NEF EFMED

Cilt 15 - Sayı 1 - Haziran 2021

Necatibey Eğitim Fakültesi

Elektronik Fen ve Matematik Eğitimi Dergisi

Necatibey Faculty of Education
Electronic Journal of Science and Mathematics Education

Volume : 15
Issue : 1
Date : June 2021
ISSN : 1307-6086

NEF-EFMED (NFE-EJSME)

ISSN: 1307-6086

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Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi
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Herkese Merhabalar,

On on beşinci yılımızın birinci sayısında toplam yedi makale yer almaktadır.

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

Saygılarımla.

Editör

Prof.Dr. Gözde AKYÜZ

Preface

Greetings to everyone,

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

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

Editor

Prof.Dr. Gözde AKYÜZ

Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi (EFMED)
Cilt 15, Sayı 1, Haziran 2021, sayfa 1-31. ISSN: 1307-6086

Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Vol. 15, Issue 1, June 2021, pp. 1-31. ISSN: 1307-6086

Araştırma Makalesi / Research Article

Formal İspatın Mevcut Olmadığı Bir Durumda İspat İmajı Var Olabilir Mi?: Başarısız Bir İspat Girişiminin Analizi

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Gönderme Tarihi: 19.12.2020 Kabul Tarihi: 21.04.2021

Doi: 10.17522/balikesirnef.843527

Özet – Matematiğin temel bileşenlerinden olan ispat ve ispatlamayı farklı perspektiflerden ele alan pek çok teorik çerçeve sunulmuştur. Bunlardan biri olan ispat imajı, Kidron ve Dreyfus'un (2014) iki profesyonel matematikçinin ispat süreci üzerinde yaptığı analizler sayesinde ortaya çıkmıştır. Yazarlar, ispat imajını bileşenleri bağlamında tanımlamış ve bunun formal ispat ile ilişkisini vurgulamıştır. Diğer yandan ispat imajının, formal ispatın ortaya çıkmadığı durumlarda da ortaya çıkabileceği belirtilmesine rağmen böyle bir örnek sunulmamıştır. Teorik çerçevedeki bu boşluk araştırmanın motivasyon kaynağı olarak benimsenmiştir. Çalışma sürecinde çok aşamalı örnekleme yaklaşımı tercih edilmiş ve öncelikle 120 öğretmen adayından cebir ile ilgili iki teoremi ispatlamaları istenmiştir. Daha sonra her iki teoremi de doğru olarak ispatlayabilen 3 katılımcı ile etkinlik temelli mülakatlar gerçekleştirilmiştir. Toplanan veriler üzerinde mikro-analitik analizler yapılmış ve alt bileşenler arasındaki ilişki tartışılmıştır. Ayrıca "aydınlanma" kavramının rolü yorumlanmış ve hislerin etkisi detaylandırılmıştır. Bu sayede katılımcılardan birinin formal ispata ulaşamamasına rağmen ispat imajına sahip olduğu belirlenmiş ve bu çalışmada buna dair verilere yer verilmiştir.

Anahtar kelimeler: ispat imajı, ispat, cebir, matematik eğitimi

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Sorumlu yazar: Ozan PALA, Milli Eğitim Bakanlığı, sfxdx@outlook.com, Manisa/ TÜRKİYE. Bu çalışmanın verileri 2017/2018 akademik yılı içerisinde toplanmış olup, bir kısmı 3–8 Temmuz 2018 tarihleri arasında İsveç'in Umeå şehrinde düzenlenen 42. PME (42nd Annual Meeting of the International Group for the Psychology of Mathematics Education) sempozyumunda sözlü bildiri olarak sunulmuştur.

Geniş Özet

Giriş

Kidron ve Dreyfus (2014) tarafından literatüre kazandırılan ispat imajı, bireyin ispata ilişkin zihninde taşıdığı yapının tamamı olarak düşünülebilir. Yazarlar iki matematikçinin ispat süreçleri üzerinde RBC (Recognizing, Building With and Construction) modeliyle yaptıkları analizler sonucunda bu kavrama ulaşmışlardır. RBC, üç gözlenebilir (*epistemik*) eylemle açıklanabilmektedir (Hershkowitz, Schwarz ve Dreyfus, 2001). Sürecin ilk basamağı "Tanıma" (Recognizing), bir problem çözümünde önceden var olan/bilinen yapının fark edilmesini içermektedir (Türnüklü ve Özcan, 2014). İkinci basamağı oluşturan "Kullanma" (Building with), fark edilen bu bilgiden yararlanmayı ifade etmektedir (Schwarz, Dreyfus, Hadas ve Hershkowitz, 2004). Son basamak olan "Oluşturma" (Construction) ise mevcut bilgi yapılarının kısmi değişimle yeniden yapılandırılmasıdır (Bikner–Ahsbahs, 2004). Dahası, bunun öngörülemeyen bir şans sayesinde gerçekleşmediği "Aha! Deneyimi'' (Liljedahl, 2004) ve Aydınlanma (Rota, 1997) gibi mekanizmaların sürece eşlik ettiği söylenebilir. Tüm bu bileşenleri dikkate alan Kidron ve Dreyfus (2014) ispat imajı bileşenlerini aşağıda yer alan Tablo 1'deki gibi ifade etmişlerdir:

Tablo 1 İspat İmajının Bileşenleri

Bilişsel Boyut	Duyuşsal Boyut
B_1. *Kişisel Olma:* İmajın, bireyin kişisel çıkarımlarından/deneyimlerinden iz taşıması ve bunlardan beslenerek gelişim göstermesidir.	İmajın ikinci bileşeni "duyuşsal düzey" olarak kabul edilen sezgisel iknadır. Bu bileşen "kesinliğin duyuşsal hissi" olarak ifade edilebilir. Sezgi, temelinde öznel bir kesinliğin bulunduğu özel bir biliş türü olarak tanımlanabilir (Fischbein, 1999). Hisler ise Clore (1992) tarafından ifade edildiği gibi "bedensel, bilişsel veya duyuşsal durumlardan kullanılabilir bir geribildirim sağlayan tüm içsel işaretler" olarak değerlendirilebilir.
B_2. *Mantıksal Bağlar İçerme:* İspat sürecinde tanınan ve seçilen matematiksel yapılar arasında sezgisel iplikleri dokumaya benzer biçimde anlamlı bağlantılar kurulmasıdır (Kidron & Dreyfus, 2014). İspat imajı açısından, seçilen kurulan kişiye özgü bu bağlantıların formel olma zorunluluğu bulunmamaktadır.	
B_3. *Dinamizm:* Davydov'un (1990) soyutlamaya ilişkin görüşlerine paralel olarak ispat imajının gelişmemiş formdan gelişmiş forma, basitten karmaşığa doğru gelişim göstermesidir.	
B_4. *Bir Oluşuma Sebebiyet Verme (Bütünlük):* Matematiksel durumun tek bir imgesidir (Kidron & Dreyfus, 2014). Diğer bir ifadeyle imajın "oluşuma" olanak sağlayacak şekilde bütüncül gelişim göstermesidir.	

