük, 2014), model and modeling (Karagöz & Şahin Çakır, 2021; Yıldız & Yenilmez, 2019), problem posing and solving (Geçici & Türnüklü, 2020; Coşkun & Soylu, 2021), experimental design (Er, 2019; Er & Biber, 2020), geogebra (Şimşek & Yaşar, 2019), misconceptions in geometry (Köprücü, 2020), spatial ability (İpekoğlu et al., 2020), math anxiety (Toptaş & Gözel, 2018), computer aided mathematics teaching applications (Tabuk, 2019), mathematics

textbooks (Dede & Arslan, 2019), origami (Kara & Bayraktar Kurt, 2021), literacy in the field of education (Oğuz Hacat & Demir, 2019), mathematics education (Sevencan , 2019; Tereci & Bindak, 2019), realistic mathematics education (Doğan & Kurt, 2019), preschool mathematics education (Yıldız Altan et al., 2021) and primary school mathematics education (Özsoy et al, 2017; Can, 2020) orientations of the postgraduate theses on the subject were examined. Two studies were found in which theses on mathematical literacy were examined. Kanbolat and Balta, (2020) examines the orientation of postgraduate theses on ML in terms of type, year, title of advisor, research approach, sample group, and the university in which it was made. Postgraduate theses on mathematical literacy studied between 2008 and 2019 were examined in terms of the university, years and type, sample characteristics, targeted purposes, methods used and data collection tools by Arı and Demir (2020). In the study, 66 (51 master's and 15 PhD theses) postgraduate theses were discussed.

In terms of Turkey's better ranking in PISA assessments, it is thought that determining the orientations of postgraduate theses on ML in detail will contribute to the literature and guide the researchers who will work in this field. This study differs from other articles and theses (Fırat, 2019; Arı & Demir, 2020; Kanbolat & Balta, 2020; Kozaklı-Ülger et al., 2020) on the examination of studies on ML in terms of the variety of criteria discussed. The current study includes postgraduate theses on ML; types, publication years, universities, subjects, keywords, sample types, number of sample, methods, distribution of methods and research designs by years, data collection tools, results and suggestions.

The aim of this research is to reveal the characteristics of the postgraduate thesis on the subject of ML in Turkey according to various criteria. The criteria determined in line with the purpose of the study are as follows.;

1) Type and publication year of the postgraduate theses,
2) The university where the postgraduate theses was made,
3) The subject of the postgraduate theses,
4) Keywords of the postgraduate theses,
5) The sample type and sample size of the postgraduate theses,
6) Research method and research design of the postgraduate theses,
7) Data collection tools of the postgraduate theses,
8) The main results of the postgraduate theses,
9) The main suggestions of the postgraduate theses.

Method

Research Design

In the study, qualitative research method was preferred since it was aimed to reveal the characteristics of the postgraduate theses on the subject of ML according to various criteria. Creswell (2012) defines qualitative research as a process of making sense of social life and human problems by questioning them with their own unique methods. In qualitative research, the researcher reads, codes and categorizes the data one by one. This reveals the results of the research based on the codes and categories it has obtained (Merriam, 2009).

In the research, the thematic analysis was carried out within the framework of the qualitative research approach, and the theses were examined and tried to be described within the framework of certain criteria. Thematic analysis includes studies focusing on the same subjects, examining, synthesizing and interpreting within the framework of certain themes or templates. It constitutes a rich source of reference for researchers, practitioners and policy makers in terms of revealing the common and similar aspects of studies that deal with a particular issue from different dimensions (Çalık, et al., 2005; Gül & Sözbilir, 2015).

Data Collection Process

The documents to be included in the research were obtained by the researchers from the database of the National Theses Center of the Council of Higher Education between April 2020 and November 2020. During the search in the database, the terms "mathematical literacy" were used in Turkish and English, including all possible situations, including all situations where the term literacy was written adjacent and separately in Turkish. The theses made in the field of ML and which are open to use are as full text; the theses, which are closed to usage permission, were evaluated by using the summary text. Since the first postgraduate theses on the subject of ML was reached in 2003, the theses prepared from 2003 to the present were discussed. 74 postgraduate theses prepared within the framework of ML between the years 2003-2020 were included in the scope of this study and examined. Of these 74 postgraduate theses, 58 are master's thesis and 16 are PhD thesis.

Data Analysis

Descriptive analysis was used in the analysis of the data obtained in this study. In descriptive analysis, the collected data is explained and interpreted in a systematic and clear way within the framework of predetermined themes. Descriptive analysis takes place in four stages (Yıldırım & Şimşek, 2016). Creating a framework for descriptive analysis, 2. Processing the data according to the thematic framework, 3. Defining the findings, 4. Interpreting the findings.

In this direction, the data of the study were organized under a total of nine themes: "type and publication year of the postgraduate theses, the university, its subject, keywords, sample type and sample size, research method and research design, data collection tools, main results and main suggestions". The documents obtained were evaluated according to the determined criteria. Frequency (f) and percentage (%) values are shown by creating tables in a systematic and clear way. The analysis of the data was completed by interpreting the identified findings.

The data obtained from a total of 74 postgraduate these included in the analysis were analyzed using descriptive analysis and content analysis methods. General information, expressed as general features, was subjected to descriptive analysis, and content features were subjected to content analysis. Descriptive analysis, percentages and frequencies of data; content analysis, on the other hand, involves coding the data first and then combining them under appropriate themes. In the final stage, frequencies and percentages were calculated for each analysis result.

The data obtained from a total of 74 postgraduate thesis included in the analysis were analyzed using descriptive analysis and content analysis methods. While information for general characteristics is given in the form of percentages and frequencies of the data as descriptive analysis; content analysis was used for data that were coded and placed in appropriate themes. Frequencies (f) and percentages (%) for each analysis result are calculated and presented in tables.

Findings and Discussions

In the findings section, theses related to ML; type and publication year, university, the subject of the theses, keywords, sample type and sample size, research method and design, data collection tools, main results and suggestions are listed in tables.

Findings Concerning the Types and Publication Years of Postgraduate Theses

The findings regarding the distribution of the theses examined according to the postgraduate level and years are given in Table 1. When the findings were examined, it was found that the number of studies conducted at the master's level was higher than PhD thesis published on ML.

Table 1. Frequencies of Postgraduate Theses According to Types

Theses Type	**f**	**%**
Master Thesis	58	78,3
PhD Thesis	16	21,7
Total	74	100

When Table 2 is examined, it can be said that postgraduate theses related to ML have been prepared since 2003. In 2004, 2005, 2007 and 2010, there was no theses about ML.

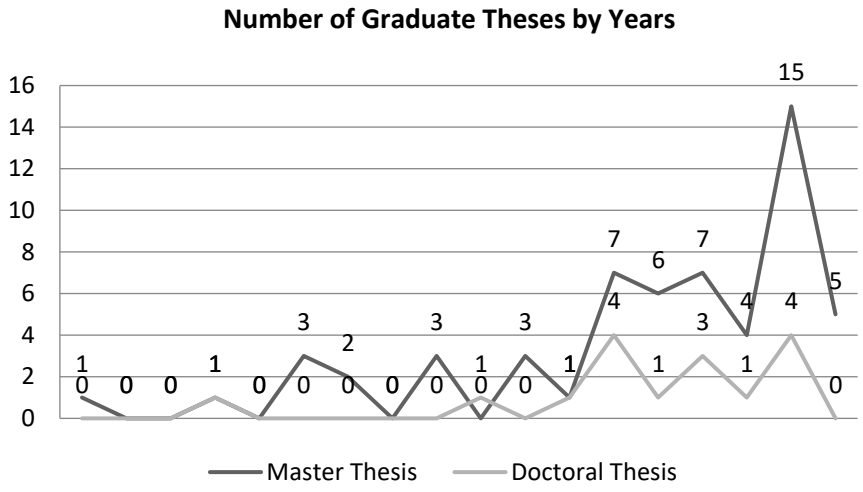
Table 2. Distribution of Postgraduate Theses in Terms of Types by Years

Theses Type	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Master Thesis	1	-	-	1	-	3	2	-	3	-	3	1	7	6	7	4	15	5	58
PhD Thesis	-	-	-	1	-	-	-	-	-	1	-	1	4	1	3	1	4	-	16
Total	1	-	-	2	-	3	2	-	3	1	3	2	11	7	10	5	19	5	74

Except for the years 2004, 2005, 2007, 2010 and 2012, master's thesis on ML was prepared every year. The number of master's theses increased in 2015 and after the following two years showed the same course, there was a decrease in 2018 and in 2019, the number of master's theses on ML reached the highest point. In addition, most of the theses prepared on ML are master's theses.

There are almost no PhD thesis written between 2003 and 2013 (only one was written in 2006 and 2012). In recent years, it is seen that PhD thesis have been prepared regularly. Until the last month of the research survey, there is no PhD thesis in the field of ML in 2020. Graph 1 shows the distribution of postgraduate theses prepared on ML in terms of their types by years.

Graph 1. Distribution of Theses Prepared Regarding ML by Types by Years



Findings Regarding the Universities where Postgraduate Theses were Made

The frequencies of the universities in which the theses on ML were published are given in Table 3.

Table 3. Distribution of Theses Prepared on ML by Universities

University	Master Theses (f)	PhD Theses (f)	Total
Ankara University	2	3	5
Balikesir University	5	2	7
Bilkent University	4	-	4
Cukurova University	3	-	3
Erzincan University	3	-	3
Eskisehir Anadolu University	-	4	4
Eskisehir Osmangazi University	4	-	4
Firat University	3	-	3
Orta Dogu Teknik University	2	2	4
Uludag University	7	2	9
Total	33	13	46

While showing the distribution of universities, those with a frequency of 3 and above are included in the table. It can be seen from Table 3 that the highest number of PhD theses were made in Eskişehir Anadolu University, and the highest number of master's theses were made in Bursa Uludağ University. Looking at the total column in the table, it is seen that the highest number of postgraduate theses related to ML were made in Uludağ University. Balıkesir University and Ankara University follow it.

Thematic Findings of the Subjects of Postgraduate Theses

The thematic distribution of the subjects of the theses on ML is shown in Table 4. The data in this section are generally the information obtained from the title, problems and sub-problems of the research.

Table 4. Thematic Distribution of the Subjects of the Theses on ML

Theme	f	%
Visual ML	7	6,3
ML Success	8	7,3
ML Education	9	8,2
Factors Affecting ML	15	13,6
Examining Different Subjects with ML	17	15,4
ML Self-Efficacy	10	9,0
ML Attitude	5	4,6
ML and Computer Communication Technologies	3	2,8
ML and Mathematical Modeling	3	2,8
ML and PISA	25	22,7
ML and Problem Solving	8	7,3
Total	110	100

According to Table 4, the themes most focused on by the subjects of ML theses are "Mathematics Literacy and PISA" and " Examining Different Subjects with ML". It is seen that the other themes on which the subjects of the prepared theses are most focused on are "Factors Affecting ML" and “ML Self-Efficacy”. In addition to these, there are 7 different themes identified in the subjects of theses written on ML.

Findings on Keywords of Postgraduate Theses

The keywords of the theses were considered important in terms of the emergence of the concepts associated with ML. Their thematic distribution is shown in Table 5.

Table 5. Distribution of Theses Prepared on ML by Keywords

Keywords	f	%
Thinking Styles-Paths	3	2,5
Visual ML	5	4,1
Mathematics Achievement	3	2,5
Mathematics Education	10	8,3
Mathematics Literacy	48	39,7
Mathematical Literacy	4	3,3
Mathematical Modeling	3	2,5
Motivation	3	2,5
Literacy	6	4,9
Self-Efficacy Perception	4	3,3
PISA	23	19,0
PISA 2012	5	4,1
Problem Solving	4	3,3
Total	121	100

While the frequency of use of keywords is shown, those with a frequency of 3 and above are included in the table. Looking at the table, the keywords of "Mathematics Literacy" is included in more than half of the ML theses. The second keywords in terms of frequency of use was “PISA”. The third place is the concept of “Mathematics Education”.

Findings Regarding the Sample Type and Sample Size of Postgraduate Theses

The distribution of theses related to ML included in the research according to sample types is presented in Table 6.

Table 6. Distribution of Theses Prepared on ML by Sample types

Sample Types		Master Theses (f)	PhD Theses (f)	Total
Primary student	Primary School-4	1	-	1
Middle school student	Middle School-6	5	-	5
	Middle School-7	6	-	6
	Middle School-8	9	3	12
	Middle School	2	1	4
High school student		4	2	6
Undergraduate student	Pre-service primary school mathematics teacher	3	-	3
	Pre-service mathematics teacher	-	1	1
	Pre-service classroom teachers	2	-	2
	Other	2	2	4
Teachers		-	1	1
PISA Participants		15	5	20
Other	Adult	2	-	2
	No Sample	6	1	7
	Teacher + Student	1	-	-
Total		58	16	74

When Table 6 is examined, it is seen that researches on ML are conducted according to different sample groups. The researches were mostly carried out with middle school students. This is followed by research with PISA participants and undergraduate students. It is noteworthy that very few studies have been conducted with primary school students, adults and teachers. The distribution of the theses prepared on ML according to the sample size is shown in Table 7.

Table 7. Distribution of Theses Prepared on ML by Sample Size

Sample Size	Master Theses (f)	PhD Theses (f)	Total
Sample size not specified	5	4	9
No Sample	6	1	7
1-40	9	4	12
41-100	9	1	10
101-200	5	-	5
201-500	11	4	15
500 and over	13	2	7
Total	58	16	74

It was seen that most of the master's theses prepared according to Table 7 were carried out with sample groups of more than 500. In addition, the sample size was not specified and studies without a sample were also conducted. In doctoral dissertations, on the other hand, it was mostly studied with sample groups between 1 and 40, between 201 and 500, and with sample groups whose sample size was not specified.

Findings Concerning the Research Method and Design of Postgraduate Theses

The distributions of the theses on ML according to the research method are given in Table 8 under four title.

Table 8. Distribution of Theses Prepared on ML by Research Methods

Research Methods	Master Theses (f)	PhD Theses (f)	Total
Quantitative Research Method	23	6	29
Qualitative Research Method	13	6	19
Mixed Research Method	21	4	25
Nested Patterns from Mixed Method Studies	1	-	1
Total	58	16	74

ML theses were conducted using the "quantitative research method" at most. It is the "Mixed Research Method" following the "quantitative research method" as frequency. It is seen that the difference between "quantitative research method" and "mixed research method" is very small compared to the number of postgraduate theses. Looking at the table specifically for master's theses, it is seen that "quantitative research method" is used the most. In the master's theses, there is one theses in which the "nested mixed method" is used, which is not included in the quantitative, qualitative and mixed research method. Looking at the doctoral theses, it is seen that quantitative and qualitative research methods are equal in number (6 each).

The distribution of research methods of theses by years is given in Table 9.

Table 9. Distribution of Research Methods of Theses on by Years

Research Methods	2003	2006	2008	2009	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Quantitative Research Method	1	2	2	1	2	1	1	-	5	2	5	1	4	2	29
Qualitative Research Method	-	-	1	1	-	-	-	1	2	2	2	2	5	3	19
Mixed Research Method	-	-	-	-	1	-	2	1	4	3	3	1	10	-	25
Nested Patterns from Mixed Method Studies	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1
Total	1	2	3	2	3	1	3	2	11	7	10	5	19	5	74

Looking at Table 9, it is seen that the "quantitative research method" has been used since 2003. However, since there is no significant difference in the frequency of use compared to

years, there is a stability. “qualitative research method” has been used since 2008. While the frequency of use of the method is in the same line, an increase is observed in the frequency of use in 2019. “mixed research method” was used for the first time in 2011 in ML postgraduate theses. It is seen that the "mixed research method" has started to be used in ML theses mostly in recent years. The frequency of use of the "mixed research method" increased significantly in 2019.

The distribution of theses on ML according to the research design is given in Table 10.

Table 10. Distribution of Theses Prepared on ML by Research Design

Research Design	Master Theses (f)	PhD Theses (f)	Total
Descriptive Design	1	-	1
Descriptive Research	3	-	3
Descriptive Content Analysis	1	-	1
Descriptive Survey Model	1	-	1
Experimental Design	7	1	8
Document Analysis	4	-	4
Case Study	4	-	4
Action Research Design	2	-	2
Nested Mixed Design	1	1	2
Relational Research Model	2	-	2
Relational Survey Model	9	4	13
Causal Comparative Research	2	-	2
Descriptive Design of the Mixed Method	2	-	2
Exploratory Case Study Design	-	1	1
(Predictive) Correlational Research	3	1	4
Causal Comparative Research Design	1	-	1
Teaching Experiment Design	-	3	3
Segmentation Model	1	-	1
Survey Design	8	3	11
Semi-Experimental Design	4	1	5
Horizontal And Vertical Comparison Design	-	1	1
Unspecified	2	-	2
Total	58	16	74

ML theses were conducted using the “relational survey model” at most. This situation was the same in both master's theses and doctoral theses. The pattern, which ranks second in terms of frequency of use according to the research pattern in master's theses, is the "survey desing". In the third place is the "experimental design". The frequency difference between the patterns in these first three rows is very small (1 frequency difference). Survey design and teaching experiment design share the second place in doctoral theses.

The distribution of the research patterns of the theses on ML by years is given in Table 11.

Table 11. Distribution of research design of theses prepared on ML by years

Research Design	2003	2006	2008	2009	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Descriptive Design	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
Descriptive Research	-	-	-	-	-	-	1	-	1	1	-	-	-	-	3
Descriptive Content Analysis	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Descriptive Survey Model	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1
Experimental Design	-	1	-	-	-	-	-	1	1	-	2	1	2	-	8
Document Analysis	-	-	-	-	-	-	-	-	-	-	-	-	2	2	4
Case Study	-	-	1	-	-	-	-	-	-	-	-	1	2	-	4
Action Research Design	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
Nested Mixed Design	-	-	-	-	-	-	-	-	-	-	-	-	2	-	2
Relational Research Model	-	-	-	-	-	-	-	-	-	1	-	1	-	-	2
Relational Survey Model	1	1	-	-	-	-	2	1	2	1	1	-	4	-	13
Causal Comparative Research	-	-	-	1	-	-	-	-	-	-	1	-	-	-	2
Descriptive Design of the Mixed Method	-	-	-	-	1	-	-	-	-	1	-	-	-	-	2
Exploratory Case Study Design	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
(Predictive) Correlational Research	-	-	-	-	1	-	-	-	1	-	-	-	1	1	4
Causal Comparative Research Design	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Teaching Experiment Design	-	-	-	-	-	-	-	-	-	1	1	-	1	-	3
Segmentation Model	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1
Survey Design	-	-	2	1	-	1	-	-	3	-	2	-	1	1	11
Semi-Experimental Design	-	-	-	-	-	-	-	-	2	1	-	-	2		5
Horizontal And Vertical Comparison Design	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1

Looking at the distribution of research designs by years, it is seen that the "Relational Survey Model" has been used since the first year when ML theses were written. It is seen that the oldest method used in ML postgraduate theses after the "Relational Survey Model" is the "Experimental Design". If we look at the table from the most recent date, two of the five postgraduate theses written in 2020 were prepared with the "Document Analysis" pattern. Four of the 19 postgraduate theses written in 2019 were prepared using the "Relational Survey Model".

Findings Regarding Data Collection Tools of Postgraduate Theses

The distribution of theses prepared on ML according to data collection tools is shown in Table 12.

Table 12. Distribution of Theses Prepared on ML by Data Collection Tools

Data collection tools	Master Theses (f)	PhD Theses (f)	Total
Questionnaire	9	3	12
Inventory	3	-	3
Scale	16	3	19
Test	30	7	37
Form	15	1	16
Document	4	4	8
Interview (Interview) Form or Interviews	10	5	15
PISA Questions - Data	6	2	8
Total	93	25	118

When Table 12 is examined, it is seen that many different data collection tools are used in theses prepared on ML. Considering the data collection tools used, data was collected mostly with the test technique. Also; scales, forms and interviews are other frequently used data collection tools. Considering all data collection tools, data was collected with the least inventory.

Findings Concerning the Results of Postgraduate Theses

The distribution of the results of the theses on ML is given in Table 13 under five theme.

Table 13. Distribution of Theses Prepared on ML by Results

Theme	Category	f	%
Factors Increasing ML Success	-Technology -Mathematics Literacy Education -Curriculum Arrangement -Valuing Mathematics -Developing a Positive Attitude -Mathematical Modeling Training -Using Mathematical Tools	19	19,8
Variables Affecting ML	-Demographic features -School Type -Classroom Management -Active Participation -Belief in Self-Efficacy -Geographical Location -Teacher-Student Relationship -Study Habits	48	50,0
Behaviors Observed in the ML Process	-Difficulties Encountered -Observed Process Skills -Observed Misconceptions	6	6,2
Determining ML Achievement Level	-Using Measuring Tools -Observing Mathematical Process Skills -Using Special Statistical Methods -Using Special Measuring Tools	23	24,0
Total		96	100

A thesis is not included in only one theme. More than one theme can be found as a result of a thesis. Looking at the table, it is seen that the results under the theme of "variables affecting ml" are found in more than half of the ML theses. In addition, the results related to "determination of ml achievement level" and "factors that increase ml success" are also given a lot. In the theme of "behaviors observed in the ML process", relatively few frequencies are seen compared to other themes.

Findings Concerning the Suggestions of Postgraduate Theses

The distributions of the theses on ML regarding their suggestions are given in Table 14 under five thematic title.

Table 14. Distribution of Theses Prepared on ML by Suggestions

Theme	Category	f	%
Academic Suggestions	-Examination of Mathematical Processes -Examination of Mathematical Literacy Levels -Working with Different Samples -Using Different Measuring Tools -Comparing Mathematics Literacy by Countries -Comparing Mathematics Literacy Among School Types	63	43,1
Suggestions for Students	-Solving ML Problems -ML Education -Using Technology	15	10,3
Suggestions for Teachers	-ML Education -Self Assessment	20	13,7
Suggestions for the Teaching Process	-Variables Influencing ML -Adult Education -Material Enrichment -Enriching Teaching Methods and Techniques	22	15,1
Suggestions for the Curriculum	-Increasing the Mathematics Applications Lesson -Updating Textbooks	26	17,8
Total		146	100

A theses is not included in only one theme. More than one theme can be found in a theses proposal. Looking at the table, it is seen that ML theses have the most "Academic Suggestions" while making suggestions. The second group of suggestions in terms of frequency among the suggestions addressed by ML theses is "suggestions for the curriculum". There is very little (two frequencies) difference in frequency between "suggestions for teachers" and "suggestions for teaching process". In almost the same number of theses, suggestions were made for the teacher and the teaching process. “suggestions for students” are the least in number.

Conclusions and Suggestions

The aim of this study was to examine the postgraduate theses conducted in Turkey on mathematical literacy, which is heavily included in the education system of countries with PISA exams, according to the determined variables, and to provide researchers with an idea for new studies. In line with the purpose of the study, 74 postgraduate theses on ML conducted between 2003 and 2020 were examined. It was determined that 58 of the postgraduate theses examined in the research were master's and 16 of them were PhD theses. Since the number of master's programs in education in Turkey is higher than doctoral programs, it is an expected result that there are more master's theses. Sevencan (2019), in his study examining postgraduate theses in

the field of mathematics education in Turkey between the years 2000-2016, stated that approximately 80% of 1276 theses consisted of master's theses. Similarly, Tereci and Bindak (2019), in their study examining postgraduate theses in the field of mathematics education in Turkey between 2010 and 2017, revealed that approximately 81% of 602 theses were master's theses. The result that 78% of the postgraduate theses in the field of ML are at the master's level, is in line with these results.

Distribution of postgraduate theses on ML by years showed that most of the theses published between 2003-2020 were made after 2015. Similarly, Şahin and Başgül (2020), in their study in which they examined a total of 109 postgraduate theses conducted between 2003-2018 in order to reveal the trends of the postgraduate theses related to the PISA exam in Turkey, found that the most thesis related to PISA was made in 2015, and that the most of the theses conducted on mathematical literacy.

It is seen that there are 10 universities in Turkey that produce three or more postgraduate theses on ML. It is seen that the highest number of doctoral theses were made in Eskişehir Anadolu University, and the highest number of master's theses were made in Uludağ University. When looking at the postgraduate theses related to ML without separating them based on their types, it is seen that they are mostly prepared in Uludağ University, followed by Balıkesir University and Ankara University. It has been determined that most of the postgraduate theses in the field of mathematics education between 2010-2017 and in the field of primary school mathematics education between 2005-2016 in Turkey were made in Gazi University (Tereci & Bindak (2019); Özsoy et al., 2017). When we look at the studies that consider the frequency of postgraduate thesis on university basis as a sub-problem, two studies that mention the frequency of doing three or more theses are included here. In the first study, Doğan and Kurt (2019) examined theses on realistic mathematics education, in three of 26 different universities; the second is Toptaş and Gözel's (2018) studies on mathematics anxiety, and four out of 29 different universities are in the scope of a subject. The fact that the number of studies in ten different universities is three or more can be considered as an indication that this subject is seriously considered in terms of graduate education.