Blum ve Kirsch (1991) formel ispatı, kabul edilebilir mantıksal çıkarımların yer aldığı ispatlar şeklinde tanımlamaktadır. Buna paralel olarak Kidron ve Dreyfus (2014) da ispat imajının formel ispatla birlikte bulunduğu aktiviteler üzerine odaklanmışlardır. İspat imajının ortaya çıktığı ancak formel ispatın ortaya çıkmadığı durumlar olabileceğini belirtmelerine rağmen bu kısmı derinleştirmemişlerdir. Bahsedilen boşluk, araştırmanın motivasyon kaynağı olarak benimsenmiş ve araştırma problemi "İspat imajının ortaya çıktığı ve formel ispatın ortaya çıkmadığı bir ispat sürecinin bileşenleri nasıl şekillenir?" şeklinde belirlenmiştir. Bu inceleme, formel ispatla ispat imajı arasındaki ilişkiyi betimlemeye olanak sağlaması açısından önemli görülmektedir.

Yöntem

Gözlem, görüşme ve yazılı verilerden faydalanılan bu araştırmada nitel analiz yöntemlerinden örnek olay çalışması kullanılmıştır. Çalışma grubu, ilköğretim matematik öğretmenliği 3. sınıf öğrencilerinden oluşmaktadır. Örnekleme işlemi iki aşamada tamamlanmıştır. Birinci aşamada, kolay ulaşılabilir durum örneklemesi tercih edilmiştir. Bu kapsamda bir devlet üniversitesinde soyut cebir dersini almakta olan 120 öğretmen adayına 2 sorudan oluşan bir form uygulanmıştır. İkinci aşamada, görüşme yapılacak bireyler ölçüt örnekleme yöntemiyle seçilmiştir. Bu bağlamda iki soruya doğru cevap veren ve gönüllü olan 3 öğretmen adayıyla mülakat gerçekleştirilmiş ve onlardan başka bir teoremi sesli düşünerek ispatlamaları istenmiştir. Görüşme video ile kayıt altına alınmıştır. Elde edilen veriler içerik analizi ile analiz edilmiştir. Analizler sonucunda katılımcılardan sadece birinin formel ispata ulaşamadığı halde ispat imajı oluşturabildiği belirlenmiştir. "Büşra" olarak isimlendirilen bu katılımcıya dair veriler bulgularda paylaşılmıştır.

Bulgular

Bu bölümde Büşra'nın ispat süreci öncelikle özetlenerek doğrudan aktarılmıştır. Daha sonra ise ispat, bir akış diyagramı ile ayrıntılı olarak görselleştirilmiş ve ispatın bilişsel ve duyuşsal boyutları için ispat imajı bağlamında analizler gerçekleştirilmiştir. Bu analizler sonucunda ulaşılan sonuçlar aşağıda özetlenmiştir:

B_1. Kişisel Olma: İspat sürecinin tamamı dışarıdan herhangi bir müdahale olmaksızın Büşra'nın tercihleri ve kendi eylemleri doğrultusunda şekillendiğinden kişisel bir anlayışı içerisinde barındırdığı yorumu yapılabilir.

B_2. Mantıksal Bağlar İçerme: Büşra'nın farklı noktada anlayışını derinleştirmek için ön bilgileri arasından eşitlik, küme, merkezleştirici, gibi matematiksel yapıları seçtiği (R-) ve çoğunlukla

mantıksal gerekçelendirmeye dayanan bağlantılar kurarak bunları kullandığı (B-) yorumu yapılabilir. Bağlantıların bir bölümünün matematiksel açıdan doğru olmasına karşın önemli bir bölümünün de doğru olmayan gerekçelendirmelere dayandığı belirlenmiştir. Bu aşamada Büşra iki kümenin de grup yapısında olduğunu bilmesine karşın bunlar arasındaki ilişkiyi “grup olma özellikleri” açısından tekrar incelemiştir. Dahası, yeterli sorgulama gerçekleştirmediğinden bu eksikliği fark edememiş ve dolayısı ile mevcut bilgi yapısı içerisinde bir dengesizlik yaşamamıştır. Bu nedenle işlemlerin doğru olduğu kanısı ile formel ispata ulaştığını belirtmiştir.

B_3. Dinamizm: Seçilen (R-) ve Kullanılan (B-) yapılar arasındaki mantıksal gerekçelendirme sayesinde ispatın gelişmemiş bir formdan gelişmiş bir forma doğru gelişim gösterdiği belirlenmiştir.

B_4. Bütünlük: Büşra’nın farklı yaklaşımlar benimsemiş olmasına rağmen tek ve bütün bir imaja sahip olduğu söylenebilir. Bu karakteristik özellik Büşra’nın tüm süreci zihninde taşımasına olanak sağlamıştır. Bu sayede Büşra, gerekli noktalarda deneyimlerinin sonuçlarını da gözden geçirerek ispatına yön vermiştir.

İç görü anları ve aydınlanma deneyimleri: Büşra’nın üç farklı iç görü (Aha! Deneyimi) yaşadığı belirlenmiştir. Bunlardan ilk ikisi, onun M(a) ve M(a^{-1}) kümelerini ayrık olarak ele almasından kaynaklı güçlüğü aşmasını sağlayacak yöntemler ortaya koymasını mümkün kılmıştır. Ardından ispatı sonuçlandırmasında önemli bir adım olan üçüncü bir iç görü daha gerçekleşmiş ve “eşitlik, merkezleştirici ve alt grup” yapılarını birlikte düşünerek “ $M(a) < M(a^{-1}) \wedge M(a^{-1}) < M(a) \Rightarrow M(a) = M(a^{-1})$ ” ölçütünü oluşturmuştur. Bu ölçüt, formel olmayan bağlantılar içermesine karşın bu onun bilgi yapısı içerisinde bir tutarsızlık ortaya çıkarmamıştır. Dolayısıyla, Büşra’nın teoremde yer alan kavramlar arasındaki ilişkilere kendi anlayışı bağlamında anlam verebildiği ve mevcut bilgi yapısı içerisinde aydınlandığı söylenebilir.

His Boyutu: Büşra’nın süreci his deneyimleri açısından incelendiğinde sürecin ilk aşamalarından son aşamalarına kadar çeşitli noktalarda aşina olma hissi, bilme hissi, doğru iz üstünde olma hissi ve kesinlik hissi gibi bu sürece yön veren çeşitli hisleri deneyimlediği ve eylemlerine bu hisleri doğrultusunda bir yön verdiği söylenebilir. Dahası, pek çok noktada doğru iz üstünde olma hissinin varlığından da söz edilebilir. Büşra’nın çelişkiye düştüğü anlarda bu hissin kısmen kesintiye uğradığı belirlenmiştir. Fakat bunun uzun sürmediği ve onun kavramsal ilişki ağını farklı yapılar/yöntemler sayesinde zenginleştirdiği ve bunu yaparken de kendisini cesaretlendirdiği görülmüştür. Dolayısıyla Büşra’nın sürecin sonunda sezgisini kesin olarak doğruladığını düşündüğünden ispatın geneline ilişkin bir tamamlanmışlık hissine ulaştığı yorumu yapılabilir.

Tartışma ve Sonuç

İspat imajının bilişsel boyutunu oluşturan bileşenler arasında, kişisel anlayış bileşeni ile şekillenen hiyerarşik bir ilişkinin varlığından söylenebilir. Buna göre, ispatlama sürecini gerçekleştiren birey sürecin herhangi bir aşamasında belirli bir amacı gerçekleştirmek için kişisel anlayışı doğrultusunda girişimde bulunarak belirli matematiksel yapıları seçer ve bunlar arasında sezgisel ya da formel olabilecek ilişkiler kurar. Eğer kurulan bu ilişkiler, mevcut aşamaya kadar benimsenmiş olan gerekçelendirme ağı ile tutarlılık gösteriyor ise bu aşama sürecin önceki aşamaları ile birleşir ve Davydov (1990) tarafından ifade edildiği anlamı ile basit bir formdan daha gelişmiş bir forma doğru gelişim mümkün olabilir. Ayrıca bu dinamik gelişim sayesinde ispatın söz konusu aşaması ile önceki aşamaları arasında bir bütünlük ortaya çıkabilir ve birey önceki adımlarda ulaştığı sonuçlardan hareketle yeni bir girişimde daha bulunarak sürece yön verir. İspatlama eylemine eşlik eden imajın oluşumunun, beraberinde getirdiği ilişki ağı sayesinde bireye iddianın neden doğru olduğu ile ilgili içsel bir görüş sağladığı yorumu da yapılabilir. Dahası, Büşra'nın olayında gözlendiği gibi ispat imajını biçimlendiren bir bireyin ulaştığı kesinlik hissi ile birlikte enformel yaklaşımının da ötesine geçerek daha formel bir bakış elde etme ihtiyacı duyduğu söylenebilir. Bu noktada sağlanan içsel motivasyon, bireyi tanımlar gibi matematikçiler tarafından kabul edilen formel yapıları kullanmaya teşvik etmektedir. Bu noktada Kidron & Dreyfus (2014) tarafından da ifade edildiği gibi söz konusu formel bilgi yapılarının, daha zayıf yapıları destekleyerek bireyin daha gerekçelendirilmiş bir çerçeveye ulaşmasını mümkün kıldığı yorumu yapılabilir. Diğer yandan kurulan matematiksel bağlantıların formel bilgi tutarlılığı ise başta hazırbulunuşluk olmak üzere pek çok faktör ile yakından ilişkilidir. Bu çalışmada olduğu gibi yeterli matematiksel olgunluk düzeyinde olmayan ve bir matematiksel durumu başka bir duruma dönüştürmede (Simon, 1996) yeterli gerekçelendirmeyi sağlayamayan bireylerin ispat imajını inşa ettikleri durumlarda dahi formel ispatı oluşturamayabilecekleri söylenebilir.

Can the Proof Image Exist in the Absence of the Formal Proof?: Analyses of an Unsuccessful Proving Attempt

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Received : 19.12.2020 Accepted : 21.04.2021

Doi: 10.17522/balikesirnef.843527

Abstract – As proof and proving are the key elements of mathematics, several frameworks evaluating this process have been presented. Proof image, being one of them, was introduced by Kidron and Dreyfus (2014) through analyses of two mathematicians' activities. Authors clarified it in the context of components, and emphasized its relation with formal proof. However, despite mentioning its possibility, they didn't present any case where proof image exists without the formal proof. This led us investigating dynamics of such cases. Multi-stage sampling was preferred, and 120 pre-service teachers were asked to prove two theorems about algebra firstly. Then, task-based interviews were conducted with 3 participants, who proved both theorems. Moment-by-moment analyses were conducted and sub-dimensions were discussed in detail. Additionally, role of "enlightenment" was reinterpreted and feeling dimension was elaborated. Consequently, it was identified that one participant had an image although she couldn't reach the formal proof, and her story was presented.

Key words: proof image, proving, algebra, mathematics education

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The data of this study were collected in the 2017/2018 academic year, and some of them were presented as oral presentations at the 42nd Annual Meeting of the International Group for the Psychology of Mathematics Education symposium held in Umeå/Sweden, between 3 and 8 July 2018.