When we look at the keywords of the postgraduate theses on ML, it is seen that the concept of "mathematical literacy" is used most frequently. This is followed by the keywords "PISA" and "mathematics education"; It is noteworthy that the keywords of "thinking styles-paths", "mathematics success", "mathematical modeling" and "motivation" are few in number. It is a predictable result that the keywords of “mathematical literacy” is used in all theses

focusing on ML. In addition, it was seen that the theses that were carried out using PISA data and that included "PISA" in their keywords mostly used PISA 2012 data.

Most of the postgraduate theses on mathematics literacy in the field of mathematics education in Turkey were conducted on middle school students. The following sample type is PISA participants and undergraduate students. When the postgraduate theses on ML are examined according to the sample size; It has been seen that the number of studies conducted with more than 500 participants in master's theses is high. It is thought that the frequent use of PISA data in theses has an effect on the number of studies conducted with more than 500 participants. The sample size of the studies show sufficient diversity.

When we look at the research methods of postgraduate theses on ML, it is seen that the most widely used method is the quantitative research method, followed by the mixed research method. It has been observed that the "quantitative research method" has been preferred since 2003. “mixed research method” was used for the first time in 2011 in ML postgraduate theses. It is seen that the "mixed research method" has started to be used in ML theses mostly in recent years.

The most commonly used research design in postgraduate theses on ML is the "relational survey model". It is seen that "survey design" and "experimental design" follow this in master's theses. It is seen that "survey design and teaching experiment design" are used in doctoral theses. Özsoy et al. (2017) found that the most commonly used research design is the survey design in their studies where they examined the research tendencies of postgraduate theses in the field of primary school mathematics education. Karagöz and Şahin Çakır (2021), on the other hand, in their study in which they examined model and modeling theses conducted in Turkey, concluded that quasi-experimental design was mostly used as a research model in theses.

When the postgraduate theses on ML are examined within the scope of data collection tools, it is seen that the test technique is used the most. After the test technique, scale, form and interviews were preferred; it is seen that the inventory is used at least. Similarly, Coşkun and Soylu (2021) found that tests were mostly used as a data collection tool in postgraduate theses on problem solving in the field of mathematics education in Turkey. In addition, Geçici and Türnüklü (2020) concluded that the most data was collected through interviews in theses on problem posing in Turkey.

While the findings related to the results of the ML theses mostly focused on the variables affecting ML, the level of success and the factors that increase success, it was seen that there was few data on the behaviors observed in the ML process. It is thought that the reason for this

may be the difficulty of interpreting and criticizing human behaviors. For the theses planned to be made on ML, studies that include the observation of the behaviors in the process may be preferred.

When the results are evaluated in general, middle school students are the most preferred sample type in postgraduate theses on mathematics education in the field of mathematics education in Turkey. The need for mathematically literate teachers to raise mathematically literate individuals, it can be recommended to increase the number of studies with teachers as a sample type in studies to be conducted in the field of ML.

It is seen that the highest number of PhD theses were made at Eskişehir Anadolu University, and the most number of master's theses were made at Bursa Uludağ University, therefore, considering the number of universities in our country, studies at the doctoral level on this subject are limited to some universities. It can be suggested that studies on this subject be extended to other universities as well. In the research, it was revealed that more master's thesis on the subject was made. In this direction, doctoral thesis supervisors can encourage their postgraduate students to work on ML.

It has been observed that almost half of the suggestions in the theses are academic suggestions. The least number of suggestions are those that are directly related to the student. Although the most frequently studied group as the study group is middle school students, the fact that the least suggestion is directly in the student theme can be considered as an indication that studies focusing on the process should be increased. Considering the importance of mathematical literacy for students, it is important to develop suggestions for students in studies that are thought to be carried out.

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Türkiye'de Matematik Eğitimi Alanında Yapılmış Matematik Okuryazarlığı İle İlgili Lisansüstü Tezlerin Tematik Analizi

Özet:

Bu çalışmanın amacı, Türkiye'de matematik okuryazarlığı konusunda yapılan lisansüstü tezlerin özelliklerini çeşitli ölçütlere göre ortaya koymaktır. Araştırmanın amacı doğrultusunda incelenen kriterler; lisansüstü tezin türü ve yayın yılı, yapıldığı üniversite, konusu, anahtar kavramları, örneklem türü ve örneklem sayısı, araştırma yöntemi ve araştırma deseni, veri toplama araçları, ana sonuçlar ve temel önerileri olarak belirlenmiştir. Araştırmada nitel araştırma yaklaşımlarından biri olan tematik analiz kullanılmıştır. Araştırmanın örneklemini Yükseköğretim Kurulu Ulusal Tez Merkezi resmi internet sitesinde kayıtlı 2003-2020 yılları arasında gerçekleşen eğitim alanında matematik okuryazarlığı ile ilgili 74 lisansüstü tez oluşturmaktadır. Bu çalışma, ele alınan kriterlerin niteliği ve çeşitliliği açısından matematik okuryazarlığı ile ilgili lisansüstü tezlerin incelenmesine ilişkin diğer makale ve tezlerden farklılık göstermektedir.

Anahtar kelimeler: Matematik okuryazarlığı, tematik analizi, matematik eğitimi, lisansüstü tez

Geniş Özet

Giriş

Matematik okuryazarlığı, kişinin matematiği hayatımızda karşılaştığımız çeşitli durumlarda formüle etme, uygulama ve yorumlama basamaklarını kullanma kapasitesi olarak tanımlanır (Organisation for Economic Co-Operation and Development [OECD], 2016). Matematik Okuryazarlığı (MO) okul matematiği ile yaşam arasındaki kopukluğun artması üzerine gündeme gelmiş olup amacı, bilgiyi beceri ile bütünleştirmek sureti ile işe koşmak ve kullanılmasını sağlamaktır (Altun, 2020). Matematik okuryazarlığının okul matematiği ile olan ilişkisi göz önüne alındığında MEB kaynaklarında raporlanan matematik okuryazarlığı başarısının irdelenmesine gerek duyulmuştur. PISA 2015 uygulaması sonuçlarına göre Türkiye matematik başarısı bakımından 420 ortalama puan ile 72 ülke arasından 50. sırada yer almaktadır. 2015'de Türkiye'de alt düzeyde yer alan öğrenci oranı artmış, üst düzeyde yer alan öğrenci oranı ise azalmıştır (MEB, 2019). Türkiye, PISA 2018 araştırmasında 454 ortalama puan ile 79 ülke arasından 42.sırada yer almaktadır. PISA 2015 uygulamasında 420 olarak hesaplanan ortalama matematik puanının 2018 yılında 454'e çıkması Türkiye'nin performansını artırdığının bir göstergesidir. (MEB, 2016). Ancak her ne kadar artmış olsa da bu sıralamanın yeterli olmadığı söylenebilir.

Türkiye'nin PISA değerlendirmelerinde daha iyi bir sıralamaya sahip olması açısından matematik okuryazarlığı ile ilgili yapılan lisansüstü tezlerin yönelimlerinin ayrıntılı olarak belirlenmesinin literatüre katkıda bulunacağı ve bu alanda çalışacak olan araştırmacılara yol göstereceği düşünülmektedir. Bu araştırmanın amacı Türkiye'de matematik okuryazarlığı konusu üzerine yapılan lisansüstü tez çalışmalarının çeşitli kriterlere göre özelliklerini ortaya koymaktır. Araştırmada matematik okuryazarlığını konu edinen lisansüstü tezlerinde, çalışmanın amacı doğrultusunda incelenen kriterler;

1) Lisansüstü tezin türü ve yayın yılı,
2) Lisansüstü tezin yapıldığı üniversite,
3) Lisansüstü tezin konusu,
4) Lisansüstü tezin anahtar kavramları,
5) Lisansüstü tezin örneklem türü ve örneklem sayısı,
6) Lisansüstü tezin araştırma yöntemi ve araştırma deseni,
7) Lisansüstü tezin veri toplama araçları,
8) Lisansüstü tezin başlıca sonuçları,
9) Lisansüstü tezin başlıca önerileri olarak belirlenmiştir.

Yöntem

Çalışmada matematik okuryazarlığı konusu üzerine yapılan lisansüstü tez çalışmalarının çeşitli kriterlere göre özelliklerini ortaya koymak amaçlandığından nitel araştırma yöntemi tercih edilmiştir. Araştırmada nitel araştırma yaklaşımı çerçevesinde tematik analiz yapılarak tezler incelenmiş ve belirli kriterler çerçevesinde betimlenmeye çalışılmıştır.

Araştırmaya dahil edilecek dokümanlar, araştırmacılar tarafından Nisan 2020 – Kasım 2020 tarihleri arasında Yükseköğretim Kurulu Başkanlığı Ulusal Tez Merkezi resmî sitesinin veri tabanından elde edilmiştir. Veri tabanında yapılan tarama esnasında *"matematik okuryazarlığı", "matematik okuryazarliği", "matematik okuryazarlık", "matematiksel okuryazarlık", "matematik okur yazarlığı", "matematik okur yazarlık", "matematik okur-yazarlık", "matematik okur-yazarlığı"* terimleri kullanılmıştır. Ulaşılan dokümanların tamamı çalışmaya dâhil edilmiştir. Matematik okuryazarlığı konusuna ilişkin ilk lisansüstü tez çalışmasına 2003 yılında ulaşılması sebebiyle 2003 yılından günümüze kadar hazırlanan tezler ele alınmıştır. 2003-2020 yılları arasında matematik okuryazarlığı konusu çerçevesinde hazırlanan 74 lisansüstü tez bu çalışma kapsamına dahil edilerek incelenmiştir. Bu 74 lisansüstü tezinin 58 tanesi yüksek lisans ve 16 tanesi doktora tezidir.

Analize dâhil edilen toplam 74 lisansüstü tezden elde edilen veriler, betimsel analiz ve içerik analizi yöntemi kullanılarak analiz edilmiştir. Genel özellikler için bilgiler verilerin yüzdeleri ve frekansları şeklinde betimsel analiz olarak verilirken; kodlanarak uygun temalara yerleştirilen veriler için ise içerik analizi kullanılmıştır. Her bir analiz sonucuna yönelik frekanslar (*f*) ve yüzdeler (%) hesaplanarak tablolar eşliğinde sunulmuştur.

Bulgular

Elde edilen bulgular incelendiğinde matematik okuryazarlığı ile ilgili yayımlanan 74 tezden yüksek lisans düzeyinde yapılan çalışmalarının sayıca daha fazla olduğu bulunmuştur. 2004, 2005, 2007, 2010 ve 2012 yılları haricinde her yıl matematik okuryazarlığı ile ilgili yüksek lisans tezi hazırlanmıştır. Yüksek lisans tezlerinin 2015 yılında sayıca fazlalaştığı takip eden iki yıl aynı seyri gösterdikten sonra 2018 yılında bir düşüş yaşayıp 2019 yılına gelindiğinde ise matematik okuryazarlığı ile ilgili hazırlanan yüksek lisans tezleri sayıca en üst noktaya ulaşmıştır. 2003-2013 yılları arasında yazılmış doktora tezi neredeyse hiç yoktur (2006 ve 2012 yılında birer tane doktora tezi yazılmıştır). Son yıllarda ise düzenli olarak doktora tezlerinin de hazırlandığı görülmektedir. Araştırma taramasının yapıldığı son aya kadar 2020 yılında da MO alanında bir doktora tezi çalışması yoktur.

Doktora tezlerinin sayıca en fazla Eskişehir Anadolu Üniversitesi'nde, yüksek lisans tezlerinin sayıca en fazla Bursa Uludağ Üniversitesi'nde yapıldığı görülmektedir. Genel olarak

bakıldığında MO ile ilgili lisansüstü tezlerin sayıca en fazla Uludağ Üniversitesi'nde yapıldığı görülmektedir. Sayıca ikinci sırada yer alan Balıkesir Üniversitesi'nde yapılan tezlerdir.

Matematik okuryazarlığı tezlerinin konularının en çok odaklandığı temalar, "matematik okuryazarlığı ve PISA" ve "matematik okuryazarlığı ile farklı konuların incelenmesi" şeklindedir. Hazırlanan tezlerin konularının en çok odaklandığı diğer temanın ise "matematik okuryazarlığını etkileyen faktörler" olduğu görülmektedir.

"Matematik Okuryazarlığı" anahtar kavramı MO tezlerinin sayıca yarısından fazlasında yer almaktadır. Kullanılma sıklığı bakımından ikinci sırada yer alan anahtar kavram "PISA" olmuştur. Üçüncü sırada "Matematik Eğitimi" kavramı yer almaktadır.

MO ile ilgili farklı örneklem gruplarına göre araştırmalar yapıldığı görülmüştür. Yapılan araştırmalar en çok ortaokul (5-8) öğrencileri ile yürütülmüştür. Bunu PISA katılımcıları ve lisans öğrencileri ile yapılan araştırmalar takip etmektedir. Yetişkinler ve öğretmenler ile çok az sayıda çalışma yapılmış olması dikkat çekmektedir. Yüksek lisans tezlerinin büyük bir kısmının 500 üstü örneklem gruplarıyla, doktora tezlerinin ise çoğunlukla 1-40, 201-500 kişi sayısına sahip örneklem gruplarıyla yürütüldüğü tespit edilmiştir.

MO tezleri en fazla "nicel araştırma yöntemi" kullanılarak yürütülmüştür. Frekans sıklığı olarak "nicel araştırma yöntemi"ni takip eden "karma araştırma yöntemi"dir. MO tezlerinde en fazla kullanılan araştırma deseni ise "İlişkisel Tarama Modeli" olmuştur.

MO ile ilgili hazırlanan tezlerde birçok farklı veri toplama aracından yararlanıldığı görülmektedir. Yararlanılan veri toplama araçlarına bakıldığında en çok test tekniği ile veri toplanmıştır.

MO ile ilgili hazırlanan tezlerin yarısından fazlasında, elde edilen sonuçların "MO'yu etkileyen değişkenler" teması altında bulunduğu görülmektedir. Bununla beraber "MO başarı seviyesi belirleme" ve "MO başarısını arttıran faktörler" ile ilgili sonuçlara da fazlaca yer verilmiştir. MO tezlerinin en fazla "akademik öneriler" de bulunduğu görülmüştür. MO tezlerinin ele aldığı önerilerde sıklık bakımından ikinci sırada bulunan öneri grubu "öğretim programı için öneriler"dir.

Sonuç ve Tartışma

Araştırmada incelenen 74 lisansüstü tezin 58 tanesinin yüksek lisans 16 tanesinin doktora tezi olduğu tespit edilmiştir. Türkiye de eğitim alanında yüksek lisans programlarının doktora programlarına göre sayıca fazla olmasından dolayı yüksek lisans tezlerinin daha fazla olması beklenen bir sonuçtur. Bu doğrultuda doktora tez danışmanları tez öğrencilerini MO ile ilgili çalışma yapmaları konusunda teşvik edebilir.

Türkiye'de matematik eğitimi alanında yapılmış matematik okuryazarlığı ile ilgili lisansüstü tezlerin yıllara göre dağılımına bakıldığında 2003-2020 yılları arasında yayınlanmış olan tezlerin büyük bir kısmının 2015 yılı sonrasında yapıldığı görülmektedir. Uluslararası düzeyde uygulanan PISA değerlendirmelerinin okul matematiği ile yaşam arasındaki boşlukla ilgili farkındalığının artırmasına ve ülke eğitim sistemlerinin yeniden düzenlenmesinde dikkate alınmasına (Kozaklı Ülger ve ark., 2020) rağmen 2015 yılı ve sonrasında düzenli bir artış söz konusu değildir.

Doktora tezlerinin sayıca en fazla Eskişehir Anadolu Üniversitesi'nde, yüksek lisans tezlerinin sayıca en fazla Bursa Uludağ Üniversitesi'nde yapıldığı, dolayısıyla ülkemizdeki üniversite sayısı göz önüne alındığında bu konuyla ilgili çalışmaların bazı üniversitelerle sınırlı kaldığı görülmektedir. Bu konuyla ilgili çalışmaların diğer üniversitelere yaygınlaştırılması önerilebilir.

Türkiye'de matematik eğitimi alanında yapılmış matematik okuryazarlığı ile ilgili lisansüstü tezlerin anahtar kavramlarına bakıldığında "matematik okuryazarlığı" kavramının en sık kullanıldığı görülmektedir ve bu tahmin edilebilir bir sonuçtur.

Türkiye'de matematik eğitimi alanında yapılmış matematik okuryazarlığı ile ilgili lisansüstü tezlerin büyük çoğunluğu ilköğretim öğrencileri üzerinde yürütülmüştür. Bunu takip eden örneklem türü ise PISA katılımcıları ve lisans öğrencileridir. Lisans öğrencileri araştırmacılar için kolay ulaşılabilir bir çalışma grubudur (Kozaklı Ülger ve ark., 2020). Matematik okuryazarı bireylerin yetişmesi için matematik okuryazarı öğretmenlere olan ihtiyaç göz önünde tutulduğunda, MO alanında yapılacak olan çalışmalarda örneklem türü olarak öğretmenlerle çalışılması önerilebilir.

MO tezlerinin sonuçlarına ilişkin bulgular daha çok MO'yu etkileyen değişkenlere, başarı düzeyine ve başarıyı artıran faktörlere odaklanırken MO sürecinde gözlenen davranışlara ilişkin çok az veri olduğu görülmüştür. Bunun nedeninin insan davranışlarını yorumlamanın ve eleştirmenin zorluğu olabileceği düşünülmektedir. MO üzerine yapılması planlanan tezler için süreçteki davranışların gözlemlenmesini içeren çalışmalar tercih edilebilir.

Tezlerde yer alan önerilerin neredeyse yarısının akademik öneriler olduğu gözlemlenmiştir. En az sayıda öneri, doğrudan öğrenciyle ilgili olanlardır. Çalışma grubu olarak en sık çalışılan grup ortaokul öğrencileri olsa da en az önerinin doğrudan öğrenci temasında olması sürece odaklanan çalışmaların artırılması gerektiğinin bir göstergesi olarak değerlendirilebilir. Matematik okuryazarlığının öğrenciler için önemi göz önüne alındığında yapılması düşünülen çalışmalarda öğrencilere öneriler geliştirilmesi önemlidir.

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Research Article

The Effects of Learning Management Systems (LMS) on Mathematics Achievement: A Meta-Analysis Study

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Abstract – The purpose of this investigation is to examine the effect of LMS (Learning Management System) use on students' mathematic achievement through a meta-analysis method. 43 experimental studies with a data set including standard deviations, mean scores and sample sizes were incorporated in the analysis. The total number of samples from the studies included in the analysis is 15.296. Data were analyzed using Comprehensive Meta Analysis (CMA) software. After the analysis was completed in accordance with the random effects model, the Cohen d effect value of LMS use on students' mathematics achievement was calculated as 0.363. The results of the subgroup analysis of this effect size value indicated that the effect of LMS use on mathematics achievement did not differ significantly between subgroups with reference to the variables of sample, type of publication, duration of application and method of application. On the other hand, it was found that there was a significant difference between the subgroups for the variables of year, country, subject and education level.

Key words: Learning management system, mathematics achievement, meta- analysis.

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Introduction

The pandemic, which has taken the whole world under its influence for the last few years, has also affected education systems. The extraordinary situation that we are in has led us to turn to distance education from face-to-face education. With the benefits of innovative educational technologies, the boundaries of educational activities have expanded. (Chang, et

al., 2015). One of the tools in which distance education activities are actively presented is learning management systems (LMS).

LMS is software that supports access to a wide variety of web-enabled tools for conducting, compiling, managing and documenting educational activities (Cole & Foster, 2008; Ellis, 2009). In other words, LMS is software that combines online learning tools in learning and teaching using internet technologies (Avgeriou, et al., 2003). LMS has allowed students to communicate and evaluate each other during the education process. LMS has also enabled students to access necessary materials for the course and to choose appropriate activities (Adzharuddin & Ling, 2013). LMS has many features such as accessing lessons without the restrictions of time and place, supporting different languages and providing fun activities suitable for students' interests (Beam & Cameron, 1998). In this respect, the process in which the teacher is at the forefront in traditional education has left its place to the active participation of students with the use of LMS.

LMSs used today can be classified as open source products, commercial products and customized software (Avgeriou, et al., 2003). The most common of open source learning management systems include Moodle (used in 220 countries around the world), Claroline, Interact, Ilias, Sakai, Canvas, which were utilized in many countries.

It has been suggested online learning environments have increased the effectiveness of virtual learning with online communications such as e-mail and live question and answer sessions (Massoud, Iqbal & Stockley, 2011; Lee, 2019; Nwaogu, 2012). To put it another way, the online learning environment is considered important in that it includes the learning-teaching process without the limitation of time and place, and presents opportunities that cannot be provided in the traditional classroom environment (Woolley & Ludwig, 2000).

There have been meta-analysis studies in which different technology-supported methods are concerned with mathematics achievement (Chadwick, 1997; Chan & Leung, 2014; Deniz, 2019; Lee 1990; Li & Ma, 2010; Tokpah 2008; Young & Hamilton, 2018; Schenker, 2007; Steenbergen-Hu & Cooper, 2013). Studies examining the effect of LMS, which are widely used in the distance education process today, on mathematics achievement also form the backbone of this research. In the relevant literature, it is seen that LMS provides convenience in learning and teaching processes (Guzer & Caner, 2014) and that it is preferred in integrating methods of flipped learning, blended learning, web based learning, online learning (Boyd, 2018; Crowley, 2018; Francis, 2016; Huang, 2012; Korucu & Kabak, 2020; Kwan lo & Foon, 2017; Liu, 2010; Newberry, 2011; Odom, 2006; Özerbaş, 2012; Renee, 2017;

Şahinoğlu, 2012; Tarazi, 2016 ; Toth, 2013; Winn, 2016; Zenati, 2020) which have been distinctive and popular in recent years.

Some research results indicate that the use of LMS positively affects mathematics achievement at different levels (Bradley, 2016; Chaney, 2016; Crowley, 2018; Comfort, 2016; Day, 2017; Kelismail, 2019; Nies, 2018; Olpak, et al., 2018; Osborne, 2020; Şimşek, 2010; Tekin, 2018; Telford, 2011; Williamson, 2017; You, 2015). On the other hand, there are also study results that show that the use of LMS has no effect on mathematics achievement (Anthony, 2015; Applebee, 2019; Belanger, 2018; Cheung & Slavin, 2013; Francis, 2016; Gangaram, 2014; Ichinose, 2011; Mills, 2016; Norvell, 2017; Pope, 2013; Renee, 2017; Smith, 2017; Williamson, 2017). This inconsistency in the results of the research necessitated revealing the real effect of the use of LMS in mathematics education on students' mathematics achievement. In fact, can we really say that LMS is so effective and efficient in terms of mathematical success in today's world where educational technologies have developed so much as mentioned above? Within the scope of this study, answers to the following questions were sought by systematically compiling LMS studies in the field of mathematics education:

1. What is the overall effect of LMS use on mathematics achievement?
2. Does the overall effect of LMS use on mathematics achievement differ significantly within the study subgroups (publication year, country, sample group, application period, education level, subject, publication type and application method)?

The present study can be seen essential as it presents a general conclusion about how effective the use of LMS is on mathematics achievement. It can also be considered up-to-date in terms of addressing LMS technology, which is one of the most popular and widely used educational technologies today. Finally, the present study can be regarded as original due to the lack of studies examining the effect size of LMS use in education on mathematics achievement. On the other hand, this study is limited to articles and theses made in the last fifteen years that can be accessed in specific databases examining the effect of LMS use on mathematics achievement.

Method

In this study, the meta-analysis method was employed to investigate the effect of LMS use on mathematics achievement. Meta-analysis is a method used to compile the results of the studies and statistically interpret the actual effect sizes (Borenstein, et al., 2009; Cohen, Manion & Morrison, 2007). The findings from experimental studies investigating the effect of LMS on mathematics achievement were combined with meta-analysis method and random effects model was used. The random effects model is applied when the population sizes of the included studies are different, the standard deviation is not equal to zero, and the study is heterogeneous (Borenstein, et al., 2009).