Introduction

As proof and proving are the key elements of mathematics, difficulties experienced (eg., Moore, 1994; Almeida, 2000; Knapp, 2005; Harel & Sowder, 2007; Ko & Knuth, 2009; Weber & Alcock, 2009) in proving in mathematics education have caused the process to be discussed in detail, and several theoretical frames (eg., Balacheff, 1988; Harel & Sowder, 1998; Tall, 1998; Blum & Kirsh, 1991; Miyazaki, 2000) which are evaluating this process through different perspectives have been presented. One of these perspectives, the proof image was introduced by Kidron and Dreyfus (2014) by correlating different frameworks which explain the learning process of individuals. Because it approaches the proving process from the knowledge construction perspective and considers its both cognitive and affective dimensions, it can be said that the proof image provides a deep understanding of proof. However, is there always a possibility of transition from proof image to formal proof? Moreover, can the proof image exist in the absence of formal proof?

In this article, firstly, basic theoretical frameworks constituting the basis for the proof image were mentioned, and the sub-components of the image were discussed in detail. Then a proving process of a prospective mathematics teacher was presented in micro-analytic (moment-by-moment) level. This process was interpreted by using the proof image and findings of all characteristics were presented with specific examples. Based on these results, the discussion about the relation between the proof image and the formal proof was presented at the end of article.

Theoretical Framework

While the importance of proving in the studies of mathematics education has been underlined in this regard, studies have shown that undergraduates have difficulties with this activity. For example, Moore (1994) stated that students do not know mathematical definitions, or they cannot explain them. However, Antonini and Mariotti (2008) stated that methods of proof are not known sufficiently and argued that the known methods are often applied incorrectly. On the other hand, Knapp (2005) stated that undergraduates have difficulty in formal thinking and understanding formal mathematics. Another point in which students have difficulties is that they cannot decide where or how to start to prove. Although, on the basis of many theories which try to explain the proof process underlining the significance of intuitive understanding, lack of intuitive understanding is one of the difficulties that the students experience (Moore, 1994). However, intuitive structures are the key elements in every type of active understanding and productive thinking (Fischbein, 1982). Weber and Alcock (2004) stated that students use intuitive reasoning in addition to formal reasoning, defined this situation as different ways that students can produce a proof. In producing a syntactic proof, which is one of them, the individual tries to prove by using mathematical expressions in a logically acceptable way, that is, in a formal way. In producing a semantic proof, the individual uses informal and intuitive representations to lead the formal processes. Having looked at difficulties experienced in the proof process from a different perspective, Weber (2001) mentioned that although students know the concepts, definitions, theorems and can apply them, they could fail in proving. She explained that situation by strategic knowledge and categorized it. The strategic knowledge is “knowledge of the domain's proof techniques, knowledge of which theorems are important and when they will be useful, knowledge of when and when not to use 'syntactic' strategies”. This strategic knowledge and attempt to prove in a semantic way through intuitive understanding can be seen as a reflection of concept image in the individual's mind. Because having a rich concept image is of great importance to be able to use a concept in a flexible way. On the other hand, having a rich concept image is possible by structuring the knowledge construction process correctly. With the aim of analysing this construction on a micro-analytic level, Hershkowitz, Schwarz and Dreyfus (2001) put forward RBC model.

RBC (Recognizing, Building- With and Construction)

According to RBC, which is a model presented in the framework of Abstraction in Context (AiC), construction of mathematical knowledge is seen as a vertical mathematization process. Vertical mathematization pointed out by Freudenthal (1991) means constructing a new knowledge by analyzing and correlating present mathematical knowledge in mathematical context (Treffers & Goffree, 1985). According to Hershkowitz, Schwarz and Dreyfus (2001) taking this view as a reference, the abstraction process can be explained by three epistemic actions. These actions are Recognizing (R-), Building- with (B-) and Construction (C-) respectively. Recognizing (R-) which forms the first step of the abstraction process is the realization of a construction already formed by students before in the process of problem solving (Türnüklü & Özcan, 2014). On the other hand, using preformed mathematical constructions to achieve a certain goal is explained through Building with- action. (Schwarz, Dreyfus, Hadas & Hershkowitz, 2004). Construction (C-), the last step of the process, refers to the reconstruction and regulation of mathematical constructions by partial changes. (Bikner-Ahsbahs, 2004). The reconstruction and regulation actions mentioned herein indicates a vertical mathematization. Thus, thanks to the Construction (C-) action, a new mathematical construction, which has not been accessible for the individual before, is put forward (Hershkowitz et al., 2001). However, it can be interpreted that this discovery has not been made by an unforeseen chance (Liljedahl, 2004) and some basic mechanisms which take place in the mathematical thinking process have important roles in forming and understanding new constructions. The "Aha! Experience” and “Enlightenment” are two of those mechanisms accompanying the knowledge construction process.

The "Aha! Experience" and Enlightenment

"Aha! Experience", which expressed by Liljedahl (2005), can be imagined as an electric spark that occurs suddenly and connects the various pre-existing knowledge constructs through appropriate selection. Thanks to this phenomenon, a new construct can be formed. Moreover, it can be said that the individual can better understand the experienced situation, and thus he or she is "enlightened" in the sense of Rota (1997). From the viewpoint of the proving process, this step can be interpreted as "providing an insight to the connections underlying the claim to be proved". By this means, for example, the role of a concept (or argument etc.) in the context of other mathematical constructs can be comprehended.

The concept of the "Aha! Experience" and the "Enlightenment" can be described as important stages in the knowledge construction (C-) process (Kidron & Dreyfus, 2010) and are explained in a mutual metaphor by the authors of this study as follows (Figure 1).

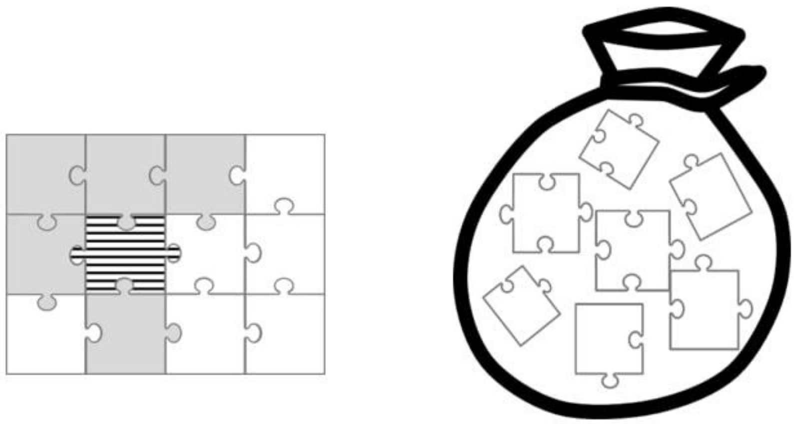

Figure 1 A metaphor explaining the relation between "Enlightenment" and "Aha! Moment"

While the marked part of the presented puzzle is determined by an appropriate approach, different features such as shape, size and color of the remaining shaded parts are taken into consideration. All of these features are considered as a whole and then the appropriate part is chosen from the pouch. At the moment in which all the features are evaluated simultaneously, clarification of which part in the pouch is appropriate for the shaded space in an undoubted way for the individual is interpreted in the context of "Aha! Experience" stated by Liljedahl (2005). On the other hand, creating a meaningful whole by this chosen part for the individual by being placed on the puzzle, and the increase of this meaningfulness level gradually have been evaluated in the context of the "Enlightenment" idea stated by Rota (1997).

Proof Image

Taking conceptual framework presented above into account, Kidron and Dreyfus (2014), examined the interplay between intuitive and logical thinking in the proving process micro-analytically and they reached the concept of the proof image by using RBC (Recognizing – Building With - Constructing) model. They described this concept as *"total cognitive structure in the person's mind that is associated with her or his proof* (Kidron & Dreyfus, 2014, p. 305)" and introduced it by comparing it to different viewpoints related to proving such as intuition, conceptual insight, semantic proof production, and they created the proof image-formal proof analogy by using a double strand concept image-concept definition structure. In this context, the writers underlined that the individual has certainly a proof image if he or she, who has attempted to understand why a given claim is true, has two main components together. Main components and their subcomponents are in the Figure 2 below.

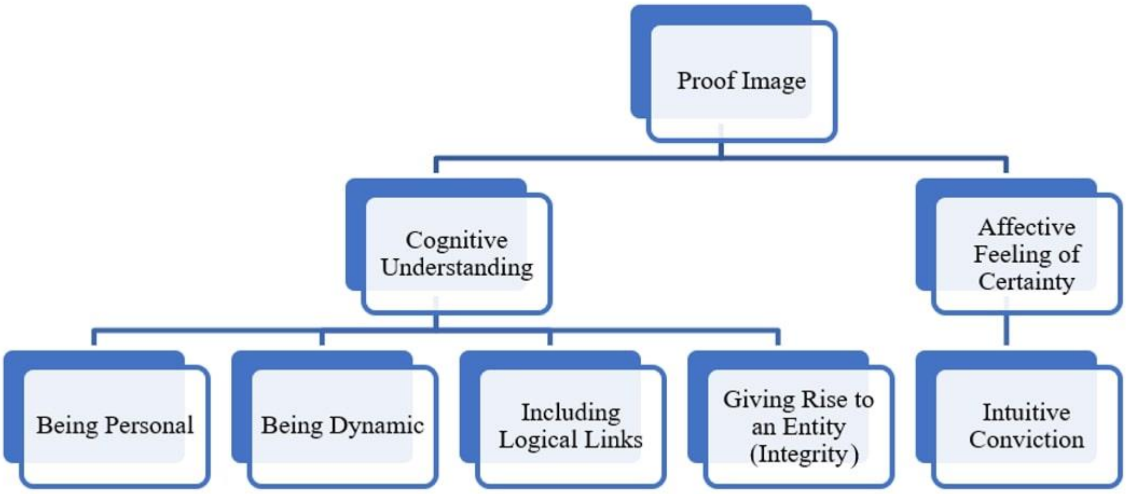

Figure 2 Components of the Proof Image

The first component is the cognitive understanding of why the proof is true. According to Kidron and Dreyfus (2014), the cognitive dimension of the proof image consists four characteristics. These are presented following Table 1:

Table 1. Cognitive Components of the Proof Image

C_1. Being personal: It means the image's having the traces of the individual's personal inferences and experiences, and making progress by being fed with them. According to Kidron and Dreyfus (2014), cognitive intuition and logic enriching the understanding of the individual on why each suggested claim is true in the proving process can be expressed in the context of personal understanding.

C_2. Including logical links: Mathematical proof requires a synthesis of various cognitive links to establish a new connection (Barnard & Tall, 1997). In this context, the meaningful links are established by the way like weaving the intuitive threads between previous mathematical constructions recognized and selected by the individual in the proving process (Kidron and Dreyfus, 2014).
C_3. Being dynamic: This characteristic which is inherent to the image's process of progress (Kidron and Dreyfus, 2014) can be expressed as image's further forms' including the former ones. In other words, in line with Davydov's view of abstraction, the progress of proof image is from backward form to developed form, from simple to complicate.
C_4. Giving rise to an entity: It means a single image of entire mathematical situation (Kidron and Dreyfus, 2014). In other words, the progress of the image in a single and entire way, which enables a construction. In present study, this characteristic was used by emphasizing the meaning of "integrity".

Kidron and Dreyfus (2014) defined the second component of the proof image as "the affective feeling of certainty, consists of the intuitive conviction". When defining the affective part of framework, they emphasized the following two concepts:

Intuition: According to the English version of the Oxford Dictionary (1989), intuition means "the ability to understand something instinctively, without the need for conscious reasoning". Fischbein (1999) defined intuition as a special cognition type on whose basis a personal feeling of certainty and generality take place, and stated that the intuition is explained together with many characteristics such as self-evident, immediacy etc. In addition to this, Fischbein (1987) defined intuitive knowledge as a knowledge type that is not based on experimental proofs or certain logical arguments.