Inclusion and Exclusion Criteria

The studies included in the present analysis were chosen based on the following criteria:

- Master's thesis, doctoral thesis and articles examining the effects of LMS on students' mathematics achievement,
- the studies with an experimental design,
- the studies with sample sizes, mean scores and standard deviation values to calculate the effect in meta-analysis,
- the studies comparing the traditional method with LMS using,
- the national and international studies published from 2005 to December 2020,
- the studies indexed in National Thesis Center, Proquest and Web of Science (WoS) databases
- by taking the LMS definitions specified in the conceptual framework as criteria the studies were included in the analysis.

During the meta-analysis process, the flow in the updated Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA 2020) guideline (http://prismastatement.org/prismastatement/Checklist.aspx) was followed. In this respect, the sample of the study consists of master's theses, doctoral thesis and articles examining the effects of LMS on students' mathematics achievement. To this end, National Thesis Center, Proquest and WoS databases were scanned. During the process of scanning, the key words of “Learning Management System”AND “math*” AND “success OR accomplish* OR acquire*”

were used. The studies obtained as a result of the scanning were examined in terms of suitability for the purpose. As a consequence, 4,503 articles and theses were listed, of which 3.231 experimental studies were identified. The contents of the experimental studies were examined in detail and 83 studies with pre-test-post-test experimental and control group designs were chosen. As a result of the exclusion of studies lacking mean scores and standard deviation values, a total of 43 studies were included in the final analysis. Of the 43 studies, 6 were articles, 4 were national theses and 33 were international thesis.

Coding Procedure and Reliability

Within the scope of the analysis, the overall effect of LMS use on mathematics achievement was also examined within some subgroups. These were coded as publication year, country, sample group, application period, education level, subject, publication type and application method. Kappa reliability value (.88) among the coders showed a satisfactory level of agreement (Cohen, 1960).

Data Analysis

Comprehensive Meta-Analysis (CMA) version.3 software was used to analyze the data. After performing the heterogeneity test, the effect size was calculated for the random effects model. When deciding on the random effects model, it was taken into account that the included studies did not have a common effect size and showed a heterogeneous structure (Borenstein, et al., 2009). To calculate the effect size, Cohen's d factor was used. When the effect size was calculated, the effect level classification was done as follows: -0,15≤ Cohen d < 0,15 insignificant, 0,15≤ Cohen d < 0,40 small effect, 0,40≤ Cohen d <0,75 moderate effect, 0,75≤ Cohen d < 1,10 large effect, 1,10≤ Cohen d < 1,45 extremely large effect, 1,45≤ Cohen d strong effect (Thalheimer & Cook, 2002). After the effect size was calculated, moderator analysis was performed to determine whether the effect size differed within the subgroup variables. Analog Anova was preferred as moderator variables were categorical (Aguinis, Gottfredson, &Wright, 2011). Whether there is publication bias in the studies included in the meta-analysis was examined by funnel plot, Orwin's Fail Safe N and Egger's regression analysis.

Findings and Discussion

Publication Bias

In this section, Funnel plot, Orwin's Fail Safe N and Egger's Regression analysis findings will be reported to evaluate publication bias. The funnel plot shows the distribution of the effect sizes for the specified sample sizes of the studies included in the meta-analysis. The absence of publication bias can be identified by the symmetrical view of the funnel plot (Card, 2012).

The funnel scatter plot of the studies included in the meta-analysis is presented in Figure 1 below

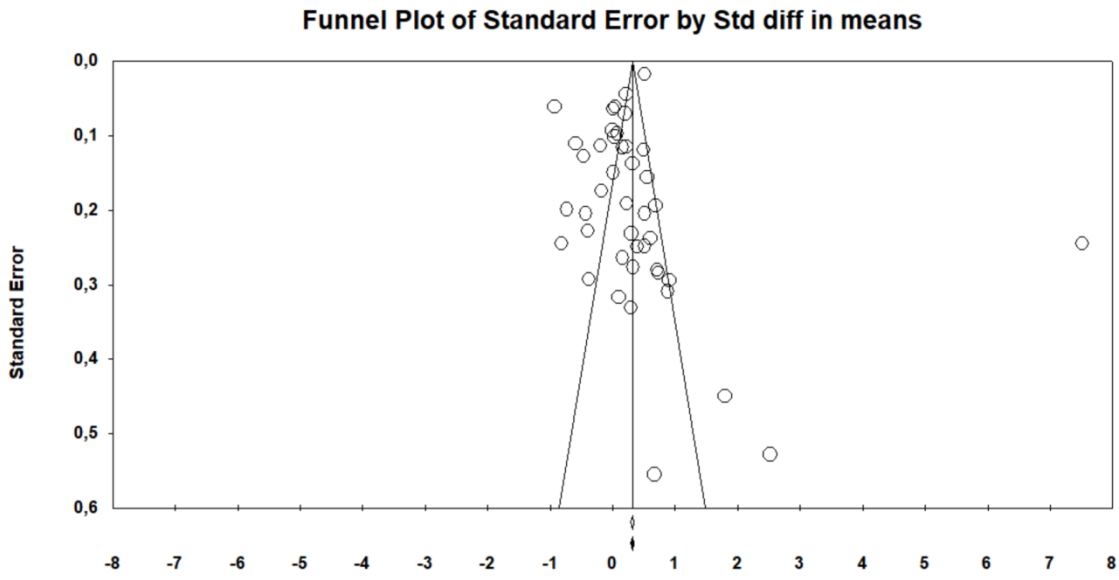

Figure 1. Funnel Plot

As seen in Figure 1, most of the studies were placed in the funnel scattered and they were centered around the average effect size. In the funnel plot, the studies are expected to show a symmetrical distribution. However, when the funnel plot is examined, it is seen that the studies do not show a symmetrical distribution. To ensure symmetry, Duval and Tweedie's (2000) trim and fill method was employed. The new funnel plot is as in Figure 2 below.

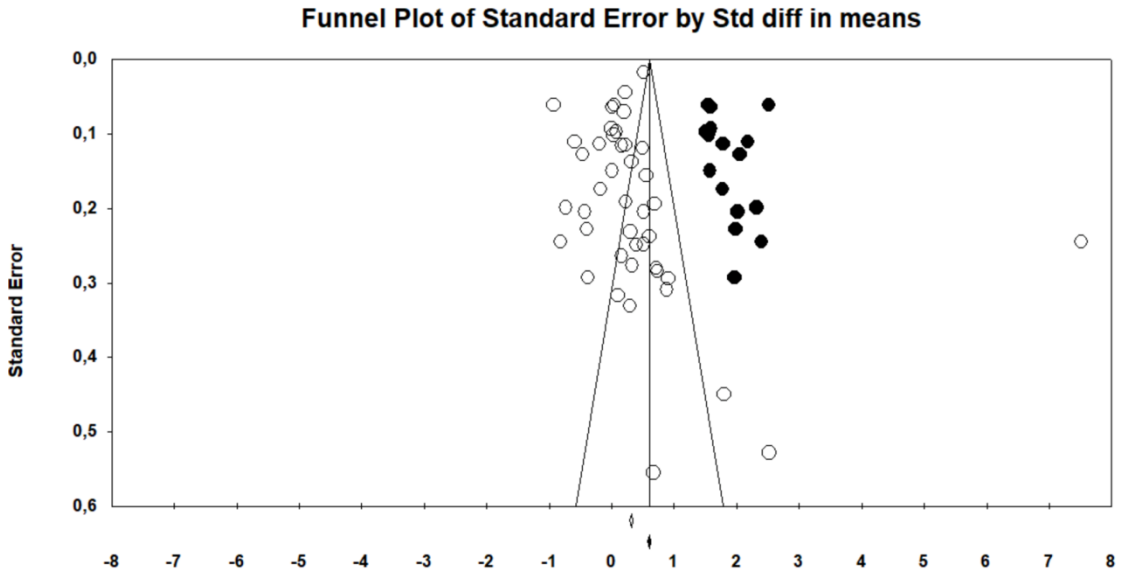

Figure 2. The Funnel Plot resulted from Trim and Fill

As seen in Figure 2, the effect size could increase on condition that 16 more studies were to be added to the present investigation (Cohen's d= 0.600). Another publication bias test is Orwin's Fail Safe N test. Orwin's Fail Safe N is a statistic that numerically shows how many more studies were to be included in this meta-analysis study to show that the calculated effect size would decrease to a meaningless value (Orwin, 1983). The numerical data from Orwin's Fail Safe N test are presented in Table 1 below.

Table 1. Orwin's Fail Safe N Test Results

Element	Value
Z-score	12.858
p	0.00
Alfa	0.05
Z score for Alfa	1.959
N	43
The number of missing studies	1808

When Table 1 is examined, the Orwin's Fail Safe N results of 43 studies included in the meta-analysis are seen. According to these results, the number of studies that can reduce the effect size to invalid degree is 1808. The 43 studies included in the meta-analysis had the number to meet both national and international criteria. Since it was not possible to reach

1808 studies more, it can be stated that there is no publication bias according to this test result. Table 2 below presents Egger's regression values.

Table 2. Egger's Regression Test Results

Element	Value
t Value	0.707
df	41.000
P Value (1-tailed)	0.241
P Value (2-tailed)	0.483

When Table 2 is examined, Egger's regression results of 43 studies included in the meta-analysis are seen. The finding that Egger test result is not statistically significant, (p>.05) indicates that there is no publication bias.

Heterogeneity and Effect Size

The results of the heterogeneity test results are presented in Table 3 below:

Table 3. Heterogeneity test and effect size results

Model	N	ES	Z	SD	%95 confidince interval		df	Q	P	I^2
					Belo	Above				
Random	43	0.363	3.546	0.10	0.162	0.564	42	1763.58	0.000	97.094
Fixed	43	0.311	24.824	0.01	0.286	0.335	42			

It is seen in Tablo 3 that the Q value is 1763.580. Since this value is greater than the chi-square value at 42 degrees of freedom and I^2 = 97.094, it is concluded that the studies show heterogeneous distribution (p=0.000). In order to determine whether the effect sizes of the studies included in the meta-analysis show a homogeneous distribution or not, p, Q veya I^2 values are taken into consideration. When the p value is smaller than 0.05 and the Q value is greater than df value, it is concluded that the studies are heterogeneous (Dinçer, 2014). The level of heterogeneity is also measured according to the I^2 statistical result. The I2 result is consider low if 25%, medium if 50% and high if 75% (Higgins, et al., 2003).

Now that the studies included in the analysis showed a heterogeneous distribution, the effect size (Cohen d) value was calculated with reference to the random effects model and evaluations were done accordingly. Based on the random effects model, the effect size value

is 0.363. Both effect size values are small and positive and statistically significant (p<.05). Considering the effect size value, it can be said that LMS-based instruction has a small effect on mathematics achievement.

The forest plot of 43 studies analyzed with the random effects model is given in Figure 3.

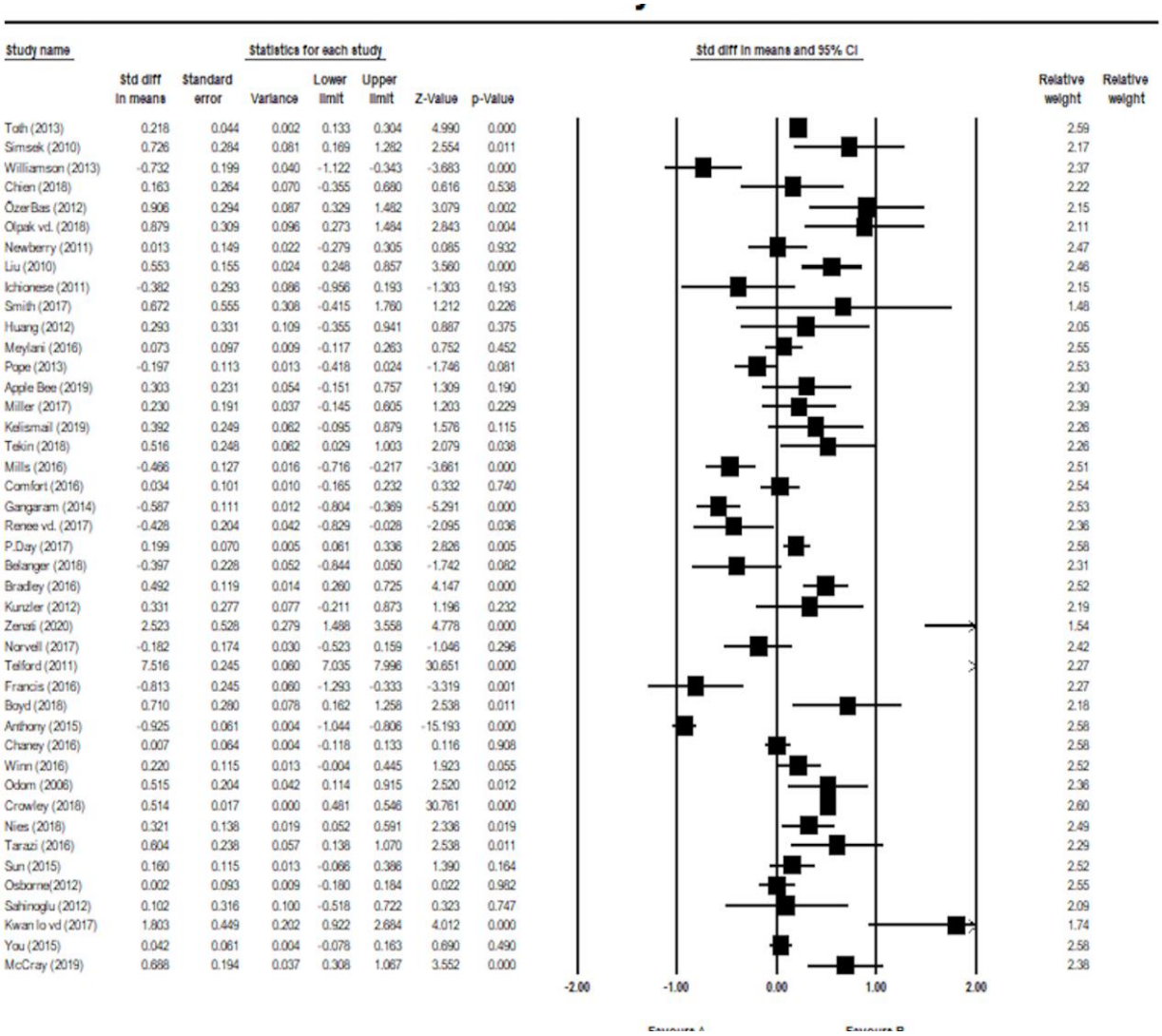

Figure 3. Forest Plot analyzed with the random effects model

A closer look at Figure 3 indicates that the largest effect size is 7,516 (Telford, 2011) and the smallest is -0.925 (Anthony, 2015). Considering the lower limit and upper limit values of the effect sizes, one can note that it varies between 1,293 (Francis, 2016) and 7,996 (Telford, 2011). It is seen that the p value is statistically significant (p<.05) in 23 studies included in the study, while 20 studies did not indicate statistical significance (p>.05). Based

on Thalheimer and Cook (2002), the classification of the effect sizes of the studies included in the forest chart is shown in Table 4.

Table 4. Effect Size Classification of Studies Included in Meta-Analysis

Effect Size Classification	Number of Studies
Insignificant	17
Small	10
Moderate	11
Strong	5
Total	43

Table 4 shows that there are 17 studies at an insignificant level, 10 at a small level, 11 at a moderate level and 5 at a strong level. Concerning the first problem statement of the study, the findings of 43 studies included in the meta-analysis with different effect sizes were combined and included in the analysis.

The difference between the effect sizes of studies investigating the effect of LMS use on mathematics achievement may depend on the independent variables of the studies included in the analysis. For this reason, the second subproblem "Does the overall effect of LMS use on mathematics achievement differ significantly by study subgroups (year of publication, country, sample group, duration of application, level of education, subject, type of publication, and method of application)?" was identified in this way. Depending on these variables, Analog Anova results are presented in Table 5.

Table 5. Sub-group analysis according to random effects model

					% 95 Confidence Interval				
Moderator	**Variable**	**N**	**ES**	**SE**	**Below**	**Above**	**df**	**QB**	**p**
Publication year	2006	1	0.515	0.204	0.114	0.915	11	94.404	0.000
	2010	2	0.592	0.136	0.325	0.859			
	2011	3	2.382	2.485	-2.488	7.252			
	2012	5	0.280	0.168	-0.051	0.610			
	2013	3	-0.204	0.245	-0.684	0.275			
	2014	1	-0.587	0.111	-0.804	-0.369			
	2015	3	-0.244	0.369	-0.967	0.480			
	2016	8	0.033	0.111	-0.185	0.251			
	2017	6	0.211	0.189	-0.159	0.581			
	2018	7	0.374	0.123	0.132	0.615			
	2019	3	0.493	0.127	0.243	0.743			

	2020	1	2.523	0.528	1.488	3.558			
	Total	43	0.162	0.047	0.070	0.253			
Country	Turkey	6	0.579	0.118	0.347	0.810			
	USA	31	0.359	0.139	0.087	0.631			
	China	3	0.440	0.536	-0.611	1.491			
	South Africa	1	0.013	0.149	-0.279	0.305	5	20.122	0.001
	Korea	1	0.042	0.061	-0.078	0.163			
	Hungary	1	0.218	0.044	0.133	0.304			
	Total	43	0.196	0.032	0.132	0.259			
Sample size	0-100	25	0.413	0.179	0.062	0.764			
	101-200	8	0.108	0.174	-0.234	0.449			
	201-300	6	0.531	0.189	0.162	0.901	3	3.060	0.382
	Above 301	4	0.246	0.298	-0.338	0.830			
	Total	43	0.330	0.098	0.137	0.523			
Duration of application	0-5	13	0.277	0.079	0.122	0.433			
	6-10	21	0.481	0.206	0.076	0.885			
	11-15	7	0.143	0.085	-0.024	0.310	3	3.257	0.354
	Above 16	2	0.017	0.348	-0.665	0.700			
	Total	43	0.229	0.055	0.121	0.337			
Level of Education	Primary	2	0.515	0.017	0.482	0.547			
	Secondary	11	0.146	0.108	-0.066	0.358			
	High School	11	0.070	0.206	-0.333	0.474	3	16.268	0.001
	University	19	0.651	0.207	0.244	1.057			
	Total	43	0.505	0.016	0.473	0.537			
Subject	Algebra	18	0.546	0.217	0.122	0.971			
	Operations	9	0.024	0.192	-0.352	0.400			
	Fraction	4	0.362	0.177	0.016	0.708			
	Probability	3	-0.099	0.359	-0.803	0.605			
	Integral	2	0.383	0.245	-0.099	0.864	11	36.253	0.000
	Derivative	1	0.726	0.284	0.169	1.282			
	Arithmetic and geometry	1	1.803	0.449	0.922	2.684			
	Cylinder	1	0.906	0.294	0.329	1.482			
	Measure	1	0.042	0.061	-0.078	0.163			
	Algebraic expressions	1	0.516	0.248	0.029	1.003			
	Quadrilateral and polygon	1	0.102	0.316	-0.518	0.722			
	Sequences	1	0.392	0.249	-0.095	0.879			
	Total	43	0.192	0.048	0.099	0.286			
Type of Publication	Article	6	0.427	0.133	0.166	0.688			
	National Thesis	4	0.451	0.135	0.187	0.716			
	International Thesis	33	0.324	0.133	0.063	0.584	2	0.518	0.772
	Total	43	0.400	0.077	0.249	0.551			
Method	Online	28	0.630	0.254	0.132	1.127			
	Blended	6	0.003	0.131	-0.254	0.259			
	Flipped	4	-0.060	0.153	-0.359	0.240	3	5.890	0.117
	Web-based	5	0.004	0.237	-0.460	0.468			

Total	43	0.055	0.086	-0.114	0.224

According to Table 5, when we examine the heterogeneity test results of the subgroups measured in accordance with the variable of publication year, it is seen that there is a significant difference between the subgroups (Q=94.404; p<.05). Based on this finding, it could be said that mathematics achievement in the use of LMS is affected by years. The highest effect size value is observed in a study conducted in 2020 and the lowest effect size in the studies conducted in 2014. It can be thought that the studies and dissemination activities on LMS in recent years have increased the effectiveness.

When the results from the variable of country are analyzed, it is noted that there is a significant difference between the subgroups (Q=20.122; p<.05). With regard to this finding, it can be argued that mathematics achievement varies in accordance with the country subgroup as a result of the LMS use. The highest effect size is seen in the studies conducted in Turkey and the lowest effect size is seen in the study conducted in South Africa.

As far as the findings from the variable of sample size are concerned, it is observed that there is no significant difference between the subgroups (Q=3.060; p>.05). This suggests that mathematics achievement as a result of using LMS is not affected by sample size. Similarly, the results from the variable of application time indicates no significant difference between the subgroups (Q= 3.257; p>.05). This points out that the application time has no effect on achieving mathematical success in the use of LMS.

The data from the variable of education level reveals that there is a significant difference (Q=16.268; p<.05). It is seen that the effect size values of the studies at the university level are higher than the effect sizes at other levels (primary school, secondary school, high school). It can be stated that the lowest effect size is in the studies at the high school level.

The findings obtained for the variable of subject displays that there is a significant difference between the subgroups (Q=36.253; p<.05). With reference to this result, it can be argued that mathematics achievement obtained with the use of LMS varies according to the subject of mathematics. Based on this data, it can be expressed that the highest effect size value is in the study that deals with arithmetic and geometry, and the lowest effect size value is in the study that deals with the subject of probability. Finally, no significant difference was

noted between the subgroups for the variable of type of publication (Q= 0.518; p>.05) and the method of application variable (Q= 5.890 ; p>.05).

This meta-analysis study aimed to investigate the effect of LMS use on mathematics achievement. After running the analysis based on the random effects model, it was revealed that the overall effect of the use of LMS on mathematics achievement was small (ES=0.363). The results obtained from the research demonstrates that the teaching carried out with the use of LMS does not increase student achievement at satisfactory levels. This finding is in compliance with that of Cheung and Slavin (2013) (ES=0.15). It can be argued that the evidence indicating that the role of LMS use in gaining mathematics achievement is not found to be highly essential might result from the abstract nature of the mathematics discipline and the fact that it requires real classroom practice involving physical-concrete activities.

The studies included in the present investigation are analyzed and compared among themselves and it was revealed that while some studies did not find a significant effect for LMS use on mathematics achievement (Anthony, 2015; Belanger, 2018; Francis, 2016; Gangaram, 2014; Ichinose, 2011; Mills, 2016; Norvell, 2017; Pope, 2013; Renee, 2017; Williamson, 2017), others suggested a significant effect for the use of LMS (Bradley, 2016; Kunzler, 2012; Meylani, 2016; McCray, 2019; Telford, 2011; Toth, 2013; You, 2015). In some meta-analysis studies examining the effects of different methods on mathematics achievement during the mathematics education, it is seen that similar effect sizes were obtained as in the current study. For instance, the findings that computer assisted instruction (Chadwick, 1997; Lee 1990; Li & Ma, 2010; Tokpah 2008; Young & Hamilton, 2018); the use of technology in instruction (Cheung & Slavin, 2013, Schenker, 2007) the smart education systems (Steenbergen-Hu & Cooper, 2013) had a very low impact on mathematics achievement are in line with the results of the present study. The effect size of these studies is quite small and does not account for the expected effect.

In this study, it was discovered that the effect of LMS use on mathematics achievement did not lead to significant difference among the groups for the variables of sample size, publication type, application method and duration of application. In this research, when the included studies are examined with reference to sample sizes, it is seen that the effect size values of the studies with small samples are higher than those with large samples. A closer look at the available literature shows that there are studies supporting this finding (Cheung & Slavin, 2013; Çelik, 2013; Young & Hamilton, 2018). In this study, it is seen that

flipped learning, blended learning, web-based learning and online learning methods are disputable because of the divergent results they produced. For example, it was demonstrated that while in some studies hybrid learning (Crowley, 2018; Francis, 2016; Korucu & Kabak, 2020; Renee, 2017; Winn, 2016; Zenati, 2020), flipped learning (Kwan lo & Foon, 2017; Tekin, 2018; Tarazi, 2016) and web based learning (Toth, 2013; Özerbaş, 2012) generated a positive effect on mathematics achievement, in other studies online learning methods had no effect on achievement (Anthony, 2015; Boyd, 2018; Chaney, 2016; Huang, 2012; Ichinose, 2011; Newberry, 2011; Norvell, 2017; Nies, 2018; Odom, 2006; Osborne, 2020; Pope, 2013; Şahinoğlu, 2012; Telford, 2011).

The results of the analysis yielded that the difference between the groups was significant for the variables of year of publication, country, education level and subject. When the effect size value is examined for the subject variable, it is shown that the highest effect size is in the study that deals with the subject of Arithmetic and Geometry. Chan and Leung (2014) researched computer assisted geometry teaching through the meta-analysis method and attained a high level of effect. Similarly, Deniz (2019) examined technology-assisted geometry teaching by employing a meta-analysis method and found a high effect size. It can be stated that these findings are in parallel with the findings of the current study.

Conclusions and Suggestions

Based on the results of this investigation, it can be claimed that LMS use has a small effect on mathematics achievement. This value shows that the use of LMS does not account for mathematics achievement at a high level, according to the results of 43 experimental studies involving 15.296 students. In this study, no significant difference was observed between the groups for the variables of sample size, duration of application, application method and publication type. On the other hand, it has been revealed that the effect of LMS on mathematics achievement differs significantly for the variables of year, education level, country and subject between subgroups.

In this direction, further research can focus on comparative studies of real course designs with virtual course designs. Additionally, considering that the use of LMS has a very small effect on mathematics achievement, and some negativities may have been mediated in terms of teacher knowledge, how the management system is used, student adaptation, and technological access, it can be suggested that this situation should be investigated with a qualitative methodology that provides more in-depth and detailed data.

It has been discovered that the use of LMS is more effective in the subject of Arithmetic and Geometry and at the university level. For this reason, especially the teaching activities on this subject can be supported by LMS and contribute to the increase in the mathematics achievement of undergraduate and graduate students. When the studies included in the meta-analysis are examined with reference to the type of publication variable, it has been uncovered that there are very few studies in the form of articles examining mathematics achievement in the use of LMS. Article studies examining mathematics achievement in the use of LMS can be prioritized. When the effect of LMS use on mathematics achievement is analyzed by country subgroup, studies conducted in Turkey have been shown to have a greater impact. The reasons for this strong effect in the use of LMS can be further investigated. This meta-analysis research covers studies between 2005-2020 and in a specific database. In new meta-analysis research, the study can be replicated by updating this time interval and expanding the databases. The present meta-analysis study examined the effect of LMS use on mathematics achievement. In future investigations, different disciplines can be identified as moderators and the results of LMS on mathematics and other disciplines can be compared.

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Öğrenme Yönetim Sistemi (ÖYS) Kullanımının Matematik Başarısına Etkisi: Meta-Analiz Çalışması

Özet:

Bu araştırmanın amacı, LMS (Learning Management System) kullanımının öğrencilerin matematik başarısına etkisini meta-analiz yöntemiyle incelemektir. Araştırmaya, 2005-2020 yılları arasındaki standart sapma, ortalama ve örneklem gibi verileri içeren 43 deneysel çalışma dahil edilmiştir. .Araştırmaya dahil edilen çalışmalardaki toplam örneklem sayısı 15.296'dır. Veriler Comprehensive Meta Analysis (CMA) yazılımı kullanılarak analiz edilmiştir.Rastgele etkiler modeline göre analiz yapıldıktan sonra, LMS kullanımının öğrencilerin matematik başarısı üzerindeki Cohen d etki değeri 0.363 olarak hesaplanmıştır. Bu etki büyüklüğü değerinin alt grup analizi sonuçlarına göre; LMS kullanımın matematik başarısı üzerindeki etkisinin örneklem, yayın türü, uygulama süresi ve uygulama yöntemi değişkenlerine göre alt gruplar arasında anlamlı olarak farklılaşmadığı görülmüştür. Diğer yandan, yıl, ülke, konu ve öğrenim düzeyi değişkenlerine göre alt gruplar arasında anlamlı bir farklılaşma olduğu bulunmuştur.

Anahtar kelimeler: Öğrenme yönetim sistemi, matematik başarısı, meta-analiz.

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Research Article

Pre-service Mathematics Teachers' Professional Self-Esteem and Beliefs about the Nature of Mathematics

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Abstract –This study aims to examine the professional self-esteem of pre-service primary school mathematics teachers in the context of their beliefs about the nature of mathematics. The study has a quantitative design and 220 pre-service mathematics teachers voluntarily participated in the study. In the data analysis of this study based on a quantitative research design, independent samples t-test, one-way ANOVA and multiple regression analyzes were performed and the Pearson correlation coefficient was determined. According to the findings of the study, professional self-esteem and belief about the mathematics' nature are not affected by gender and grade level. In addition, professional self-esteem of the pre-service teachers who believe that mathematics is a branch of science open to exploration, knowledge generation, and related to other sciences and daily life, may be said to be higher-positive than the professional self-esteem of the pre-service mathematics teachers who perceive mathematics as a set of unrelated concepts and formulas or believe that mathematics is a deductive and precise body of knowledge.

Key words: professional self-esteem, beliefs on the nature of mathematics, pre-service mathematics teachers

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Introduction

Teaching is accepted as a profession that requires high qualifications that can fully bear the responsibility of human life (Ministry of National Education (MNE), 2017, p.2). It is a known fact that teachers, who are the most vital element of the education system, should have high qualifications to meet these responsibilities and expectations. And this requires them to be individuals who are open to continuous development. Among these high qualifications, besides

professional knowledge and skills, the "attitude and values" competence expects teachers to respect individual and cultural differences, value each student, be a role model for students with their attitudes and behaviors, be empathetic and tolerant in human relations, do their profession lovingly and willingly, to make self-evaluation, be open to communication and cooperation, to protect professional commitment and dignity by complying with professional, ethical principles and more (MNE, 2017). These concepts and principles (competence indicators) are closely related to how the teacher perceives themselves and their profession and how s/he values their profession, in other words, the professional self-esteem of the teacher. On the other hand, the necessity of teachers to have particular competencies in the field they teach requires a mathematics teacher to ensure professional development as a mathematics teacher and to have attitudes and values in the context of mathematics teaching. This raises the question of whether the value and dedication a mathematics teacher attributes to the teaching profession in the context of professional self-esteem are affected by the nature of mathematics. Beliefs about mathematics' nature, in fact, form the basis of beliefs about learning and teaching mathematics (Dede & Karakuş, 2014). And this then affects teachers' instructional behaviors and decisions about teaching (Abrosse et al., 2004; Handal, 2003; Thompson, 1992). This study aims to examine the professional self-esteem of pre-service primary school mathematics teachers in the context of their beliefs about the nature of mathematics. The study examined whether gender and grade level variables made a difference in pre-service teachers' beliefs about the nature of mathematics and their professional self-esteem levels. The relationship between belief in the mathematics' nature and professional self-esteem was investigated.

Self-Esteem and Professional Self-Esteem

Self-esteem is an individual's evaluation of his or her own self. There are common elements used in the literature to define this concept. These elements make up the concept of competence, respect, worthiness, identity, belonging, security, etc. (Tabassum & Ali, 2012). Another important concept that can be evaluated as a reflection of self-esteem in an individual's life is professional self-esteem. The value and importance that an individual attributes to a profession is named professional self-esteem, even if it does not turn into a preference for herself/himself (Arıcak & Dilmac, 2003). Arıcak (1999) defined occupational self-esteem as "the individual's judgment of worthiness formed regarding the self-attributions accepted by the individual as related to the profession, whether or not it was transformed into a professional preference". It is stated that professional self-esteem is closely related to professional adaptation and professional satisfaction (Arıcak & Dilmaç, 2003). In fact, it was determined that pre-

school teachers with positive professional self-had developed empathic skills (Ceylan et al., 2009) that empathy is an essential skill for teachers to respond to the individual needs and differences of students. On the other hand, in a study conducted with teachers, it is found that professional self-esteem is closely related to professional burnout (Khezerlou, 2017). Khezerlou (2017) stated that this result means that a teacher with positive professional self-esteem will experience less emotional exhaustion, suffer less depersonalization, and spend more effort to succeed in their profession and improve themselves. On the other hand, it was determined that pre-active teachers with high professional self-esteem had increased life satisfaction (Aktac & Cetinkaya, 2019).

When examining the literature, it can be thought that there are more studies on teachers' professional self-esteem in the national literature compared to the international literature. It can be said that studies on professional self-esteem generally focus on health and education (e.g., Efilti & Çıkılı, 2017; Varol et a.,2020; Polat & Balaban, 2021). It is possible to say that especially pre-school (Polat & Balaban, 2021), special education (Efilti & Çıkılı, 2017), music (Tokinan, 2013), science (Aktaç & Çetinkaya, 2019), physical education, information technologies (Dursun et al., 2014) and primary education (Ünal & Şimsek, 2008), secondary education (Tabassum & Ali, 2012) teachers or pre-service teachers are studied in this field. While some of these studies directly examine the professional self-esteem of teachers or pre-service teachers, some of them examine professional self-esteem, self-esteem, attitude towards the profession (Altunay & Yazıcı, 2021), the type of appointment to the teaching profession (Kurt & Demirpolat, 2020), professional resilience belief (Dönmez & Kavuncuoğlu, 2019), professionalism (Polat & Balaban, 2021), and life satisfaction (Aktaç & Çetinkaya, 2019). It is possible to say that the study is new to the literature in terms of examining pre-service mathematics teachers' professional self-esteem by associating it with their belief in mathematics' nature.

Beliefs about the Nature of Mathematics

Beliefs are essential in learning and teaching mathematics (Ernest, 1989; Pajares, 1992; Thompson, 1992). Although there is no clear definition of belief in the literature (Beswick, 2005; McLeod & McLeod, 2002; Thompson, 1992), Philipp (2007) defined belief as understanding, assumption, or proposition that is considered to be true, and similarly, Richardson (1996) considered it as propositions that a person thinks to be true, Ponte (1994) as a phenomenon with solid emotional and selective components, which is a part of knowledge and shaped by experiences. Thompson (1992) claimed that belief equates to concepts,

meanings, propositions, rules, or mental images, while Schoenfeld (1985) stated that belief represents perceptions and cognitions. The common view in the definitions of belief in the literature is that belief is shaped by experiences (Ponte, 1994), it is personal (Philipp, 2007), it is based on emotional and cognitive (Pehkonen, 2004) foundations and can affect behaviors (Pajares, 1992; Philipp, 2007).

Belief in mathematics was expressed as reflecting experiences related to mathematical concepts (Hart, 1989; Thompson, 1984) and personal evaluations based on past experiences related to mathematics (Raymond, 1997). Researchers (Raymond, 1997; Op't Eynde et al., 2002) consider mathematical belief as beliefs about the nature of mathematics, learning, and teaching mathematics. Belief in the mathematics' nature is concerned with what mathematics does and its quality (Dede & Karakuş, 2014; Ernest, 1989). It was claimed that these types of beliefs are related to each other, and that belief in the nature of mathematics forms the basis of beliefs about learning and teaching mathematics (Dede & Karakuş, 2014; Philipp, 2007; Richardson, 1996; Thompson, 1992). Pajares (1992) emphasized that teachers' beliefs affect their perceptions, decisions, and performance in the lesson. Examining teachers' beliefs about mathematics can reveal their classroom activities, teaching processes, and classroom performances (Handal, 2003; Irez, 2007; Philippou & Christou, 1999). In that case, it is a matter of curiosity whether the belief in the mathematics' nature affects professional self-esteem (Altunay & Yazıcı, 2021), which affects the attitude towards the profession and motivation. In this sense, in the present study, determining the professional self-esteem of pre-service primary school mathematics teachers, who are the teachers of the future, in the context of their beliefs about the nature of mathematics was found to be important in terms of determining the possible effects of belief in the nature of mathematics, better recognizing the factors affecting professional self-esteem and making inferences for teacher education.

In this context, the questions to be answered in the study are:

1. Do primary school mathematics pre-service teachers' professional self-esteem and beliefs about the nature of mathematics differ significantly according to gender?
2. Do primary school mathematics pre-service teachers' professional self-esteem and beliefs about the nature of mathematics differ significantly according to grade level?
3. What is the relationship between primary school mathematics pre-service teachers' professional self-esteem and their beliefs about the nature of mathematics?
4. Do primary school mathematics pre-service teachers' beliefs about the nature of mathematics predict their professional self-esteem?

Method

Research Design

In this study, the survey model, one of the quantitative research methods, was used in the data collection process. The preferred survey model is the cross-sectional survey model (Fraenkel et al., 2012), in which the data are collected from the sample at once, and the relational survey model.

Sample Group

The study sample consisted of 220 pre-service teachers studying in the Department of Primary Mathematics Education of a university in the west of Turkey in the 2019-2020 spring semester. Of the 174 female and 46 male pre-service teachers, 60 are in the first grade, 47 are in the second grade, 57 are in the third grade, and 56 are in the fourth grade. Since the sample selection in the research is vital in representing the research results or significance in similar situations, the study group was determined according to the purposive sampling method, which is one of the non-random sampling methods. Here, too, the easily accessible case sampling method was preferred based on voluntariness. In the easily accessible sampling method, the researcher chooses close and easy to reach people for speed and practicality purposes (Merriam, 2009). Accordingly, all pre-service teachers studying in a mathematics education undergraduate program of a faculty were sent an invitation to participate, only 220 pre-service teachers volunteered to participate in the study.

Data Collection Tools and Process

In the study, validity and reliability studies were conducted as data collection tools, and two different scales were used: the "Professional Self-Esteem Scale" developed by Arıcak (1999) and the "Belief Scale About the Nature of Mathematics" developed by Akyıldız and Dede (2019).

Mathematics Self-Esteem Scale: This scale, developed by Arıcak (1999), consists of 30 items. 14 of these items contain positive and 16 negative statements. The scale is in 5-point Likert type as "Strongly Agree (5)", "Agree (4)", "Undecided (3)", "Disagree (2)", and Strongly Disagree (1)". The lowest score possible on the scale is 30, and the highest score is 150. The scale has three dimensions: "Accepting the Profession", "Valuing the Profession", and "Belief in the Functionality of the Profession". The scale was applied to the study group to re-determine the validity and reliability values and the Cronbach alpha reliability coefficient was determined to be 92.

The scale of Belief in the Nature of Mathematics: This scale, developed by Akyıldız and Dede (2019), consists of 41 items. The scale is in 5-point Likert scale as "Strongly Agree (5)", "Agree (4)", "Undecided (3)", "Disagree (2)" and "Strongly Disagree (1)". High scores obtained from the scale represent more advanced beliefs about the nature of mathematics. The scale has two dimensions: "Associated Belief" and "Dissociated Belief". Associated belief encompasses progression-oriented mathematics and function-oriented mathematics viewpoints obtained from semantic content analysis, while dissociated belief encompasses tool-oriented mathematics and goal-oriented mathematics perspective. Progress-oriented belief is focused on discovering mathematics and producing knowledge and is intertwined with other sciences. Function-oriented belief evaluates mathematics as a tool in daily life and is used to meet daily life needs. Tool-oriented belief, on the other hand, considers mathematics as the sum of unrelated concepts, operations, formulas, and rules, whereas goal-oriented belief considers mathematics as a systematic and completely abstract science consisting of definite information based on deduction (Akyıldız & Dede, 2019). The scale was applied to the study group to re-determine the validity and reliability values, and the Cronbach alpha reliability coefficient was found to be 84.

The study data were collected in the 2019-2020 spring semester, which coincided with the pandemic. Since the universities had distance education then, the pre-service teachers' data were collected via e-mail. The scales used in the study were created on the Google Forms platform and sent to the pre-service teachers' e-mails, and the researcher informed them about the voluntary basis and the confidentiality of the participants. In addition, the researcher stated that there is no time limit for the pre-service teachers to answer the items on the scale. It was accepted that the pre-service teachers answered the statements on the scale correctly and sincerely.

Data Analysis

SPSS 20.0 package program was used to analyze this research, which has a quantitative research design. In this study, independent samples t-test was used to determined the total scores of the participants' professional self-esteem and beliefs about the nature of mathematics and the scores of its sub-dimensions differed significantly by gender, One Way ANOVA was used to reveal whether there was a significant difference between the total scores and sub-dimensions of pre-service mathematics teachers' professional self-esteem and belief in mathematics in terms of grade level, and correlation analysis was used to determine the relationships between the pre-service mathematics teachers' beliefs about the nature of mathematics and their professional

self-esteem and its sub-dimensions were conducted. In addition, multiple regressions were conducted to determine the predictive power of pre-service teachers' beliefs about the nature of mathematics, associated and dissociated belief sub-dimensions on the professional self-esteem.

Findings

Whether pre-service teachers' professional self-esteem and beliefs about the nature of mathematics differed significantly according to gender and grade levels was determined by one-way ANOVA in this study. In addition, the correlation between pre-service teachers' professional self-esteem and their beliefs about the nature of mathematics was analyzed by correlation.

Investigation of Pre-service Teachers' Professional Self-Esteem and Beliefs on the Nature of Mathematics in Terms of Gender Variable

Whether the total scores of the participants' professional self-esteem and beliefs about the nature of mathematics and the scores of its sub-dimensions differed significantly by gender was determined by the Independent samples t-test (Table 1).

Table 1. *Descriptive Statistics Results on Occupational Self-Esteem and Its Sub-Dimensions in terms of Gender and Belief in the Nature of Mathematics and its Sub-Dimensions*

The scales	Sub-Dimensions	Gender	N	$\overline{X}$	Ss	df	t	p
Professional Self-Esteem	Accepting the job	Female	174	54.5115	54.5115	218	1,106	,270
		Male	46	53,0217	9,40801			
	Valuing the profession	Female	174	41,8391	4,57531	218	2,631	,009*
		Male	46	39,7174	5,84109			
	Believing in the functionality of the profession	Female	174	24,6667	2,76295	218	1,030	,304
		Male	46	24,1739	3,31531			
	Total	Female	174	121,0172	13,57892	218	1,737	,084

		Male	46	116,9130	16,57284			
Belief in the nature of mathematics	Associated Belief	Female	174	119,0920	11,64368	218	2,584	,010
		Male	46	114,2826	9,45554			
	Dissociated belief	Female	174	35,9253	5,21782	218	-1,835	,068
		Male	46	37,6087	6.60800			
	Total	Female	174	155,0172	12,17762	218	1,591	,113
		Male	46	151,8913	10,51608			

*p< .05, p>.05

As seen in Table 1, the mean of professional self-esteem of the females in the total score ($\overline{X}$ =121.01), is higher than the mean of males ($\overline{X}$ =116.913). However, this difference between occupational self-esteem total scores by gender is insignificant, t (218)= 1.737, p>.05. The average of the females' scores in professional acceptance, which is the sub-dimension of professional self-esteem ($\overline{X}$ =54.51), is higher than the mean of males ($\overline{X}$ =53.02). However, the difference between the total scores in this sub-dimension according to gender is insignificant, t (218)= 1.106, p>.05. The average of the females believing in the functionality of the profession, one of the sub-dimensions of professional self-esteem ($\overline{X}$ =24.66), is higher than the mean of males ($\overline{X}$ =24.17). However, the difference between the total scores in this sub-dimension according to gender is also insignificant, t (218)= 1.030, p>.05. The average of females valuing the profession, one of the sub-dimensions of professional self-esteem ($\overline{X}$ =41.83), is higher than the mean of males ($\overline{X}$ =39.71). The difference between the total scores of only this sub-dimension according to gender is significant, t (218)= 2.631, p<.05. Therefore, valuing the profession only in the sub-dimension for professional self-esteem varies between females and males; that is, females value their profession more than males. The effect of gender on professional self-esteem r^2 was calculated as r^2=0.013. According to this, 1.3% of the variance in the professional self-esteem of pre-service teachers was due to gender. According to Cohen (1988), this was accepted as a minor effect.

As seen in Table 1, the average of the females in total scores in belief in the nature of mathematics ($\overline{X}$ =155.01), is higher than the mean of males ($\overline{X}$ =151.89). However, this

difference between the total scores in belief in the nature of mathematics by gender is insignificant, t (218)= 1.591, p>.05. The average of the females' scores in dissociated belief, which is the sub-dimensions of belief in the nature of mathematics ($\overline{X}$ =35.92), is lower than the average of males ($\overline{X}$ =37.60). However, the difference between the total scores in this sub-dimension according to gender is insignificant, t (218)= 1.106, p>.05. The average of the females' scores in the associated belief, which is one of the sub-dimensions of belief in the nature of mathematics ($\overline{X}$ =119.09), is higher than the average of males ($\overline{X}$ =114.28). The difference between the total scores of only this sub-dimension according to gender is significant, t (218)= 2.631, p<.05. Therefore, from the belief about the nature of mathematics, only the associated belief differs between females and males; that is, girls think mathematics is more progress-oriented and function-oriented than boys do. The effect of gender on belief in the nature of mathematics r^2 was calculated r^2=0.011. Accordingly, 1.1% of the variance in the pre-service teachers' belief in the nature of mathematics originated from gender. According to Cohen (1988), this was accepted as a minor effect.

Investigation of Pre-service Teachers' Professional Self-Esteem and Beliefs on the Nature of Mathematics in Terms of Gender Variable

A One-Way ANOVA analysis was used to reveal whether there was a significant difference between the total scores and sub-dimensions of pre-service mathematics teachers' professional self and belief in mathematics in terms of grade level (Table 2).

Table 2. One-Way ANOVA Results on Occupational Self-Esteem and Its Sub-Dimensions and Belief in the Nature of Mathematics and Sub-Dimensions Scores in Terms of Grade Level

The scales	Sub-Dimensions	References	Sum of squares	Sd	Average of Squares	F	p
Professional Self-Esteem	Accepting the job	Intergroup	551,779	3	183,926	2,853	, 038*
		In-group	13923,421	216	64,460		
		Total	14475,200	219			
	Valuing the profession	Intergroup	148,159	3	49,386	2,062	,106
		In-group	5172,437	216	23,946		
		Total	5320,595	219			
	Believing in the	Intergroup	10,015	3	3,338	,397	,755

	functionality of the profession	In-group	1814,094	216			
		Total	1824,109	219			
	Total	Intergroup	1183,704	3	394,568	1,951	,122
		In-group	43687,728	216	202,258		
		Total	44871,432	219			
Belief in the nature of mathematics	Associated Belief	Intergroup	914,779	3	304,926	2,403	,069
		In-group	27404,580	216	126,873		
		Total	28319,359	219			
	Dissociated Belief	Intergroup	567,299	3	189,100	6,577	,000*
		In-group	6210,787	216	28,754		
		Total	6778,086	219			
	Total	Intergroup	786,205	3	262,068	1,874	,135
		In-group	30200,704	216	139,818		
		Total	30986,909	219			

*p< .05, p>.05

As seen in Table 2, the total mean score of professional self-esteem of pre-service teachers did not show significant differences according to grade level (p>.05). When the sub-dimensions of professional self-esteem were examined, a significant difference was observed in accepting the profession according to the grade level (p<.05), but no significant difference was observed in other sub-dimensions according to grade levels. It was determined that the total score of belief in the nature of mathematics did not differ significantly according to grade levels (p>.05). There was a significant difference between the pre-service teachers according to the grade level in dissociated belief, one of the sub-dimensions of the belief in the nature of mathematics (p<.05), but no significant difference was observed in associated beliefs according to grade level (p>.05). Which of the post-hoc multiple comparison techniques will be used to determine the difference between the scores in accepting the profession and dissociated belief according to grade levels was decided by the Levene test, and it was determined that the variances in accepting the profession were not homogeneous. For this sub-dimension, F(3, 216)= 3.713, p>.05 value was found. Dunnet C test results were used to find the source of the difference

between the groups. The results revealed a significant difference between 1st and 4th grades in accepting the profession, in favor of 4th graders, p<.05. In other words, 4th graders accepted the profession more than 1st graders. As for dissociated belief, since the variances are homogeneous, F(3, 216)= 0.769, p>.05 values were reached. In this case, Tukey test results from post-hoc multiple comparison analyzes were examined to find the source of the difference between the groups. The results revealed a significant difference between the 2nd and 3rd grades in favor of the 2nd grade and between the 2nd and 4th grades in favor of the 2nd grade, p<.05. In other words, 2nd graders thought that mathematics was more means and ends-oriented than 3rd and 4th graders.

Investigation of the Relationship Between Pre-service Teachers' Professional Self-Esteem and Beliefs on the Nature of Mathematics

The Pearson Correlation Coefficient was calculated to determine the relationships between the education faculty students' beliefs about the nature of mathematics and their professional self-esteem and its sub-dimensions (accepting the profession, valuing the profession, and believing in the functionality of the profession). The analysis results are in Table 3.