Feelings: The context of the feeling concept is a subject of debate in the literature. Many researchers (e.g., Hannula, Evans, Philippou & Zan, 2004; Grootenboer & Marshman, 2016; Selden, McKee & Selden, 2010) described this concept as affective. However, some researchers claim that feelings cannot be restricted in a domain. One of them, Clore (1992) stated that "feelings" can be seen as both affective and cognitive and even physical. Because he considered the feeling as internal indications deducted from the bodily, cognitive and affective states, which provide usable feedback or information about these states. Affective feelings include fear, happiness, satisfaction, and many other feelings like those attached to the affective domain, while reactions for physical conditions such as hunger, ache and pain are bodily feelings (Clore, 1992). Cognitive feelings are also the feelings that the individual provides feedback for their own cognitive processes (ibid). Knowing, confusion, certainty, rightness, familiarity and completeness are some cognitive feelings. These three domains take place in different categories in regard to the way that they are felt; however, they are connected with each other and are interchangeable. That is to say, feelings in different categories can direct, launch or have an interaction with each other mutually. To illustrate, we can be happy to know something, be in dread of a situation that we feel confused about or be sad about being tired (Clore, Ortony & Foss, 1987, cited from Clore, 1992) or we can welcome an "Aha! Experience" with enthusiasm (Goldin, 2000). As Clore (1992) said, stating that some feelings aren't affective doesn't mean that they won't cause affective reactions.

As accepted by Kidron and Dreyfus (2014), in this present article, the intuition was discussed in the sense, which Fischbein (1982; 1987; 1999) used. In addition, the concept of feeling was adopted in the sense, which Clore (1992) used. Especially, affective and cognitive feelings have been taken into consideration due to their effect on justification in proving activities.

Motivation of Study

In their article, Kidron and Dreyfus (2014) presented two proving stories (the case of K and the case of L) both of which included a proof image and formal proof together. On the other hand, despite mentioning its possibility, they did not present any specific case, which includes a proof image and does not include formal proof. This gap, which is an incomplete part of the theoretical framework, led us to be sensitive about these type possibilities. For instance, Pala and Narlı (2020) examined the proof image of a student when the student had and did not have formal knowledge, and detailed the effect of formal knowledge on the proof image and on reaching formal proof. As a result, they emphasized the positive effect of formal knowledge on the proof image and on reaching formal proof, but also stated that the student had the proof image even when she did not have formal knowledge. Thus, such findings directed us to the following question for this study:

"How can a proving activity occur in which the proof image emerges but the formal proof does not?"

By the light of this question, in this present study, proof image, feelings, and epistemic actions were used to analyze an unsuccessful proving process of an undergraduate who attended abstract algebra course. Because of having a rich content in terms of proving activities, abstract algebra course is considered as a suitable context for revealing the difficulties in proving. In this way, it is thought that the relationship between the formal proof and the proof image can be elaborated and some of the reasons preventing the transition to the formal proof can be revealed. This analysis is of importance mainly because of its contributions to the educational practices for instructors' proof presentations, and the description of the process, which students experience within the scope of mathematics education in a multidimensional way. Furthermore, the data obtained from in-depth and multi-perspective analyses of the proving process can include suggestions for the educational practices for proof.

Method

Because a student's proving process was aimed to be analyzed without any intervention, the case study, which is one of the qualitative analysis methods, was used for this study. Case study is an in-depth description and analysis of a limited area (Merriam, 2009). Observation, interview, and written data were used to comprehend the student's proving process throughly.

Sampling

Participants of the study were pre-service middle school mathematics teachers attending a state university. Before the research, they took the Fundamentals of Mathematics, Abstract Mathematics, Linear Algebra I-II, and Analysis I-II courses previously. During this research, they were also taking Introduction to Algebra, Analysis III and Analytic Geometry I courses. The third writer was the instructor of Introduction to Algebra course. Because the sampling process completed in two stages, the multi-stage sampling was preferred in the study. In the first stage, the convenience-sampling method was preferred and 120 juniors taking Introduction to Algebra course were given a questionnaire including two proof questions. In the second stage, students whom would be interviewed were selected by the criterion sampling method. This method was preferred because it enables the selection of the individuals who had the determined qualification. In this stage, three students who answered both of the questions correctly and volunteered for the study were selected for task-based interview.

During the research and analysis process, attention was paid to the criteria that would ensure the validity and reliability of the study. The most basic and first of the strategies that increase credibility in a qualitative study is data triangulation (Merriam, 2009). In this study, data triangulation (interview and observation) was performed to ensure the credibility of the findings. Sufficient (rich and dense) descriptive data were provided in the findings to ensure transferability (Merriam, 2009). Peer evaluation, which is one of the strategies that can be used to ensure the reliability of qualitative research, is explained in the data analysis section.

Data Collection

The questionnaire, given to 120 students to determine the students with whom a task-based interview would be conducted, was an open-ended exam, which did not include any multiple-choice questions. The exam consisted of two questions about proving two theorems. Because the questions include advanced cognitive skills and required long answers, the number of questions was limited. Expert opinions on the validity of the questions were taken from two instructors working in the primary mathematics teaching department. The theorems in the questionnaire included proving tasks on a subgroup and centralizer concepts in abstract algebra. These concepts were preferred because they are the basis of many subjects in abstract algebra. The theorems were as follows:

- Theorem 1: Let (G,.) be a group and a ∈ G. In this case: Is the set of C (a) = {x ∈ G: a.x = x.a} a subgroup of the group G? Prove it.
- Theorem 2: Let (G,.) be a group and H<G. In this case: The set of C (H) = {x∈ G: ∀ h∈ H, h.x=x.h} is defined. What kind of a set is this? Explain it. Is the set of C(H) a subgroup of the group G? Prove it.

Before the practice exam, the students learned the subjects of operation, group, subgroup, and the center of a group in the introduction to the algebra course. Also, the statement “the center of a group is a sub-group” was proven in the course with the students. Therefore, the students were thought to have a sufficient background necessary to use statements such as “the center of group, subgroup requirements, properties of commutation and association, etc.” to prove the two theorems above. In answering the questions, no limitation was placed on the undergraduates. After the preparation of the questionnaire, a key form was prepared to evaluate the items in the questionnaire. Taking into consideration that an individual can prove in different ways, all-different proving ways, which can be formed through the subjects taught within the scope of the course, were tried and added onto the key form. To be accepted as successful in demanded proving, an individual should complete the steps on the form. Answers taken from the questionnaire were evaluated by the first and second writers individually, and three students who received full marks from both of the researchers were selected. These students, whom we called Rabia, Büşra, and Merve, were given the necessary ethical information about the study. In the interview, they were asked to prove the theorem given below in order to observe how they proved a theorem, which they had never come across before.