Table 3. *Results Regarding the Determination of the Relationship Between Belief in the Nature of Mathematics and Professional Self-Esteem and Its Sub-Dimensions by Pearson Correlation Coefficient*

The scales	Belief in the nature of mathematics	Associated Belief	Dissociated belief
Professional Self-Esteem	.369**	.449**	-.129

**p<0.05*

As seen in Table 3, there is a positive but weakly significant (r = .369, p< .05) relationship between pre-service teachers' professional self-esteem and their total beliefs about the nature of mathematics. In addition, there is a positive but weakly significant (r = .449, p< .05) relationship between professional self-esteem and associated belief, and a negative weakly insignificant (r = -.129, p. >.05) relationship between dissociated belief.

Investigation of Pre-service Teachers' Beliefs on the Nature of Mathematics Predicting Professional Self-Esteem

Multiple regressions were performed to reveal the effect of the change in beliefs about the nature of mathematics and its sub-dimensions (associated and dissociated beliefs) on the professional self-esteem of pre-service teachers (Table 4).

Table 4. *Multiple Regression Analysis Results on the Prediction of Belief in the Nature of Mathematics on Occupational Self-Esteem*

Variable	B	Std. Error	Std. Beta	t	p	R	R^2
Belief in the nature of mathematics	.444	.076	.369	5.865	.000	.369	.136
Associated Belief	.566	.076	.449	7.427	.000	.449	.202
Dissociated Belief	-.332	.173	-.129	-1.923	.056	.129	.017

As seen in Table 4, when the multiple regression analysis of belief in the nature of mathematics and the sub-dimensions associated belief and dissociated belief predict professional self-esteem, it was found that belief in the nature of mathematics predicted professional self-esteem statistically (F= 34,401, R= .369, R 2= .136, p<.05). Accordingly, it was observed that belief in the nature of mathematics explained approximately 13% of the total variance regarding professional self-esteem. In other words, as pre-service teachers' beliefs about the nature of mathematics increase, their professional self-esteem also increases. In addition, while the associated belief, one of the sub-dimensions of belief in the nature of mathematics, statistically predicted professional self-esteem (F= 55.161, R= .449, R 2= .202, p<.05), dissociated belief was not a statistically significant predictor (F= 3.699, R= .129, R 2 = .017, p>.05). These findings were found to explain approximately 20% of the total variance regarding professional self-esteem. In other words, as the associated beliefs of pre-service mathematics teacher increase, their professional self-esteem also increases.

Discussion, Conclusion, and Suggestions

The current study examined the professional self-esteem of primary school mathematics pre-service teachers in the context of their beliefs about the nature of mathematics. When their professional self-esteem was evaluated independently of their beliefs about the nature of mathematics, it was determined that gender did not influence the professional self-esteem of primary school mathematics teachers. These results differ from the results of the research in the literature that female teachers develop more positive professional self-esteem than male teachers (Güleç & Özbek Ayaz, 2017; Tabassum & Ali, 2012; Ünal & Şimşek, 2008). Although few, it should be said that there are also studies supporting that professional self-esteem does not make a difference between the genders (e.g., Dursun et al., 2014; Efilti & Exit, 2017). However, in this study, a difference was found in favor of female pre-service mathematics

teachers valuing the profession dimension, a sub-dimension of professional self-esteem. In this context, it is possible to say that female mathematics pre-service teachers value the profession more than males. In studies claiming that gender is a variable that makes a difference, females' professional self-esteem was found to be higher in general (Güleç & Özbek Ayaz, 2017; Tabassum & Ali, 2012; Ünal & Şimşek, 2008). However, in the study conducted by Yıldırım et al. (2010), the professional self-esteem of male physical education teachers was found to be higher than that of females. These results raise the question of whether the effect of gender on professional self-esteem is related to the subject of teaching. However, no significant difference was found in the professional self-esteem of the candidates according to their grade levels. This is consistent with Tokinan's (2013) study results that teaching experience and practice courses do not affect the professional self-esteem of pre-service music teachers. At the same time, this finding can be evaluated as consistent with the conclusion that the affective education course taught with creative drama does not significantly influence the professional self-esteem of pre-service teachers, as observed in the study conducted by Akdemir (2020). However, as the grade level progressed, it was observed that the pre-service teachers' professional acceptance increased. This means that pre-service teachers accept the profession more over time and with the education they get in faculties. Therefore, although it does not affect valuing the profession and believing in its functionality, it may suggest that undergraduate education has an effect on accepting the profession.

Examining a pre-service mathematics teacher's professional self in the context of his belief in the nature of mathematics is important in showing whether the belief in the nature of mathematics will affect the perception of mathematics teaching and the professional attitudes and behaviors of the individual. According to the current study's findings, it can be said that belief in the nature of mathematics significantly predicts professional self-esteem, and there is a significant but weak relationship between them. In particular, it was determined that dissociated beliefs did not predict professional self, and there was no relationship between them. It was determined that associated belief influences professional self-esteem, and there is a significant but weak relationship between them. When these results are interpreted according to Akyıldız and Dede's (2019) definition of belief in the nature of mathematics, it can be concluded that the professional self-esteem of pre-service teachers who have a progression and function-oriented mathematics perspective is higher than that of who have a means and end-oriented mathematics perspective. This means that pre-service teachers who believe that mathematics is a branch of science that is open to exploration, knowledge generation, and

related to other sciences and daily life have more positive professional self-esteem. On the other hand, it can be said that the professional self-esteem of the pre-service teachers who perceive mathematics as a set of unrelated concepts and formulas or who believe that mathematics is a deductive and definite body of knowledge is lower than the other pre-service teachers. Therefore, the finding that a pre-service teacher's belief influences professional self-esteem, which influences many other factors such as enjoying life, empathy skills, attitude towards the profession, and professional burnout, is significant. However, when the pre-service teachers' beliefs about the nature of mathematics are evaluated within themselves, it can be said that pre-service female teachers have more associated beliefs than males; that is, they believe that mathematics focuses on progress and function. It was observed that the dissociated belief with a tool-oriented and goal-oriented mathematics perspective adopted by pre-service mathematics teachers at the 2nd-grade level decreased in the pre-service teachers of the 3rd and 4th grades. As the grade level progresses, the decrease in the level of dissociated beliefs can be perceived as a positive result in the belief in the nature of mathematics in professional self-esteem. Considering that the acceptance of the profession and the tendency to associated beliefs increase according to the grade level, these results may suggest the positive effect of the undergraduate education received. As mentioned before, teachers need to have positive professional self-esteem to have the professional competencies determined by the Ministry of National Education (2017), fulfill their responsibilities, improve themselves, and be motivated for this. Based on the conclusion that the belief in the nature of mathematics obtained through the study influences professional self-esteem, it is considered important to systematically plan and employ teaching and practices that will positively affect the belief in the nature of mathematics as well as the view on the profession in teacher education. As a matter of fact, it is known that teacher education affects teachers' beliefs in mathematics (Raymond, 1993).

The question of why female pre-service mathematics teachers values the profession more than males and have an associated belief about the nature of mathematics, obtained in this study, can be answered with qualitative studies that illuminate these quantitative data. It can be thought that the different effects of gender on occupational self-esteem observed in the literature may be affected by the culture of belonging or the micro-culture created by people belonging to the profession. As a matter of fact, it can be thought that professional self-esteem, which is the subject of an affective field, may be influenced by the personal experiences of the individual and the culture of the society in which s/he lives. In this context, studies examining prospective teachers' professional self-esteem and beliefs about the nature of mathematics in different cultures are important to observe the effect of culture on concepts. In addition, studies aimed at

understanding the relationship between professional self-esteem and important affective factors such as social and socio-mathematical norms and values that may affect professional self-esteem are valuable in terms of improving the quality of undergraduate education in this direction.

Matematik Öğretmen Adaylarının Mesleki Benlik Saygısı ve Matematiğin Doğasına Yönelik İnançları

Özet:

Bu çalışmanın amacı ilköğretim matematik öğretmen adaylarının mesleki benlik saygılarının adayların matematiğin doğasına ilişkin inançları bağlamında incelenmesidir. Çalışma nicel tasarıma sahiptir ve 220 öğretmen adayı çalışmaya gönüllü olarak katılmıştır. Çalışmanın veri analizinde bağımsız örneklemler t testi, tek yönlü ANOVA ve çoklu regrasyon analizleri yapılmış ve pearson korelasyon katsayısı belirlenmiştir. Araştırmada elde edilen bulgulara göre, mesleki benlik saygısı ve matematiğin doğasına yönelik inancın cinsiyetten ve sınıf düzeyinden etkilenmediği tespit edilmiştir. Ayrıca matematiğin keşfetmeye, bilgi üretmeye açık, diğer bilimlerle ve günlük hayatla ilişkili bir bilim dalı olduğuna inanan öğretmen adaylarının mesleki benlik saygılarının, matematiği ilişkisiz kavramlar, formüller bütünü olarak algılayan veya matematiğin tümdengelimli, kesin bilgiler bütünü olduğuna inanan adayların mesleki benlik saygılarından daha olumlu olduğu söylenebilir.

Anahtar kelimeler: mesleki benlik saygısı, matematiğin doğasına yönelik inanç, matematik öğretmen adayları

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Research Article, Review

The Current State of Turkish STEM Research: A Systematic Review Study

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Abstract – In the 21st century, STEM education is gaining importance day by day. In this study, the purpose was to reveal the content analysis of master's thesis and dissertations conducted on STEM education in the field of science education in the last five years in Turkey. A total of 117 theses and dissertations, 18 of which were dissertations and 99 of which were theses, were examined in terms of academic discipline, theoretical frameworks, instructional design models, research designs and models, research areas, statistical analyses, keywords, data collection tools, participants, variables/research focuses and related institutions. In this respect, the present study, which examined the theses and dissertations, is thought to be important with respect to revealing the current situation in the field of science education in Turkey and determining the research trends for researchers.

Key words: science, dissertation, thesis, STEM, content analysis

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Introduction

STEM was formed by combining the initial letters of the concepts of Science, Technology, Engineering and Mathematics. STEM is an educational approach in which individuals identify problems from pre-school to higher education levels with an interdisciplinary approach and which aims to help produce practical and accurate solutions to these problems. This approach prioritizes learning based on research and inquiry by

emphasizing the feelings of curiosity that actually exists in individuals but has become blunt over time. Individuals are expected to transform their knowledge into products and to solve problems by stimulating their sense of curiosity (Altunel, 2018).

The purpose of STEM education is to bring together the disciplines of science, technology, engineering and mathematics. Thus, STEM education aims to train individuals who ask questions, produce solutions with creative thinking and turn solutions into products. It could be stated that STEM education incorporates technology and using technology in education has a positive effect on motivation. Considering the direct contribution of motivation to learning, STEM education could be said to make positive contributions to learning. Another point is that good-quality STEM education can transform students from being passive to being active in lessons. It could be stated that activating students will also stimulate productivity and originality and thus increase students' desire to learn. Another advantage of STEM education is that it supports the transformation of the acquired theoretical knowledge into practice. At the same time, considering the competition on a global scale, it should be emphasized that individuals should be trained in a way to acquire the STEM skills (Eroğlu & Bektaş, 2016). Figure 1 presents the distribution of the numbers of STEM-related studies in the Scopus database by year.

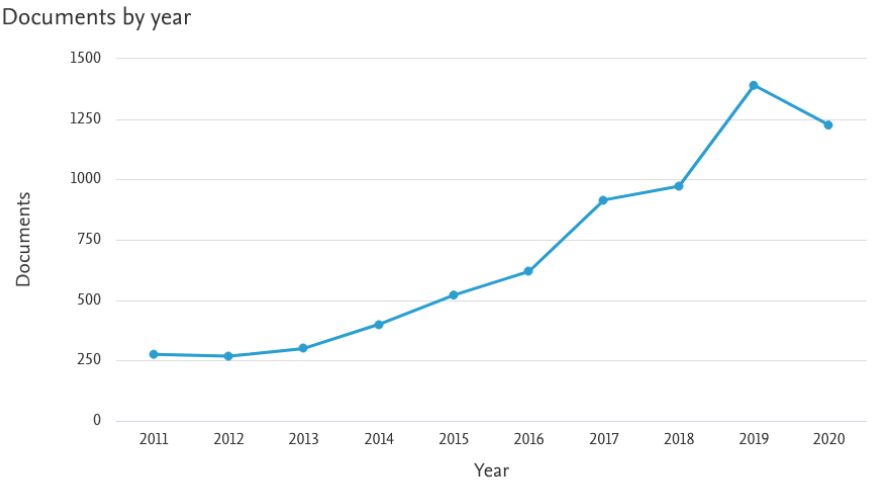


Figure 1. The numbers of STEM-related studies by year

According to Figure 1, it could be stated that there has been a tremendous increase in the number of studies conducted in the last 10 years. It was seen that a lot of research was conducted in the field of STEM, especially until 2019.

Review Studies About STEM

In the literature, there are many content analysis and meta-analysis studies carried out in the field of STEM. The distribution of the studies between 2016-2020 by year, number of studies and prominent research findings is as follows.

Table 1. STEM research in literature

Author(s)	Highlights of Research Findings	Years	Number of papers
Ormancı (2020)	Mostly preferred method: Mixed method. Mostly preferred data collection tool: Interview form Mostly preferred dependent variable: Academic success Mostly preferred participant type: K-12 students	-2020	30 dissertations
Josh Brown (2012)	Mostly preferred participant type: K-12 students University with the most studies: Purdue University	2007-2010	60 articles
Çevik (2017)	Mostly preferred method: Qualitative method Mostly preferred participant type: Undergraduate students Mostly preferred topics: STEM Evaluation University with the most studies: Gazi University intensely years: 2016	2014-2016	34 articles
Kaleci and Korkmaz (2018)	Mostly preferred method: Qualitative method Mostly preferred participant type: K-12 students Mostly preferred data collection tool: Document analysis Mostly preferred dependent variables: Attitude, precision, perception, attention	2009-2018	40 articles
Aydın Günbatar and Tabar (2019)	Mostly preferred method: Qualitative method Mostly preferred participant type: K-12 students Mostly preferred data collection tool: Scale Mostly preferred dependent variables: Attitude and opinion	-2018	67 articles
Güntaş et al. (2019)	Mostly preferred method: Qualitative method Mostly preferred dependent variable: Attitude	2009-2018	95 articles
Zengin et al. (2020)	Mostly preferred data collection tool: Scale Mostly preferred dependent variables: Attitude, perception, belief	2014-2019	40 articles
Kaya and Ayar (2020)	Mostly preferred method: Qualitative method Mostly preferred participant type: Teacher Mostly preferred dependent variable: Opinion	2011-2020	50 articles
Elmalı and Balkan Kıyıcı (2017)	Mostly preferred method: Qualitative method Mostly preferred data collection tool: Scale Mostly preferred dependent variable: Academic success	2013-2016	50 articles and 5 theses
Daşdemir et al. (2018)	Mostly preferred method: Qualitative method Mostly preferred participant type: K-12 students Mostly preferred data collection tool: Tests Universities with the most studies: Gazi University, Middle East Technical University and Yüzüncü Yıl University intensely years: 2017	2012-2017	32 articles, 13 theses and 6 dissertations
Çavaş et al. (2020)	Mostly preferred method: Quantitative method Mostly preferred participant type: K-12 students Mostly preferred data collection tool: Scale Mostly preferred dependent variables: Ability University with the most studies: Kastamonu University intensely years: 2018	2010-2018	52 articles, 39 theses and 6 dissertations
Bozkurt et al. (2019)	Mostly preferred method: Quantitative method Mostly preferred data collection tool: Questionnaire	2014-2016	258 articles
Jayarajah et al. (2014)	Mostly preferred method: Qualitative method İntensely years: 2012 Mostly preferred participant type: Graduates (University)	1999-2013	57 articles

Göktepe Yıldız and Özdemir (2015)	Mostly preferred method: Quantitative method Mostly preferred participant type: K-12 students İntensely years: 2014	2010-2015	51 articles
Li et al. (2020)	Mostly preferred method: Quantitative method İntensely years: 2018	2000-2018	798 articles
Kartika et al. (2021)	Mostly preferred participant type: K-12 students İntensely years: 2010, 2012, 2014	2010-2019	86 articles

When the Table 1 is examined in general, it is seen that only three of the content analysis studies partially examined the dissertations. Most of the content analyses in the table were applied on the articles. In terms of method, qualitative methods were used most in the studies, which was followed by quantitative methods. In the studies examining the data collection tools, it was seen that the most common data collection tool was scale with a rate of 50%, which was followed equally by interview form, document analysis, test and questionnaire. In the studies examining dependent variables, attitude was found as the dependent variable with the highest rate (45%), which was followed by academic success with a rate of 22%. The dependent variables of opinion and ability were equally distributed at 11%. In the studies examining the type of participant, it was seen that the most common type of participant was K-12 students with a rate of 73%. The participant type of K-12 students was followed equally by undergraduate students, teachers and graduates (university) with a rate of 9%.

There are academic studies on STEM education, which has become widespread in Turkey recently. In order for researchers who want to study on STEM to have an idea about the current situation, it is known that there is a need for studies compiling the studies carried out with the content analysis method on STEM with certain features. When the content analysis studies on STEM education were examined, it was seen that there were studies that compiled master's thesis and dissertations. However, it was revealed that there were no content analysis studies on STEM in science education. Therefore, it is thought that in order to overcome this deficiency in the literature, compiling the studies on STEM in science education will provide convenience to researchers who will study on STEM in the field of science education in the future. In this respect, the purpose of this study is to reveal the content analysis of master's thesis and dissertations conducted on STEM education in the field of science education in the last five years in Turkey.

Method

In this study, a systematic review (Gough et al., 2012) was used to identify the research trends in STEM education. Researchers made use of content analysis (Wilson, 2011). In the study, content analysis was conducted for theses and dissertations in the field of STEM in

science education in Turkey between the years 2016-2020. These theses and dissertations were reached through the National Thesis Center database. The National Thesis Center database is an electronic database which contains all the theses and dissertations conducted in Turkey and which allows researchers to benefit from the permitted theses and dissertations. While reviewing the literature, the following criteria were taken into consideration for the relevant theses and dissertations:

1. Being included in the database of the National Thesis Center,
2. Being conducted between 2016-2020,
3. Being a thesis or dissertation,
4. Having permission to access.

The search for determining the theses and dissertations was done by using the conjunctions of "and" and "or" within the scope of the selected keywords and by choosing the field of Education and Training.

A total of 121 permitted theses and dissertations were reached by using the keywords of "science" and "STEM" or "FETEMM". FETEMM is the Turkish translation of STEM. In addition, four of them were excluded from the scope of the study for various reasons. These reasons included the fact that there were studies not related to STEM and that there were studies not related to STEM in general though STEM was mentioned in their section of literature review. After the thesis and dissertation studies that were not related to the scope of this study were excluded, a total of 117 permitted studies, 18 of which were dissertations and 99 were theses, were reached.

In order to find answers to the research questions, the content analysis method was used and the related theses and dissertations were examined within the scope of various variables. Figure 2 presents the general research flow.

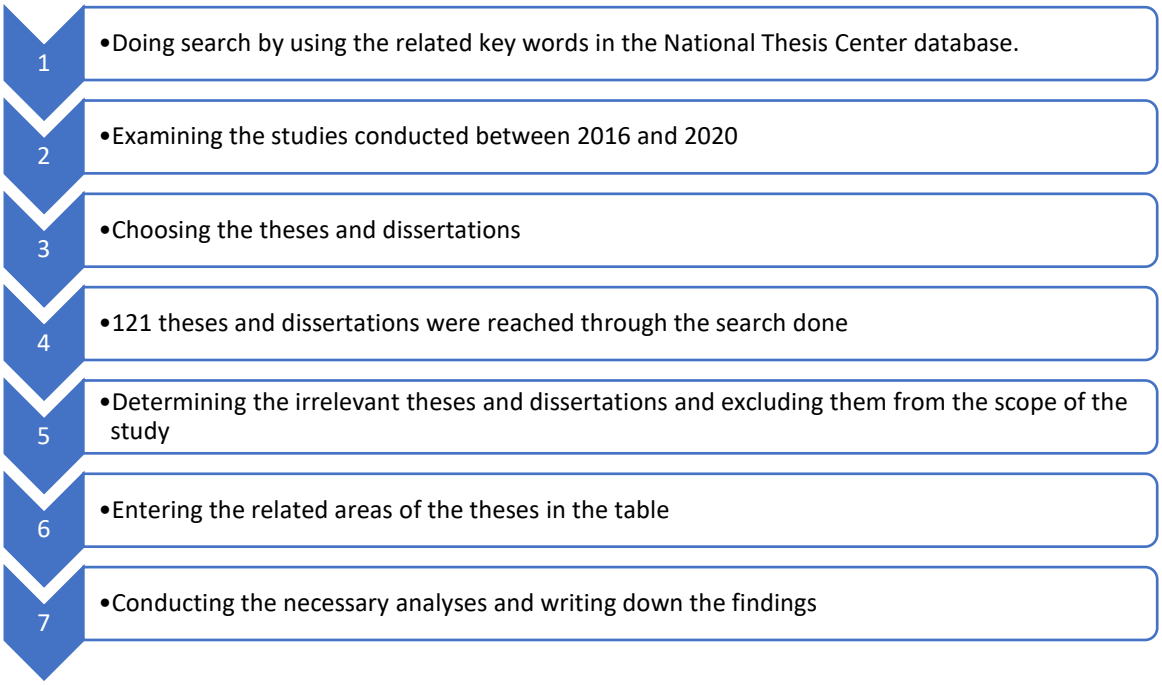


Figure 2. Diagram of the research process

Reliability

A table was prepared according to the criteria determined with the theses and dissertations reached as a result of the search, and each researcher analyzed the theses and dissertations separately and transferred the results they obtained to their own table. Afterwards, these tables prepared by the researchers were compared, and the differences were identified. Next, the related theses were examined again. A consensus was reached on all the findings, and the content analysis was completed.

Findings and Discussions

In this part of the study, the results are presented.

Keywords

The keywords used in the theses and dissertations within the scope of the study were analyzed. The results obtained are given in Figure 3

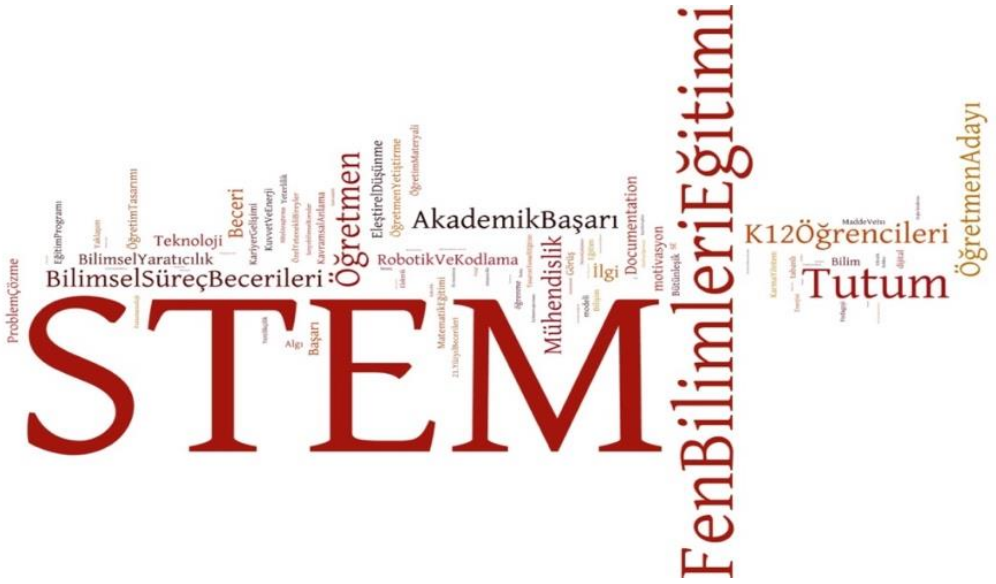


Figure 3. Keywords in the theses and dissertations

When Figure 3 was examined, the most frequently used keyword in the theses and dissertations was determined as "STEM", which was followed by the keywords of “Science education (Fen Bilimleri Eğitimi)” , “Attitude (Tutum)”, “K12 students (K12 Öğrencileri)”.

Academic Discipline

It was seen that 99 theses and 18 dissertations within the scope of this study were conducted in the field of Education and Training.

Theoretical/Conceptual Framework

Among the theses and dissertations examined, only 12 studies were found to be grounded on a theoretical basis. These theoretical foundations were as follows: entrepreneurship, innovation, science education, STEM education. No theory was found in 105 theses and dissertations examined within the scope of the present study.

Research Design

The research designs used in the theses and dissertations were discussed in four categories: quantitative, qualitative, mixed and practice-based. The distribution of these categories is given in Figure 4.

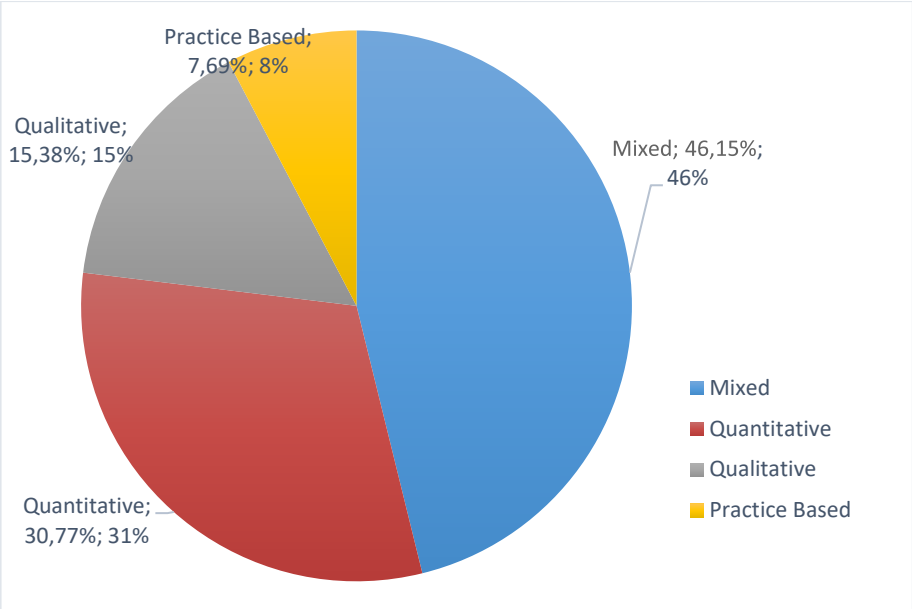


Figure 4. Research designs in theses and dissertations

The percentages and frequencies for all the methods are shown in Table 2.

Table 2. Distribution of STEM publications by research method and model/design

Method	F	%	Model/Design	F	% Cum	% Total
Quantitative	36	30,77	Survey	7	19,44	5,98
			Correlational	3	8,33	2,56
			Experimental	26	72,22	22,22
			Meta analysis	0	0	0
			Causal comparative	0	0	0
Qualitative	18	15,38	Descriptive	0	0	0
			Case study	0	0	0
			Ethnography	10	55,56	8,55
			Phenomenology	0	0	0
			Grounded theory	7	38,89	5,98
			Narrative	0	0	0
			Content analysis	0	0	0
			Meta-synthesis	1	5,56	0,85
			Delphi	0	0	0
			Historical	0	0	0
			Heuristic	0	0	0
			Discourse analysis	0	0	0
Mixed	54	46,15	Explanatory sequential	7	12,96	5,98
			Exploratory sequential	0	0	0
			Convergent parallel	36	66,67	30,77
			Embedded	10	18,52	8,55
			Multiphase	0	0	0
			Transformative	1	1,85	0,85

Practice based	9	7,69	Design based research	3	3,33	2,56
			Action research	6	66,67	5,13
Other / Theoretical / Descriptive	0	0	Literature review	0	0	0
			Position paper	0	0	0
			Opinion paper	0	0	0
			Report	0	0	0
			Field notes	0	0	0
			Comparative	0	0	0
			Reflection paper	0	0	0
			Systematic review	0	0	0
			Technical papers	0	0	0
			Narrative review=Lit.review	0	0	0
Network analytics / Digital / Innovative	0	0	Log analysis	0	0	0
			Social network analysis	0	0	0
			Learning analytics	0	0	0
			Text (data) mining	0	0	0
			Internet and traffic ranks	0	0	0

As a result of the analysis of the data included in the study, among the theses and dissertations conducted in the field of STEM in Turkey between 2016-2020, 47% were carried out with the mixed design (N=54); 31% with the quantitative design (N=36); 15% with the qualitative design (N=17); and 7% were carried with the practice-based design (N=9). The results of the analysis revealed that mixed methods were used more. Ormancı (2020) supports this finding, while Çevik (2017), Keeper and Korkmaz (2018), Aydın-Günbatar and Tabar (2019), Güntaş et al. (2019), Kaya and C.Ayar (2020), Elmalı et al. (2017), Daşdemir et al. (2018) and Jayarajah et al. (2014) concluded that there were more qualitative studies and Çavaş et al. (2020) Bozkurt et al. (2019) Yildiz et al. (2015) and Li et al. (2020) concluded that quantitative methods were used more.

Table 3. Research Designs by Year

Research design	2016	2017	2018	2019	2020	**Total**
Qualitative	1	1	4	12	-	**18**
Quantitative	-	4	7	18	7	**36**
Mixed	2	2	9	29	12	**54**
Practice-based	-	1	1	6	1	**9**
Total	**3**	**8**	**21**	**65**	**20**	**117**

According to Table 3, it could be stated that the number of theses and dissertations increased especially after 2019. A graphical representation of Table 1 is given in Figure 5.

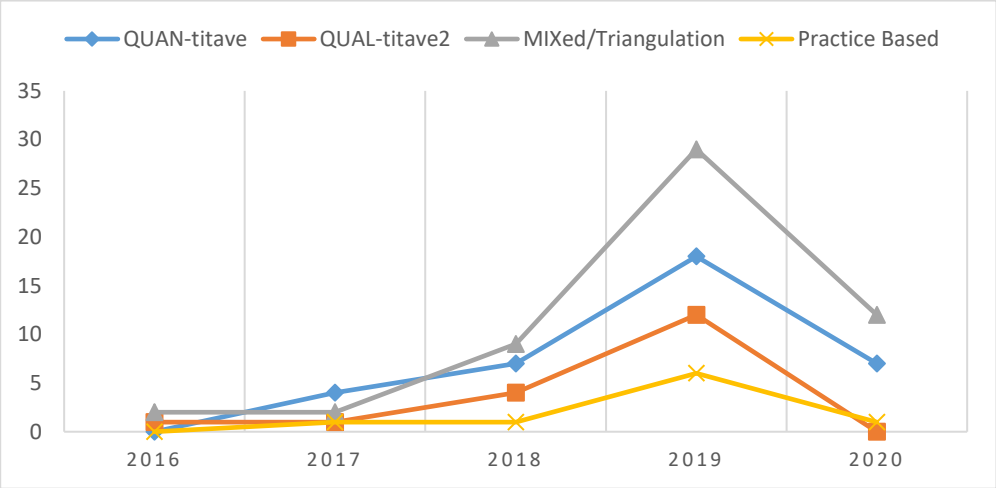
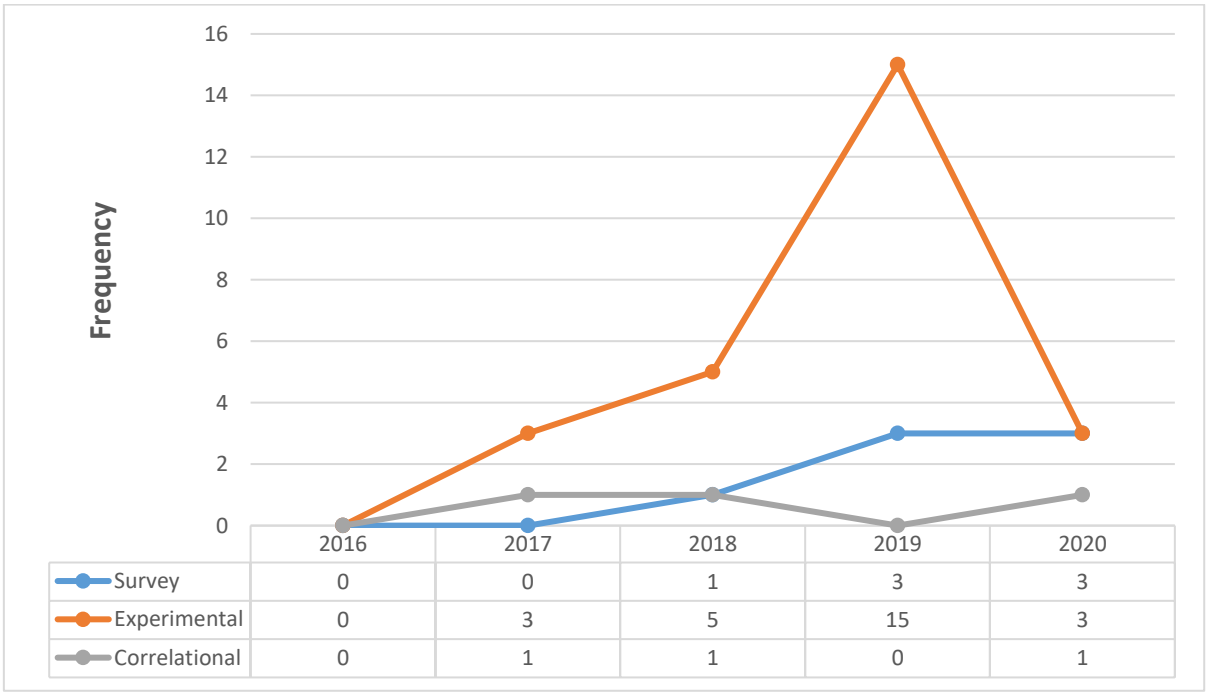


Figure 5. Distribution of research designs by years

According to Figure 5, when the distribution of the research designs was examined by year, it was seen that the first study was conducted using a qualitative and mixed design in 2016. In addition, in 2019, there was a remarkable increase in the number of theses and dissertations included in the scope of the present study.

Research Model

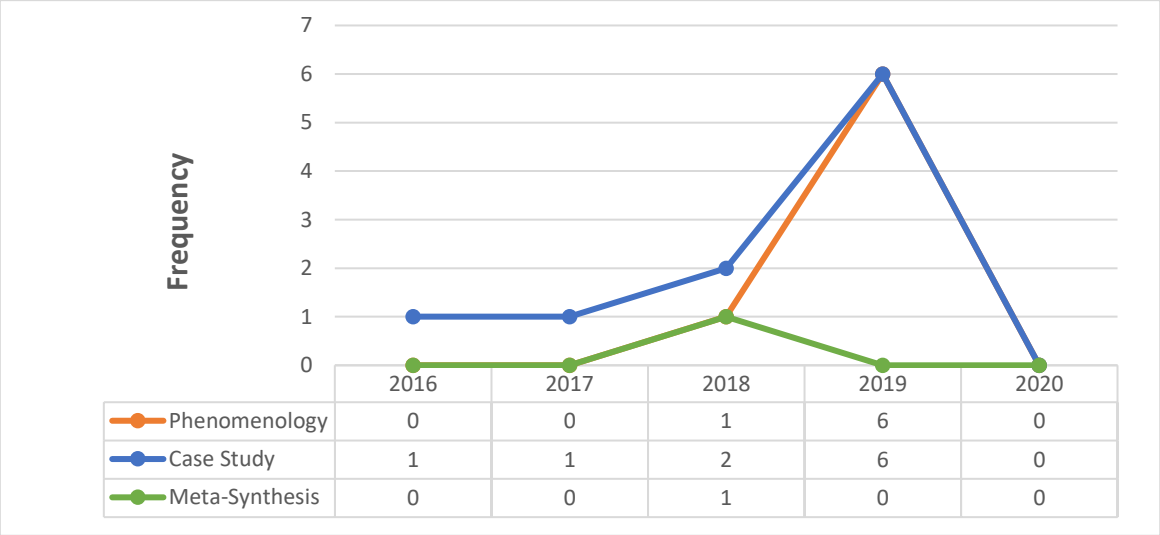
Under this title, the four research models were evaluated within themselves, and the related findings have been presented in comparison with the other findings in the literature.



	2016	2017	2018	2019	2020
Survey	0	0	1	3	3
Experimental	0	3	5	15	3
Correlational	0	1	1	0	1

Figure 6. Distribution of Quantitative Methods by year

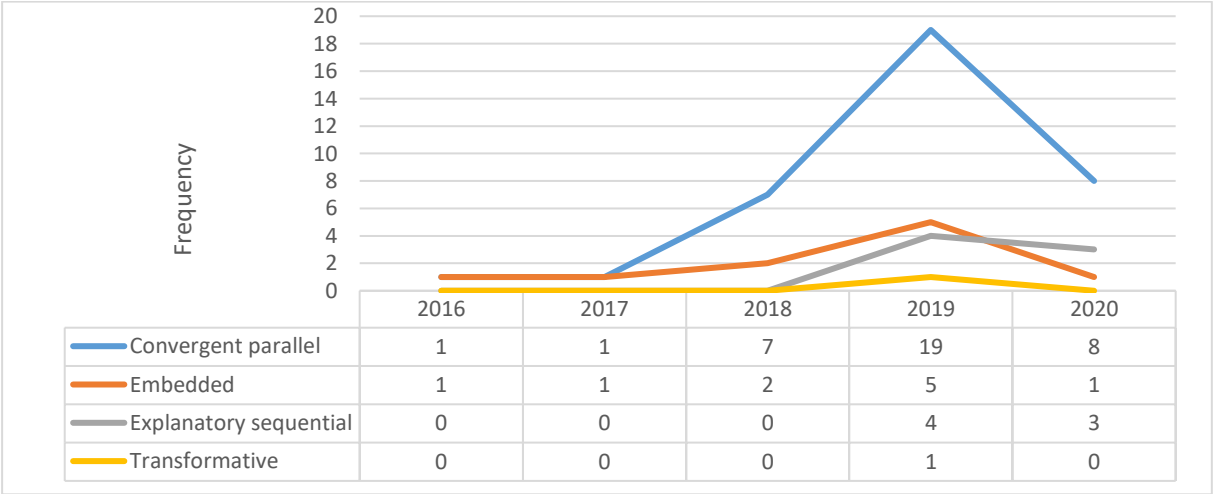
In the theses examined within the scope of the study, it was revealed that the first study with the quantitative method was carried out in 2017. In studies conducted with quantitative methods, the experimental method (N=18) was used most, and the correlational method (N=3) was used least. Çavaş et al. (2020), Bozkurt et al. (2019), Yıldız et al. (2015) and Li et al. (2020) concluded that quantitative methods were used more.



	2016	2017	2018	2019	2020
Phenomenology	0	0	1	6	0
Case Study	1	1	2	6	0
Meta-Synthesis	0	0	1	0	0

Figure 7. Distribution of Qualitative Methods by year

In the theses and dissertations examined within the scope of the study, it was seen that the first study in which qualitative methods were used was carried out in 2016. In studies conducted with qualitative methods, the case study method (N=9) was used most. This finding was supported by Ormancı (2020), while Çevik (2017), Kaleci and Korkmaz (2018), Aydın-Günbatar and Tabar (2019), Güntaş et al. (2019), Kaya and C.Ayar (2020), Elmalı et al. (2017), Daşdemir et al. (2018) and Jayarajah et al. (2014) concluded that qualitative studies were used more.



	2016	2017	2018	2019	2020
Convergent parallel	1	1	7	19	8
Embedded	1	1	2	5	1
Explanatory sequential	0	0	0	4	3
Transformative	0	0	0	1	0

Figure 8. Distribution of Mixed Methods by year

In the theses and dissertations examined within the scope of the study, it was found that the first study using mixed methods was carried out in 2016. Convergent parallel method (N=36) was used most in the studies conducted with mixed methods.

In the theses and dissertations examined within the scope of the study, it was seen that the first study using design-based research methods was carried out in 2017. The convergent parallel method (N=36) was used most in studies conducted with design-based research methods.

Analysis of the findings revealed that the researchers mostly preferred the Mixed research method (46%), which was followed by Quantitative methods (31%), Qualitative methods (16%), and Application-based (8%) methods, respectively. Explanatory sequential design (n = 7), embedded design (n = 10), convergent parallel design (n = 36) and transformative design (n = 1) were used in mixed method studies. Among the quantitative methods, experimental (n = 26), Survey (7%) and Correlation (n=3) research models were used. Qualitative methods (17%) were the third most preferred research paradigm, and in this paradigm, case study (n = 10), Phenomenology (n=7), Metasynthesis (n=1) were the leading research models. Lastly, after the design-based research (n = 3) and action research (n = 6) approaches, the application-based research methods (8%) were found to be the least preferred method.

Tests and Analysis

In Table 4, the analysis of the analysis techniques in the theses and dissertations included in the scope of the present study were given as numbers and percentages. According to the data in the table, descriptive statistics were used in 41% of quantitative statistical tests, and inferential statistical methods were used in 59% of them.

Table 4. Test and Analysis

QUANTITATIVE					
Statistical Tests					
Descriptive (%41)		**Inferential (%59)**			
		Parametric (%45)		**Non-Parametric (%14)**	
Central Tendency	39	t-test	56	Chi-square	3
Relative Standing (Percentage/z-scrore)	28	Variance Analysis (Anova/Manova/Mancova)	20	Mann Whitney U	17
Variability (Variance/Standard Deviation/Range)	26	Reliability Analysis (Cronbach's Alfa)	19	Wilcoxon Test	16
		Correlation (Pearson)	3		
Descriptive Statistics (Non-Specified)	23	Factor Analysis (Confirmatory/Exploratory)	30	Kruskal Wallis	4
		Regression Analysis	1		

QUALITATIVE	
Content Analysis	34 (%100)
Thematic Analysis	0

When Table 4 was examined, it was seen that most of the descriptive statistics consisted of central tendency statistics such as mean/median and mode. This was followed by the percentage and z-score values and variability statistics such as variance/standard deviation and range. Most of the inferential statistics included parametric tests. Among the parametric tests, the t-test and factor analysis were the most prominent. When non-parametric tests were examined, it was found that Mann Whitney U and Wilcoxon tests were predominantly used.

Data Collection Tools

In Table 5, the analyses of the data collection tools in the theses and dissertations included in the scope of this study were presented as numbers and percentages. According to the data in the table, the most preferred data collection tools were pretest – posttest (n=65), interview (n=60) and scale (n=51), respectively.

Table 5. Data Collection Tools

Data Collection Tools	**Frequency**	**Percentage**
Pre-test / Post-test	65	%28
Interview	60	%26
Scale	51	%22
Questionnaire	22	% 1
Observation	19	% 8
Documents analysis	8	% 3
Recorded audio	2	% 8
Focus group	1	% 4
TOTAL	**228**	**100**

It was seen that the use of pre-test and post-test as a data collection tool was preferred much more than other data collection tools. These findings were supported by Daşdemir et al. (2018), while Aydın-Günbatar and Tabar (2019), Zengin et al. (2020), Elmalı et al. (2017) and Çavaş et al. (2020) reported that scale, one of the data collection tools, was used more; Bozkurt et al. (2019) concluded that the most used data collection tool was the questionnaire; Ormancı (2020) found that the interview form was the most frequent data collection tool; and Kaleci and Korkmaz (2018) pointed out that the most used data collection tool was document analysis.

Participants

In Table 6, the analysis of the participant groups in the theses and dissertations included in the scope of the study was given as numbers and percentages.

Table 6. Participants

Participants	Frequency	Percentage
K12-Students	77	%60
K12-Teachers	28	%22
Undergraduate Students	16	%12
System/Program	4	% 3
K12-Administrators	1	% 1
Academicians	1	% 1
TOTAL	**127**	**100**

When the data in the table were examined, it was seen that K-12 students (N=77), K-12 teachers (N=28) and undergraduate students (N=16) were in the top three and constituted approximately 98% of all the participants. Accordingly, the sample of K-12 students was preferred more than other samples. These findings were reported by Ormancı (2020), Josh Brown (2012), Kaleci, Korkmaz (2018), Aydın-Günbatar and Tabar (2019), Daşdemir et al. (2018), Çavaş et al. (2020), Yıldız et al. (2015) and Kartika et al. (2021), while Çevik (2017) stated that the most used sample was Undergraduate students. In addition, Kaya, C.Ayar (2020) reported that the most used sample was K-12 teacher, and Jayarajah et al. (2014) concluded that the most used sample was Graduates (University).

Variables/Research Interests

The theses and dissertations examined were categorized as dependent variables and listed according to their frequencies as shown in Table 7.

Table 7. Variables / research interests

Variables / research interests	Frequency	Percentage
Attitude	42	%25
Success	39	%24
Perception	22	%13
Skill	16	%10
Motivation	14	%9
Opinion	13	%8
Attendance	9	%5
Self-efficacy	5	%3
Effectiveness	3	%2
Competence	2	%1
Total	**165**	**100**

According to Table 7, "attitude" (25.4%) was used most as a dependent variable in 42 studies. The variable of “attitude” was followed by “success” (23.6%), “perception” (13.3%), “skill” (9.6%) and “motivation” (8.5%) in 39 studies. The data revealed that researchers studied on the dependent variable of attitude more than other variables. These findings were supported by Kaleci and Korkmaz (2018), Aydın-Günbatar and Tabar (2019), Güntaş et al. (2019), Zengin et al. (2020), while Ormancı (2020) and Elmalı et al. (2017) reported that the most researched dependent variable was academic success. In addition, Kaya and C.Ayar (2020) found that the most researched dependent variable was opinion, and Çavaş et al. (2020) concluded that the most researched dependent variable was ability. Lastly, Çevik (2017) pointed out that the most researched topic was STEM evaluation.

Leading Contributor Institutions

The universities were ranked from the highest to the lowest number of theses and dissertations, and the top 10 universities in the ranking are given in Figure 9.

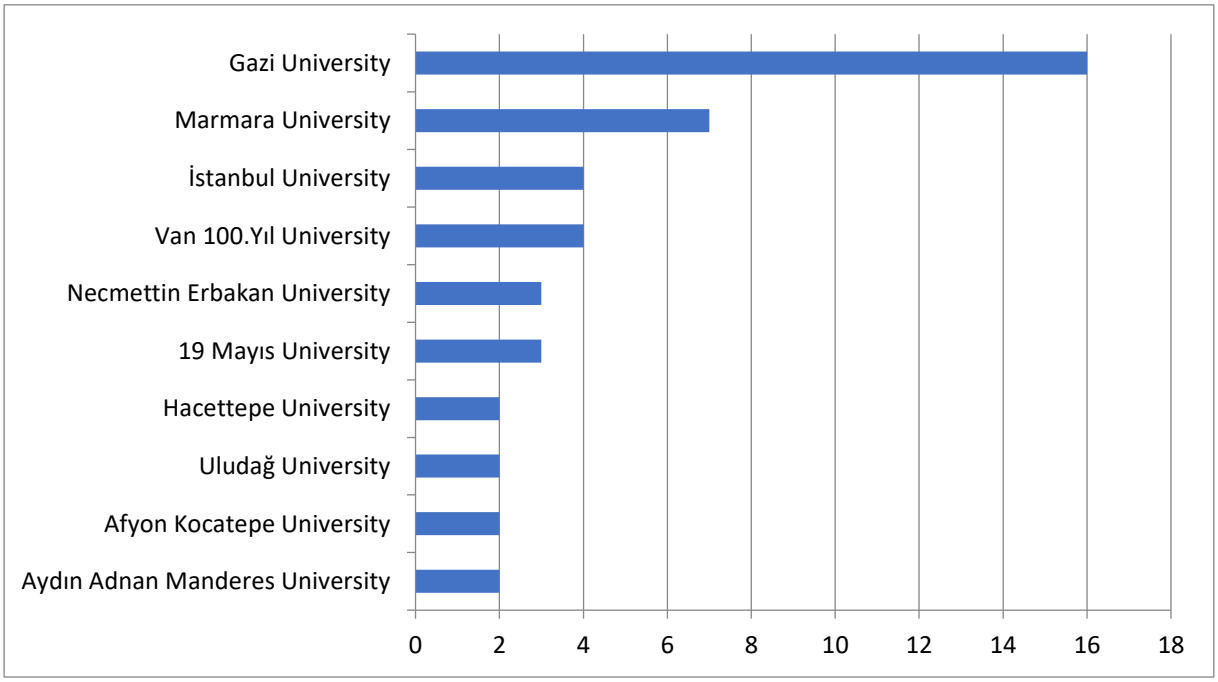


Figure 9. Leading Contributor Institutions

It was seen that Gazi University and Marmara University were the leading universities in terms of the number of theses and dissertations in the field of STEM. These two universities were followed by İstanbul University and Van 100.Yıl University. These findings were supported by Çevik (2017) and Daşdemir et al. (2018), while Josh Brown (2012) reported that Purdue University had the highest number of studies. In addition, Çavaş et al. (2020) concluded that the university with the highest number of studies was Kastamonu University.