- Theorem 3: Let G be a group and a∈G. If C(a)= {x∈G: a.x=x.a}, show that $C(a)=C(a^{-1})$

This interview was conducted by the first writer and recorded by two video cameras. One of these cameras was placed in such a way that it could record the paper of the student, and the other was placed in such a way that it could record the face of the student. When proving the given theorems, the students were asked to think aloud and to give explanations at critical points. Right after each proving activity, a semi-structured interview was carried out with participants about their proving process. This interview form, which was developed by the light of opinions of three mathematics education experts, included 13 questions about components of the proof image.

Data Analysis

Content analysis was used in the analysis of the data received from the task based activity and the interview. After the interview was transcribed, the data was analyzed according to the cognitive and affective components and their sub-components. The RBC (Recognizing-, Building With- and Construction-) model was used as an analytic tool in the evaluation of knowledge construction processes on proving.

In the data coding process, firstly, main indicators of each sub-component were identified by three authors. For example "clear expression of remembering any pre-knowledge" was one of the indicators of Recognizing (R-) epistemic action, "relating at least two concepts for any procedure" was one of the indicators of including logical links characteristics or "expressing thoughts without any hesitation" was one of the indicators of the feeling of rightness. Especially, camera records (focused to face) and statements in the interview were used for coding feelings. Having identified these indicators, the coding process was executed by the first and the second authors separately. The same coded variables of both authors were included in the study. For different situations, the third author's opinion was taken into account. The codes of the researchers were compared and the consistency between the coders was calculated using Miles and Huberman's (1994) formula (Reliability of the study = consensus / (disagreement + consensus) x100). As a result, the reliability percentage between the encoders was calculated as approximately 80%. After the coding process, analyzes were conducted. As a result of these analyzes, it was observed that only one of the participants had the proof image but did not reach the formal proof. In light of the motivation of the study, the proving process of this participant, whose name is Büşra, will be presented with findings related to her activity.

Findings

In this section, first of all, Büşra's proving activity is summarized and then interpreted in the context of the components of the proof image.

Summary of Büşra's Proving Process

After having read the theorem Büşra started to explain her thoughts to herself. She stated that there existed two centralizer sets in the theorem and she should show their equality. After having thought for a while, she said: "*I got what the question asked but I don't know how to point this out".* At this time she first questioned whether the commutative elements with an element of $a \in G$ could also be commutative with the inverse of this element. She linked the condition of equality of the sets to the condition of being commutative with exactly the same elements, and so started to create a framework within the context of commutative property on the equality of the sets. Then she decided to focus on the concept of a centralizer. She clearly expressed that the objects used to comprehend this concept existed in her mind, and she detailed her thoughts as follows using the concrete objects on her desk:

> For example *(she takes an eraser*) let this be the element of 'a'. If this eraser is commutative with these 4 pencils (*pointing out the pencils*), the inverse of the element of 'a' should be commutative only with these 4 pencils.

She stated that she had difficulty to express this relationship mathematically. At this point, she first focused on the approach of finding a contradiction. According to this approach, if any element in the centralizer sets were commutative with only one of the elements of $a \in G$ and $a^{-1} \in G$, it would certainly be commutative with the other. However, she gave up on proceeding in that way because she had a doubt that this approach could provide the essential conditions in terms of the formal proof. After having thought for a while, she excitingly expressed her thoughts:

> I wonder whether there exists an element a^{-1} in the set of C(a)? If I choose an element of a^{-1} from the set of C(a) and show that it is commutative with every element in the set of C(a), it will mean that this set is the centralizer of the element a^{-1}. Yes, I can do this now!

After making this explanation self-assuredly, she focused on the question of $a^{-1} \overset{?}{\in} C(a)$.

To answer this question, she focused on $a \overset{?}{\in} C(a^{-1})$ which she thought that it was easier to be answered and equivalent to other question. After having remained silent for a while, by stating that the set of $C(a^{-1})$ is a subgroup just like the set of $C(a)$, and so it should provide the group characteristics, she wrote "$a.a^{-1}=a^{-1}.a=e \Rightarrow a \in C(a^{-1})$". She couldn't continue with this expression and in order to overcome this difficulty, she expressed that she would define a new centralizer set and wrote "$C(a)=\{\forall x \in C(a^{-1}):\ a.x=x.a\}$". She stated that the sets needed to be equal according to the new definition. Because she had difficulty in expressing her thoughts and she repeated same concrete objects as follows:

> I said that (*she took the eraser*) let this be the element 'a'. Let them (pencils) be the centralizer set of the inverse of 'a'. If this one (*means the element 'a'*) is commutative with all these (*means the centralizer set of the inverse of the 'a'*), then the centralizer of the element 'a' is the same set.

Having made this explanation confidently, she stopped and didn't continue prove. After having thought for a while, she said that she made it much more confusing by defining the set of $C(a)=\{\forall x \in C(a^{-1}) | a.x=x.a\}$ in that way and then deleted it.

> If all elements of the set $C(a^{-1})$ is commutative with the element a, then it means that I'll show the set C(a) as a subgroup of the $C(a^{-1})$. If I show these sets are subgroups of each other, then it means I'll show the equality.

After having formed her criterion about the proof, Büşra, finally, was observed as being motivated. She produced the proof of "$C(a) < C(a^{-1})$" through a similar procedure of the proof of "$C(a) < G$" which she knew already. At the end of the following operations (presented in Figure 3), which she performed without hesitation, she arrived at the conclusion that this is a subgroup.