Limitations and Strengths

Within the scope of our study, the database of National Thesis Center was searched, and 121 theses and dissertations with access permission were reached. In addition, four theses and dissertations were excluded from the scope of the study for various reasons such as the fact that there were studies not related to STEM and that there were studies not related to STEM in general though STEM was mentioned in their literature sections. These reasons can be considered as the limitation of our study.

This study revealed the current state of STEM studies in Turkey by examining the theses and dissertations from a multi-dimensional perspective which were conducted in the last five years. It is known that there were studies in this field analyzing the content of theses and dissertations until 2015, but the present study is considered to be important because it is the first study to examine both theses and dissertations after 2015. In addition, it is thought that the findings of the study will make an important contribution to the literature and future studies.

Conclusions and Suggestions

In this study, theses and dissertations on STEM studies in science education between 2016-2020 were examined in terms of various variables and research tendencies. It was seen that the theses and dissertations covered in the study were in the field of Education and Training. It was also seen that the keyword of "STEM" was used more frequently than other keywords in the theses and dissertations examined. On the other hand, no keywords were used in two theses and dissertations, and only 12 of the theses and dissertations were based on a theoretical basis.

When the frequency of use of the research design in the theses and dissertations examined was examined, it was seen that the most frequent method was the Mixed method and the least was the practice-based method. When the studies included in the scope of the present study and conducted in the last five years (2016-2020) were examined, it was seen that the designs increased until 2020. The mixed method studies increased more, and this method was preferred more than others. Theses and dissertations on STEM studies in science education were conducted at most in 2019. It was revealed that there was a serious decrease in the studies in 2020. The reason for this decrease could be the Coivd19 pandemic, which broke out in 2020. STEM education is one that requires practice. Conducting STEM studies via distance education will be much more difficult than via face-to-face education. In this respect, it could be thought that the number of theses and dissertations decreased as of 2020. Based on this situation, it should not be thought that the topic of STEM lost its importance. In the studies conducted with the mixed method, it was seen that the convergent parallel method was used most and the

transformative method was used least. However, there was an increase in convergent parallel, embedded, explanatory sequential and Transformative methods in 2019. In the studies conducted with the quantitative method, the experimental method was used most, and the correlational method was used least; in addition, there was a significant increase in the studies carried out with the experimental method in 2019. In studies conducted with the Qualitative method, the case study method was used most, and the Meta-Synthesis method was used least. On the other hand, there was a significant increase in case study and Phenomenology methods in 2019. In the studies carried out with the practice-based design, the Action research method was used most, and the Design-Based research method was least. In addition, the practice-based design was used most in studies in 2019. It was seen that researchers did not use other / theoretical / descriptive, network analytics / digital / innovative methods. In the studies examined, when analyzing the data obtained with the quantitative method, the researchers preferred the Inferential statistical methods more frequently; parametric tests, one of Inferential statistical methods, were used more frequently; and t-test, one of parametric tests, was used more. In addition, when analyzing the data obtained with the Qualitative method, the researchers preferred the content analysis method. This finding was supported by Ormancı (2020), while Çevik (2017), Kaleci and Korkmaz (2018), Aydın-Günbatar and Tabar (2019), Güntaş et al. (2019), Kaya and Ayar (2020), Elmalı et al. (2017), Daşdemir et al. (2018) and Jayarajah et al. (2014) reported that there were more qualitative studies; on the other hand, Çavaş et al. (2020), Bozkurt et al. (2019) Yildiz et al. (2015) and Li et al. (2020) concluded that quantitative methods were used more.

In the studies examined, it was revealed that the use of Pre-test/Post-test as a data collection tool was more frequent than other data collection tools. The data collection tool of Pre-test/Post-test was followed by interview and scale. These findings were supported by Daşdemir et al. (2018), while Aydın-Günbatar and Tabar (2019), Zengin et al. (2020), Elmalı et al. (2017) and Çavaş et al. (2020) reported that the data collection tool of Scale was used more; Bozkurt et al. (2019) concluded that the most used data collection tool was the questionnaire; Ormancı (2020) found that the interview form to be data collection tool used most; and Kaleci and Korkmaz (2018) pointed out that the most used data collection tool was document analysis.

It was seen that the researchers investigated the dependent variable of attitude more than the other dependent variables. The dependent variable of attitude was followed by the dependent variables of success, perception and skill, respectively. These findings were

supported by Kaleci and Korkmaz (2018), Aydın-Günbatar and Tabar (2019), Güntaş et al. (2019) and Zengin et al. (2020), while Ormancı (2020) and Elmalı et al.(2017) reported that the most researched dependent variable was academic success; Kaya, C.Ayar (2020) found that the most researched dependent variable was opinion; Çavaş et al. (2020) concluded that the most researched dependent variable was ability; and Çelik (2017) pointed out that the most researched topic was STEM evaluation.

It was seen that the researchers preferred the K12-students sample group more than the other sample groups. The sample of K12-students was followed by K12-teachers and undergraduate students, respectively. These findings were supported by Ormancı (2020), Josh Brown (2012), Kaleci, Korkmaz (2018), Aydın-Günbatar and Tabar (2019), Daşdemir et al. (2018), Çavaş et al. (2020), Yıldız et al. (2015) and Kartika et al. (2021), while Çelik (2017) reported that the most used sample was Undergraduate students; Kaya, C.Ayar (2020) found that the most used sample was K-12 teachers; and Jayarajah et al. (2014) concluded that the most used sample was Graduates (University).

Gazi University was the one which conducted the highest number of studies on STEM studies in science education. Gazi University was followed by Marmara University, Istanbul University and Van 100.Yıl University, respectively. In addition, the highest number of studies at Gazi University took place in 2019. These findings were supported by Çevik (2017), Daşdemir et al. (2018), while Josh Brown (2012) reported that Purdue University had the highest number of studies. On the other hand, Çavaş et al. (2020) concluded that the university with the highest number of studies was Kastamonu University.

STEM Araştırmalarında Güncel Eğilimler: Sistematik Tarama Çalışması

Özet:

21. yüzyılda, STEM eğitimi her geçen gün önem kazanmaktadır. Bu çalışmada fen bilimleri eğitimi alanında STEM çalışmaları konusunda son 5 yılda yapılmış yüksek lisans ve doktora tezlerinin içerik analizinin ortaya konulması amaçlanmıştır. 18'i doktora 99'u yüksek lisans olmak üzere toplam 117 yüksek lisans ve doktora tezi, akademik disiplin, kuramsal çerçeveler, öğretim tasarım modelleri, araştırma desen ve modelleri, araştırma alanları, istatistiksel analizler, anahtar kelimeler, veri toplama araçları, katılımcılar, değişkenler/araştırma odakları ve ilgili kurumların belirlenmesi amacıyla incelenmiştir. Bu doğrultuda yüksek lisans ve doktora tezlerinin incelendiği bu çalışmanın Türkiye'deki Fen Bilimleri eğitimi alanında STEM çalışmaları konusunda mevcut olan durumun ortaya çıkarılması ve araştırmacılar için araştırma eğilimlerinin belirlenmesi yönünden önemli olduğu düşünülmektedir.

Anahtar kelimeler: fen bilimleri, doktora tezi, tüksek lisans tezi, STEM, içerik analizi.

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Research Article

Content Analysis of the APOS Theory Studies on Mathematics Education Conducted in Turkey and Internationally: A Meta-Synthesis Study

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Abstract – This study aimed to review the APOS Theory, which was developed within the context of conceptual understanding as one of the main aims of mathematics education, studies in the field of mathematics education. The studies with Turkey and international samples related to the APOS Theory were subjected to descriptive content analysis, and a systematic summary was presented. As a result of the analysis, three themes, namely the purpose of using the theory, the use of genetic decomposition, and the aim of the study were identified. There are descriptive studies (39%) in the literature that determine the mental structures and mechanisms rather than the structure of mathematical concepts. Such studies are weak in terms of the theory's aim of reinforcing conceptual understanding.

Key words: APOS Theory, conceptual understanding, concept teaching, mathematics education.

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1. Introduction

Conceptual understanding must be acquired in order to gain a full understanding of mathematical concepts and to ensure meaningful learning. In this context, mathematics learning theories are effective tools in interpreting students' work and needs (Trigueros & Possani, 2013). There are two characteristics that should be present in a theory in mathematics education. First, a theory must try to understand how mathematics can be learned. Second, it should reveal what can be done to improve mathematics teaching programs (Dubinsky &

McDonald, 2001). One of the learning theories that has these characteristics and that was developed specifically for mathematics education is the APOS Theory.

The main aim of the APOS Theory is to reveal how a mathematical concept is structured in the mind of an individual and to develop activities pertaining to the way to be followed in teaching (Arnon et al., 2014). In other words, the main focus of the APOS Theory is to try to explain the phenomena that can be observed in students trying to build an understanding of mathematical concepts, and to present methods for the learning process to be effective (Dubinsky & McDonald, 2001).

The APOS Theory has an important place in the development of mathematics education within the context of its own terms and phenomena. For this reason, there are many national and international studies carried out based on the APOS Theory in the literature. While the theory has so far been widely focused on in the international literature, it is seen that studies on the APOS Theory have been increasingly carried out in the national literature in the last ten years.

1.1. The APOS Theory

The APOS Theory proposed by Dubinsky (1984) emerged as a result of the effort to understand the reflective abstraction mechanism put forward by Piaget to describe the development of logical thinking in children and was extended to the process of structuring advanced mathematical concepts. Although the theory was developed for advanced mathematical concepts, it is also an effective theory in examining the understanding of more basic mathematical concepts such as fractions (Dubinsky & McDonald, 2001). In addition, the theory can be characterized as a tool to explain the difficulties students experience related to mathematical concepts and to suggest ways on how students can learn these concepts (Dubinsky & McDonald, 2001; Trigueros & Possani, 2013).

According to the APOS Theory, while learning a mathematical concept, the individual builds mental structures named Action, Process, Object and Schema. These mental structures are formed by mental mechanisms based on reflective abstraction. According to the theory, there are five types of reflective abstraction, which are interiorization, encapsulation, de-encapsulation, coordination, and reversal. For example, as the individual repeats Actions that depend on external stimuli (such as formulas), he gains Process insight through interiorization. The individual with the understanding of the Process develops an internal control over the Actions and gains an understanding of the Object through encapsulation.

However, the understanding of the Object is the most difficult mental construct to acquire. Schema, on the other hand, is the entire cognitive structure in the mind of an individual regarding a mathematical concept (Arnon et al., 2014). For the development of Schema understanding, different Actions, Processes and Objects should be associated in the construction of new knowledge (Trigueros & Possani, 2013). The relationships between mental structures and mechanisms related to a mathematical concept can be summarized as follows:

• Action can be interiorized into a mental Process.

• Two mental Processes can be coordinated or a Process can be reversed to construct a new Process.

• The Process can be encapsulated to create a mental Object.

• The Schema can be thematized into a mental Object (Arnon et al., 2014).

The hypothetical model that defines these mental structures and mechanisms predicted by the APOS Theory is called genetic decomposition (Arnon et al., 2014).

1.1.1. Genetic Decomposition

A study to be conducted within the context of the APOS Theory should have the following cyclical content:

• Theoretical analysis of a mathematical concept,

• Development and implementation of instructional practices based on this theoretical analysis,

• Collecting and analyzing data to test and organize both the initial theoretical analysis and teaching (Dubinsky & McDonald, 2001).

This cyclical content continues until we have enough understanding of the epistemology of a mathematical concept and effective methods that will contribute to learning. In general terms, the purpose of theoretical analysis is to reveal the genetic decomposition of a mathematical concept (Dubinsky & McDonald, 2001).

The most important component of the APOS theory is genetic decomposition, which is a teaching model consisting of mental structures and mechanisms that students can create to understand a mathematical concept (Arnon et al., 2014; Dubinsky & McDonald, 2001; Trigueros & Possani, 2013). Genetic decomposition that needs to be tested experimentally (Arnon et al., 2014; Trigueros & Possani, 2013) is a hypothetical model until tested. This model guides the teaching of mathematical concepts. In summary, genetic decomposition is a

pedagogical strategy that predicts how a concept is learned and how it can be taught (Arnon et al., 2014).

Within the context of the APOS Theory, genetic decomposition can be constructed depending on the researcher's experience in learning and teaching the concept and the knowledge of the APOS Theory, the researcher's mathematical knowledge, the literature on the concept, and the historical development of the concept (Arnon et al., 2014). The function of genetic decomposition in the APOS Theory is to explain how a concept can occur in the mind of an individual and to present what the individual's prior knowledge of the concept should be. In this context, genetic decomposition can list the reasons for the difference in students' math performance (Arnon et al., 2014). In summary, while the APOS Theory is based on the question of how a mathematical concept is structured in the mind of the individual, genetic decomposition provides the description of these mental structures and mechanisms.

1.1.2. ACE Teaching Cycle

According to the APOS Theory, instructional practices should be developed depending on the theoretical analysis performed to construct genetic decomposition. The purpose of these instructional practices is to design activities to help students create mental structures for a mathematical concept and to understand the relationship of these structures with the concept (Dubinsky & McDonald, 2001). Activities designed using genetic decomposition contribute to the development of new mathematical concepts in the mind of the individual (Trigueros & Possani, 2013). Constructivist learning environments can be designed with these activities. One of these learning environments is the ACE teaching cycle, which is specific to the theory.

ACE teaching cycle includes three components: Activities, Classroom Discussions, and Exercises. Activities designed within the context of the APOS theory are based on students' prior knowledge (Trigueros & Possani, 2013). These activities are prepared in relation to the genetic decomposition of a mathematical concept. For example, the aim of the activities in the action phase is to guide the construction of a new concept. Activities performed to gain a process understanding further aim to help students make transformations into internalized Actions in which they can apply rules without outside help. Activities performed to acquire Object understanding aim to help students think about a Process and be aware of it as a whole so that they can apply new Actions (Trigueros & Possani, 2013). According to the ACE teaching cycle, in the second stage, students participate in class

discussions in collaborative groups, and finally, they continue the cyclical order by doing exercises and homework (Arnon et al., 2014).

1.2. The APOS Theory In The Literature

No studies have yet been conducted to evaluate how the APOS Theory is addressed in a detailed and systematic way in mathematics education research. In this study, the studies on the APOS Theory have been reviewed in terms of the handling of the topic and the general trends in order to fill the gap in the relevant literature. The way the theory has been addressed in studies can be grouped under four themes, which are the purpose of using the theory, the use of genetic decomposition, the teaching method, and the aim of the study.

1.2.1. The Purpose of Using the APOS Theory

The APOS Theory can be used for data analysis or as a teaching method in a study (Dubinsky & McDonald, 2001; Trigueros & Martinez-Planell, 2010). For data analysis, the theory is used to examine the structures formed in the minds of students after the application or teaching of a mathematical concept. As a teaching method, the theory is used to design activities for the teaching of a mathematical concept and to examine the mental structures of students after the implementation of these activities (Trigueros & Martinez-Planell, 2010). As seen in the related literature, although the APOS Theory is mostly used for data analysis (Bansilal, 2011; Brijlall & Maharaj, 2015; Brijlall & Ndlazi, 2019; Chimhande, Naidoo, & Stols, 2017; Martinez-Planell, Gaisman, & McGee, 2017) and as a teaching method (Martin, Loch, Cooley, Dexter, & Vidakovic, 2010; Possani, Trigueros, Preciado, & Lozano, 2010), it is also possible to find studies in which the APOS Theory was used for both purposes (Figueroa, Possani, & Trigueros, 2018; Maharaj, 2013; Moon, 2019; Ndlovu & Brijlall, 2019; Trigueros & Possani, 2013). In summary, the APOS Theory can be used for data analysis, as a teaching method, or both.

1.2.2. The Use Of Genetic Decomposition

Although the APOS Theory is used for different purposes (data analysis or teaching method), it is essential to include genetic decomposition for the related concept in studies (Dubinsky & McDonald, 2001; Trigueros & Martinez-Planell, 2010; Trigueros & Possani, 2013). Genetic decomposition, which is the main component of the APOS Theory, can be constructed within the study or the existing genetic decomposition can be used. However, there are APOS Theory studies in the relevant literature (Hannah, Stewart, & Thomas, 2016; Maharaj, 2015, 2018a, 2018b; Makonye, 2017) that did not use genetic decomposition.

1.2.3. Teaching Method

One of the main goals of the APOS Theory is to present effective teaching methods related to a mathematical concept (Arnon et al., 2014). The ACE teaching cycle is a teaching method developed specifically for the APOS Theory. In this regard, the use of the ACE teaching cycle (Figueroa et al., 2018; Ndlovu & Brijlall, 2016; Siyepu, 2015) is common in the APOS Theory studies. However, different teaching methods can also be used in APOS Theory studies such as modeling (Possani et al., 2010), learning trajectory (Avcu & Cetinkaya, 2019; Trigueros & Possani, 2013), and realistic mathematics education (Deniz, 2014).

1.2.4. Aim Of The Study

The APOS Theory focuses on conceptual understanding and aims to develop instructional ways to achieve conceptual understanding. The aim of the APOS Theory to measure conceptual understanding is related to determining the mental structure and mechanisms of the sampling regarding a mathematical concept. However, in addition to the aim of the theory to reveal conceptual understanding (Bansilal, Brijlall, & Trigueros, 2017; Borji & Martinez-Planell, 2019; Maharaj, 2013), there are studies on the development of the theory (Dubinsky & McDonald, 2001; Moll, Trigueros, Badillo, & Rubio, 2016; Stenger, Weller, Arnon, Dubinsky, & Vidakovic, 2008) and on developing teaching methods in the literature (Moon, 2019; Possani et al., 2010).

In the related literature, there are many national and international studies on the APOS Theory. A systematic summary of the general approaches and trends of these studies from a holistic perspective can enable both the development of the theory and the identification of the needs for future research. When the literature is examined, it is seen that there is one study (Bayraktar, Tutak, & İlhan, 2019) that examines the studies on the APOS Theory in terms of document analysis and no meta-synthesis research has been found.

The aim of this study is to review the studies on the APOS Theory. In this context, the research problem is "What is the current status of the APOS Theory studies in the field of mathematics education?". Accordingly, the sub-research questions are as follows:

1. How are the APOS Theory studies with a national sample distributed in terms of research type, year, sampling, research method, qualitative research design and the learning area?

2. How are the studies with a national sample distributed in terms of the purpose of using the APOS Theory, the use of genetic decomposition, the teaching method, and the aim of the study?

3. How are the APOS Theory studies with an international sample distributed in terms of research type, year, sampling, research method, qualitative research design and the learning area?

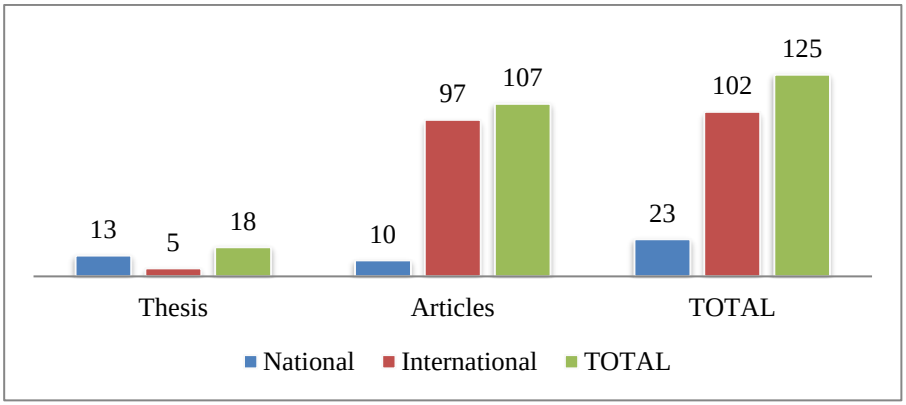
4. How are the studies with an international sample distributed in terms of the purpose of using the APOS Theory, the use of genetic decomposition, the teaching method and the aim of the study?

2. Method

In this study, the descriptive content analysis and thematic content analysis methods (meta synthesis) were used in order to review the studies on the APOS Theory in the field of mathematics education. Based on the main concepts of the theory, the available studies were examined under various categories, the general approaches were determined, and systematic analyses were conducted by trying to reveal the deficiencies that could lead to a new research topic.

2.1. Data Collection

The data consists of a total of 125 studies, including 18 theses and 107 articles, published between 2000 and 2020, focusing on the APOS Theory in mathematics education. The distribution of the types of the studies with national and international samples is given in Graph 1.



Graph 1. The distribution of the studies according to research type

Web of Science (WOS), ERIC, Yöktez and Dergipark databases were scanned three times to obtain the data of the study. The search was made using the keywords “apos theory” and “apos AND mathematics” in WOS and ERIC databases, and using the keywords "apos" in the Yöktez database and "apos AND mathematics" in the Dergipark database. In addition, the accuracy of this data was checked by searching with the keyword "APOS theory" in Google Scholar. If a thesis and an article belonged to the same author, the thesis has been included in the study. If the thesis was not accessible, the article was used in the study. In addition, the studies in the form of papers were excluded from the study by the researchers with the thought that they do not include sufficient data.

In this study, a Data Collection Tool Form (Table 1) was prepared for both descriptive and thematic content analysis, considering the way the APOS Theory has been addressed in the literature.

Table 1
Data Collection Tool Form

A. INFO ON THE STUDY	
Research Type	Article [ ] Master’s thesis [ ] PhD thesis [ ]
Year of publication	
Title of the study	
Author(s)	
B. RESEARCH QUESTION	
C. SUB-RESEARCH QUESTIONS	
D. AIM	
E. FINDINGS	
F. SAMPLING	
Secondary School ( )	Sample size

High School ( )

Undergraduate ( )

Graduate ( )

Teachers ( )

G. METHOD

Quantitative	**Qualitative**	**Mixed** ( )
Case Study ( )	Experimental Design ( )	
Action Research ( )	Quasi-experimental Design ()	
Design-based Research ( )		
Teaching Experiment ( )		
Document Analysis ( )		

H. LEARNING AREA

I. PURPOSE OF USING THE THEORY	**J. THE USE OF GENETIC DECOMPOSITION**
For data analysis ( )	Constructed within the study ( )
As a teaching method ( )	Used the existing genetic decomposition ( )
Both ( )	Not used ( )

K. TEACHING METHOD (If applicable)	**L. AIM OF THE STUDY**
ACE Teaching Cycle ( )	To measure conceptual understanding ( )
DNR Based Teaching ( )	To create a teaching model ( )
Learning Trajectory ( )	Theoretical ( )
Plomp Model ( )	To describe ( )
Emporium Model ( )	To review ( )
Modelling ( )	
Manipulative ( )	
Computer Assisted Instruction ( )	
Realistic Mathematics Education ( )	
Teaching Experiment ( )	

Activity Based Learning Approach ( )
Problem-Based Teaching ( )

Each study constituting the data of our study was examined based on the data collection tool form, and the analyses were conducted as described below.

2.2. Data Analysis

While analyzing the data, firstly descriptive content analysis was conducted, and then, thematic content analysis was performed to analyze the data in depth (Au, 2007; Çalık & Sözbilir, 2014).

While performing the descriptive content analysis, data such as the type of research used in the study, publication year, having a national or an international study, sampling, research method, and the learning domains were taken into consideration, and descriptive statistics of these data were determined.

In the thematic content analysis, considering the ways in which the APOS Theory is addressed in the literature, three main themes were determined, which are "the purpose of using the theory", "the use of genetic decomposition" and "the aim of the study". The first two of these themes were created to address the existing APOS Theory in the literature. The theme of "the aim of the study" was determined by the authors of this study based on the data. Information on the context in which these themes and sub-themes were created is given in Table 2.

Table 2
Brief explanations on the themes and sub-themes created in the study

Themes	Sub-themes	Explanation
The purpose of using the theory	For data analysis	Analyzing data using mental structures and mechanisms in the APOS Theory
	As a teaching method	Using the APOS Theory as a teaching method with the ACE teaching cycle and genetic decomposition of the concept

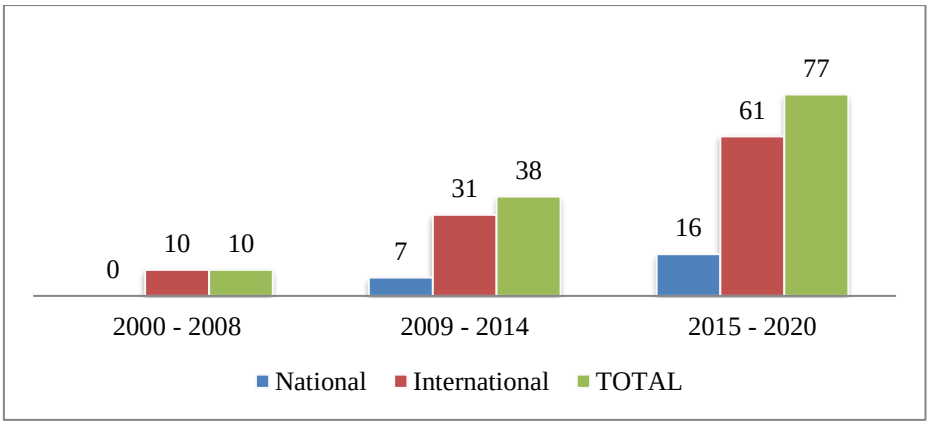
	Both	Analyzing the results in accordance with the mental mechanisms and structures in the theory using the APOS Theory, using the genetic decomposition of a concept and the ACE cycle, and implementing a teaching method
The use of genetic decomposition	Constructed within the study	Establishing the genetic decomposition of a concept through the study
	Used the existing genetic decomposition	The use of the existing genetic decomposition of the concept in analyzing data or creating a teaching method
	Not used	Not using any genetic decomposition for a concept
The aim of the study	To measure conceptual understanding	Studies conducted to determine the conceptual understanding of the sample about a concept
	To create a teaching model	Studies on teaching a concept using the APOS Theory
	Theoretical	Studies to develop the APOS Theory
	To describe	Studies in which the mental structures and mechanisms in the APOS Theory were used as themes rather than to determine the structure of the concept.
	To review	Studies examining the research on the APOS Theory

3. Findings

This section includes two parts: the findings obtained as a result of descriptive analysis and the findings obtained as a result of meta-synthesis analysis.

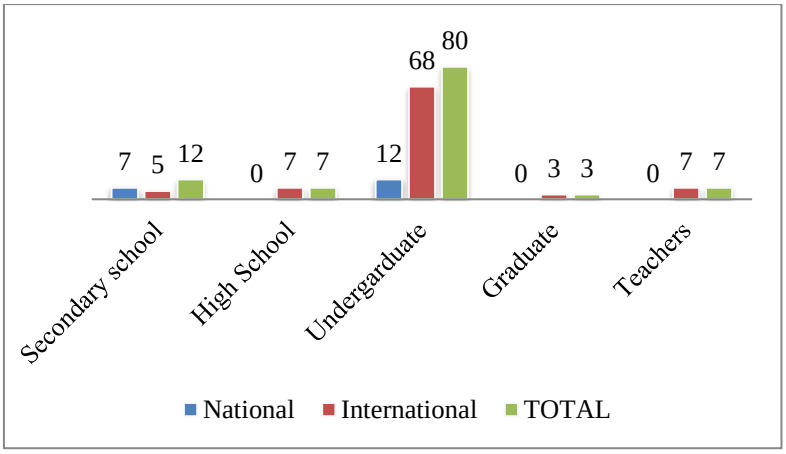
3.1. Findings obtained as a result of descriptive analysis

In this study, the distribution of the studies including national and international samples and published between 2000 and 2020 across years is given in Graph 2.



Graph 2. Distribution of the studies across years

As seen in Graph 2, studies with national samples started as of 2009. The studies conducted between 2000 and 2008 (n=10) correspond to 8% of the total number of studies. Studies with international samples were not common before 2009. The sample of the studies was examined considering the following groups: secondary school, high school, undergraduate, graduate and teachers and was presented in Graph 3.

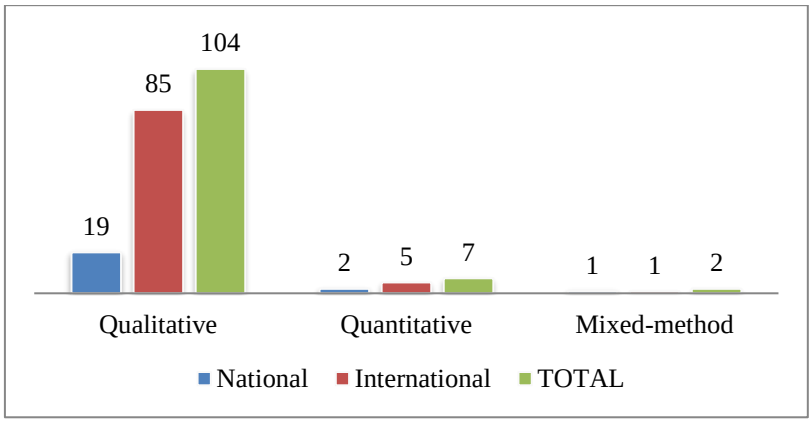


Graph 3. Distribution of the studies across sampling

When Graph 3 is examined, it is seen that 64% (n=80) of the studies were conducted with undergraduate students. In addition, while 36% (n=12) of the studies with a national sample were conducted with secondary school students, only 6% (n=5) of the studies with an international sample were conducted with secondary school students. Besides, one study was conducted with three sampling (secondary school students, high school students, and

teachers). Some studies did not use a sampling because they were theoretical or review studies.

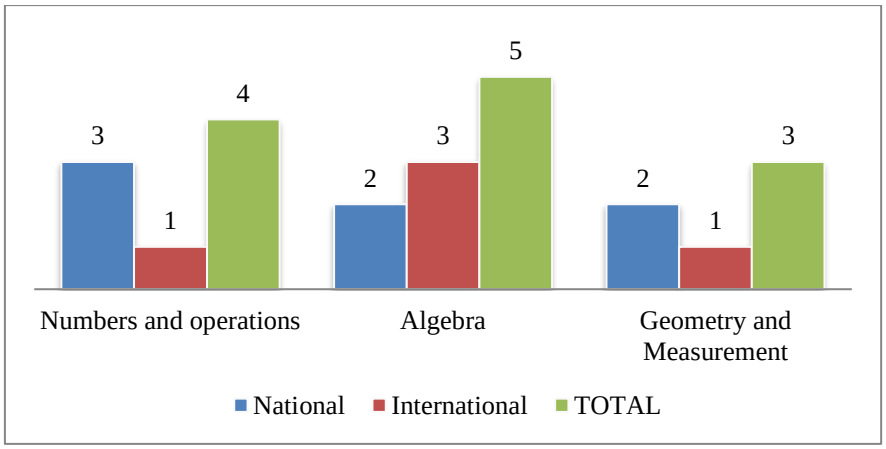
It is seen that the vast majority of the studies (n=104) are qualitative research. There are few quantitative studies (n=7) and mixed-method studies (n=2). The distribution of the studies according to the research method is presented in Graph 4.



Graph 4. Distribution of the studies according to the research method

It was also observed that most of the qualitative studies (n=91) are case studies. In national studies, case studies correspond to 57% (n=12) of all qualitative studies, while they constitute 93% (n=79) of all qualitative studies within international studies. Other qualitative research methods used in the reviewed studies include design-based research (n=1), teaching experiment (n=8), action research (n=1) and document analysis (n=3).

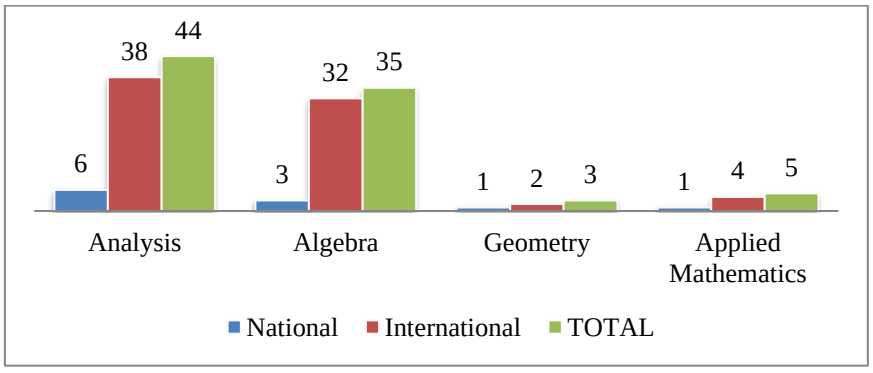
In addition, the distribution of the mathematical teaching points across different levels (secondary school, high school, undergraduate and graduate) was investigated. In this context, secondary school mathematics learning domains were determined to be "numbers and operations", "algebra" and "geometry and measurement" as given in the Ministry of National Education (MoNE) (2018a) curriculum. The distribution of the studies across the secondary school mathematics learning domains is given in Graph 5.



Graph 5. Distribution of the studies across the secondary school mathematics learning domains

On the other hand, high school mathematics learning domains were determined to be "numbers and algebra" and "geometry" as stated in the MoNE (2018b) curriculum. It is seen that among seven studies with international samples examining high school mathematics concepts, four studies focused on numbers and algebra and three studies focused on geometry. In addition, it is seen that studies with national samples did not include high school mathematics concepts (See Graph 3).

Undergraduate and graduate mathematics learning domains were determined to be analysis (such as function, limit, derivative, integral), algebra (such as slope, group, sets, linear algebra, matrix), geometry (such as angles, triangles, reflection, volume), and applied mathematics (such as interest rates, probability, statistics, differential). The distribution of the studies across these learning domains is presented in Graph 6.

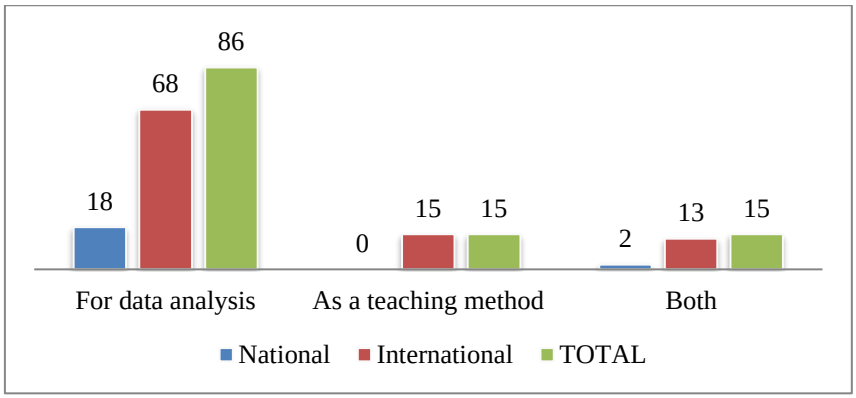


Graph 6. Distribution of the studies across undergraduate and graduate mathematics learning domains

When Graph 6 is examined, it is seen that the majority of the studies with both national and international samples are in the fields of analysis (n=44) and algebra (n=35). On the other hand, one study focused on the field of computer programming, and the mental structures of the loops were analyzed.

3.2. Findings obtained as a result of the meta-synthesis analysis

The first of the three themes developed as a result of the meta-synthesis analysis of the studies is the purpose of using the theory. Three sub-themes were determined under this theme, which are “for data analysis”, “as a teaching method” and “both” (See Table 2). In this context, the distribution of the studies with national and international samples according to the purpose of using the APOS Theory is given in Graph 7.

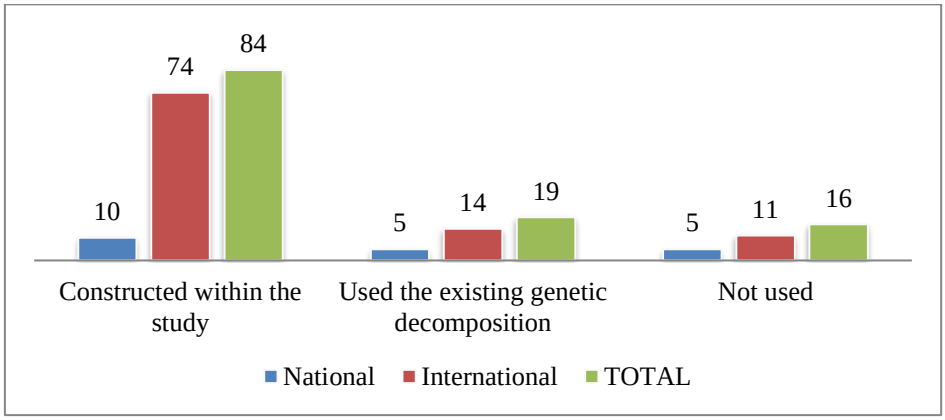


Graph 7. Distribution of the studies according to the purpose of using the APOS Theory

According to Graph 7, the majority of the studies with national samples (n=18, f=90%) used the APOS Theory for data analysis, while the theory was used for data analysis in 68 studies with international samples (f= 71%), as a teaching method in 15 studies (f= 16%), and for both purposes in 13 studies (f= 14%). When all the studies are examined, it is seen that 74% of them used the APOS Theory for data analysis.

Another theme obtained as a result of the meta-synthesis analysis was "the use of genetic decomposition". Three sub-themes emerged under this theme, which are "constructed within the study", "used the existing genetic decomposition" and "not used" (See Table 2).

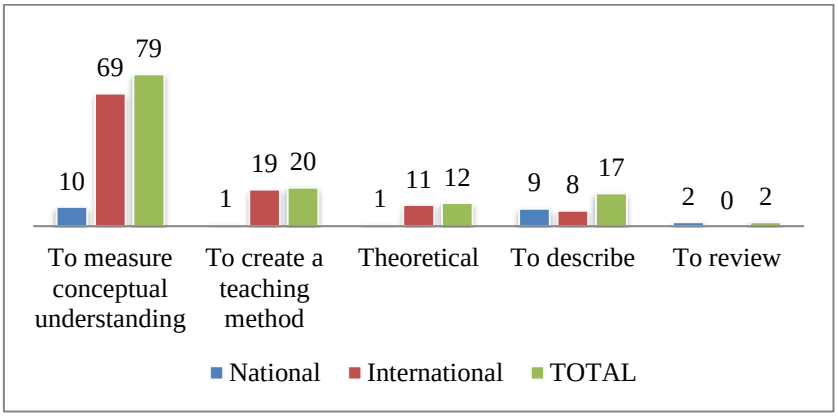
The distribution of the studies with national and international samples according to the use of genetic decomposition is presented in Graph 8.



Graph 8. Distribution of the studies according to the use of genetic decomposition

According to Graph 8, genetic decomposition was constructed within the study in 50% (n=10) of the studies with national samples. In addition, 25% (n=5) of the studies did not use genetic decomposition. On the other hand, in 75% (n=74) of the international studies, genetic decomposition was constructed within the study, and it is seen that 11% of the studies (n=11) did not use genetic decomposition.

Finally, the theme of "the aim of the study" was created depending on the aim of the study to use the APOS Theory. The meta-synthesis analysis revealed the sub-themes of "to measure conceptual understanding", "to create a teaching method", "theoretical", "to describe" and "to review". The distribution of the studies according to their aims is given in Graph 9.



Graph 9. Distribution of the studies according to their aims

According to Graph 9, most of the studies aim to measure conceptual understanding (n=79, f=61%). In addition, the aim of the 39% (n=9) of the studies with national samples was to describe. It is observed that this rate is 7% (n=8) in studies with international samples.

4. Discussion, Conclusions and, Recommendations

The main purpose of mathematics education is to provide opportunities for students to learn and understand mathematical concepts (NCTM, 2000). For this purpose, *Principles and Standards for School Mathematics* (NCTM, 2000) was prepared and the importance of concept teaching was emphasized by identifying important mathematical concepts from preschool to eighth grade (NCTM, 2014). The APOS Theory, which is based on conceptual understanding, emerged with the studies of Dubinsky in 1984, and the studies in this field increased after 2000 (See Graph 2). In Turkey, with the curriculum introduced in 2009 (MoNE, 2009), it was aimed to develop the skills of learning mathematical concepts and the relationships between concepts. Parallel to this, APOS Theory studies started with Çetin (2009)'s doctoral thesis and have increased since 2009 (See Graph 2). On the other hand, the increase in both national and international APOS Theory studies shows that the APOS Theory is an important theory in terms of concept teaching.

According to Piaget (1975), students studying at secondary school and higher levels perform actions on abstract objects, while students in primary school perform their actions on concrete objects. According to the APOS Theory, the reason for this difference is the nature of the objects to which the actions are applied (Arnon et al., 2014). In this context, the APOS Theory, which is based on Piaget's work, was developed to understand the process of structuring abstract mathematical concepts (Dubinsky & McDonald, 2001). Considering the findings of this study, it is seen that the majority of the APOS Theory studies (64%) were conducted with undergraduate students (See Graph 3). This finding is compatible with the

purpose of the emergence of the theory. On the other hand, the theory can also be used for concepts at primary and secondary level (Arnon et al., 2014). As a matter of fact, according to the findings of this study, it is seen that the number of studies conducted with secondary school (11%) and high school (6%) students is few in the literature and has increased in recent years (See Graph 3). For example, Deniz (2014) examined 8th graders' process of constructing the concept of slope in his master's thesis. According to the study, slope is a prerequisite concept for the abstraction process of the derivative of the function, which is a preliminary mathematical concept in terms of concept hierarchy, and students encounter the concept of slope for the first time in the 8th grade. Similarly, Brijlall and Ndlovu (2013) examined 12th grade high school students' processes of structuring the maximum–minimum problems required for the derivative scheme. Accordingly, it can be said that in order to create the mental structures of high-level mathematical concepts, it is necessary to include the mental structures for pre-mathematical concepts within the context of concept hierarchy. In this sense, it can be stated that more studies should be conducted at secondary and high school levels in order to reveal the mental structures of mathematical concepts related to the theory.

It must be noted that more studies were conducted with secondary school students in Turkey (36%). When these studies (7 in total) are examined in general, some common features stand out. These studies used the APOS Theory for data analysis and six studies used genetic decomposition, which is the most important component of the theory. In addition, one study did not use genetic decomposition and two studies used the mental structures of the APOS Theory as a theme. In summary, although there are more studies conducted with secondary school students within the national context, only 57% of these studies focused on conceptual understanding and used the components of the theory. Thus, it can be stated that although abstract relationships can be established between mathematical concepts at undergraduate level, this is not easy for secondary school mathematics concepts. It is

observed that these studies focus on the structures established by the individual in a descriptive way rather than on the mathematical concept. Considering the historical development and abstract structure of the concepts, it can be said that there are difficulties in terms of compatibility with the level while constructing genetic decomposition for the mental structures of the mathematical concepts at the secondary school level within the context of the APOS Theory. This may be the reason why genetic decomposition was not used in studies conducted with secondary school students and why the mental structures in the theory were used descriptively.

The APOS Theory is a teaching model used to explain how mathematical concepts are learned. It is also a theoretical framework used to explain how individuals mentally construct their understanding of mathematical concepts (Arnon et al., 2014). In this context, it can be concluded that the theory focuses on the "how" question. On the other hand, case studies are studies that deal with “how” and “why” questions (Yin, 2018). Our findings revealed that the majority of the APOS Theory studies (90%) are qualitative research and 93 percent of these qualitative studies are case studies (See Graph 4). In this context, it can be said that the aims of the theory and the case study design overlap. In addition, it has been observed that the APOS Theory studies with teaching experiment have been increasing in the last decade. For example, Harel (2017) designed a teaching experiment based on the sources of student difficulties for linear equation systems and examined how students construct knowledge. During the teaching experiment, the difficulties experienced by the students regarding the linear equation systems were determined and ideas for the development of their schemas emerged. Therefore, it can be stated that the teaching experiment designed on the basis of student difficulties overlaps with the aims of the theory in terms of making a positive contribution to concept teaching.

The APOS Theory first focused on the concept of function (Dubinsky, 1984), which is thought to be one of the fundamental concepts of mathematics (NCTM, 1989; Ponte, 1992). It is observed that studies previously focused on basic analysis and algebra concepts. The findings of the present study revealed that the APOS Theory was mostly used in the fields of analysis and algebra (See Graphs 5 and 6). The scarcity of APOS Theory studies in the field of geometry is noteworthy. It must be noted that examining geometric transformations allows students to form the basis of a number of mathematical concepts and to improve their mathematical and cognitive skills (Clements, Battista, Sarama, & Swaminathan, 1997; Hollebrands, 2003; Portnoy, Grundmeier, & Graham, 2006; Yanik & Flores, 2009). On the other hand, when the findings of the study are examined, it has been observed that although there are few studies on the concepts directly related to the field of geometry, conceptual understanding studies have been carried out on the geometric transformations of mathematical concepts such as the geometric dimension of the derivative concept and the graphical representations of functions.

The APOS Theory can be used for data analysis, as a teaching method, or for both purposes (Arnon et al., 2014). On the other hand, the theory is described as a method in important journals such as the *Journal for Research in Mathematics Education* of NCTM. Our findings show that 74 percent of the studies used the APOS Theory for data analysis (See Graph 7). One of the main goals of the theory is to design activities related to the path to be followed in teaching (Arnon et al., 2014; Dubinsky & McDonald, 2001). It can be said that with this aim, the importance of using the theory as a teaching method is emphasized. However, when the findings are examined, it is noteworthy that there are few studies using the theory as a teaching method (13%) or for both purposes (13%). For example, Borji and Martinez-Planell (2019), who used the both purposes together, revealed the mental structures students form when taking the derivative of closed functions and designed an ACE teaching

cycle to ensure the development of these mental structures. Such studies aiming both diagnosis and treatment are very few (only 2 studies) within the national context, which indicates the need for research in this area.

The first step of the APOS Theory studies is to investigate the epistemological structure of the concept and to construct genetic decomposition (Dubinsky & McDonald, 2001). Genetic decomposition has two important functions: to guide the analysis of the data obtained from students and to provide a theoretical basis for designing instructional activities (Arnon et al., 2014). In other words, genetic decomposition is a bridge between the APOS Theory and its application (Trigueros & Oktac, 2019). For this reason, genetic decomposition has an important place in APOS Theory studies. However, it is seen that genetic decomposition was not used in 13 percent of the studies examined (See Graph 8). Although the theory was used for data analysis in these studies, genetic decomposition was not used in data analysis.

The APOS Theory draws its power from mathematics in constructing mental structures related to mathematical concepts. Mathematical concepts and the relationships between concepts enable genetic decomposition to be revealed. When the findings of the present study are examined, it is seen that the majority of the studies (61%) used the theory to measure conceptual understanding, which is compatible with the aim of the theory. However, it is seen that 39 percent of the studies conducted in Turkey used the theory to make descriptions (See Graph 9). In other words, it is noteworthy that the number of studies using the mental structures and mechanisms proposed by the APOS Theory as themes rather than to determine the structure of the concept is high within the national context. Such studies focus on the mental structures of the individual rather than the structure of mathematical concepts and use these structures as themes. In addition, it was revealed that the majority of the studies (62%) that did not use genetic decomposition were studies that used the theory to make

descriptions. It can be stated that studies within this scope position students' understanding of mathematical concepts according to the mental structures of the theory, but do not propose a mind map for mathematical concepts. In this context, it can be said that such studies do not have an aspect to reinforce conceptual understanding.

In sum, the APOS Theory, which emerged from the very essence of mathematics, is an important learning and teaching theory in terms of conceptual understanding. The aim of our meta-synthesis study was to reveal why the APOS Theory has an important place in mathematics education. The studies on the theory were classified according to the purpose of using the theory in mathematics education. In addition, studies with national and international samples based on the APOS Theory were reviewed and compared. In this context, the aim was to shed light on future studies by taking the studies conducted so far into account.

Türkiye'de ve Uluslararası Alanda Yapılan Matematik Eğitimine Yönelik APOS Teorisi Çalışmalarının İçerik Analizi: Meta Sentez Çalışması

Özet:

Bu araştırmada matematik eğitimi alanında yapılan, matematik eğitiminin temel amaçlarından biri olan kavramsal anlama bağlamında geliştirilen, APOS teorisi çalışmalarının mevcut durumunun belirlenmesi amaçlanmıştır. Bu amaç doğrultusunda APOS teorisi ile ilgili ulusal ve uluslararası örneklemli çalışmalar betimsel içerik analizine tâbi tutularak sistematik özet bilgiler sunulmuştur. Daha sonra, bu çalışmaları eleştirel bakış ile yorumlamak için meta sentez (tematik içerik analizi) yöntemi kullanılmıştır. Tematik içerik analizi sonucu; teoriyi kullanma amacı, genetik ayrışım kullanma durumu ve çalışmanın hedefi olmak üzere üç tema ortaya çıkmıştır. APOS teorisinin öngördüğü zihinsel yapı ve mekanizmaları matematiksel kavramların yapısından ziyade bu yapıları tema olarak belirleyen betimsel nitelikli çalışmalar (%39) alanyazında yer almaktadır. Bu türden çalışmaların APOS teorisinin kavramsal anlamayı pekiştirme amacı bakımından zayıf kaldığı söylenebilir.

Anahtar kelimeler: 3 to 5 key words in Turkish, lowercase, comas between the key words.

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