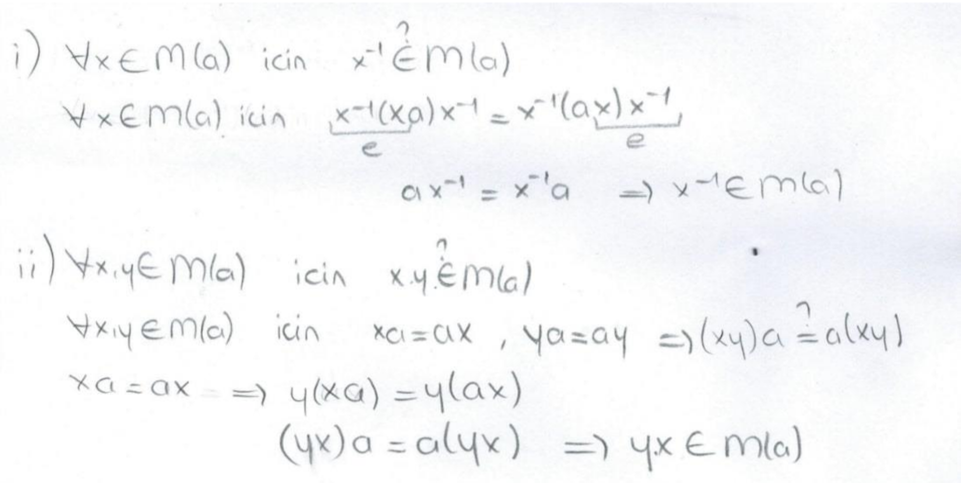

Figure 3 Büşra's approach for $C(a) < C(a^{-1})$

Following this step, she showed through a similar procedure that the expression $C(a^{-1}) < C(a)$, which is the inverse of the previous step, was valid, and then she stated that she completed her proof.

Figure 4 visualizes Büşra's proving approach (including mathematical connections, statements, actions, mimics and feelings) moment-by-moment. In addition, Table 2 elaborates her statements and actions step-by-step and shows her epistemic actions in each step.

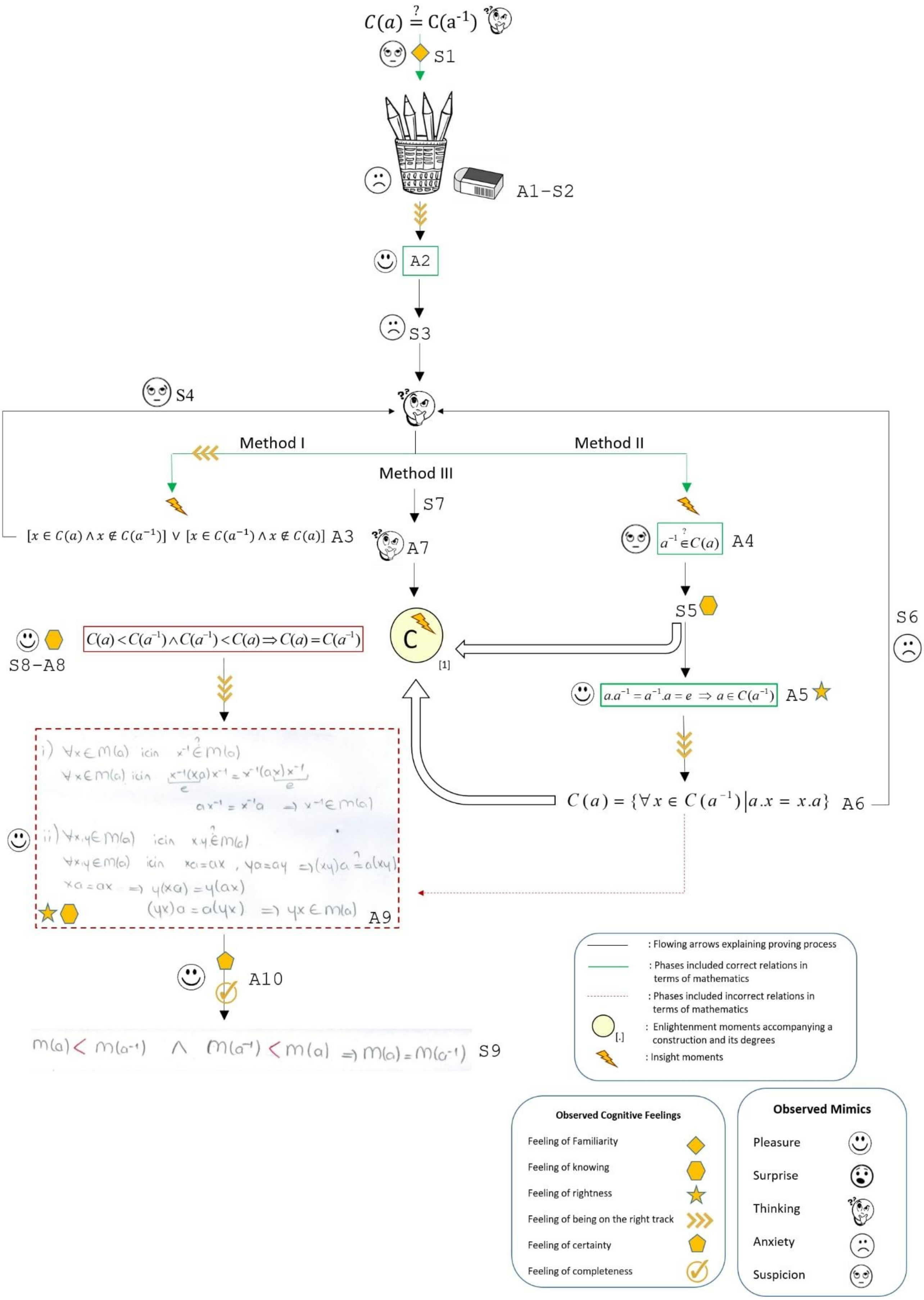

Figure 4 The Case of Büşra

Table 2. Micro-analytic analyses of Büşra's proving process

Statement (S) Action (A)	Explanation	Observed Epistemic Actions
S1	She stated that she has to demonstrate equality of centralizer sets. However, she also stated that she was not sure about this equality.	Action (R-)
A1-S2	She stated that the constructs, which she need for understand centralizer concept, exist in her mind. Afterwards, she interpreted the meaning of the equality of centralizer sets by using concrete objects (pens & eraser).	Action (R- & B-)
A2	She reached the conclusion that equal centralizers are the sets, which are commutative with same elements.	Action (R- & B-)
S3	She stated that she could deal centralizer sets separately and could not deal them together.	
A3	After for a while she suggested following approach: '*'Demonstrating that if any element in the centralizer sets were commutative with only one of the elements of* $a \in G$ *and* $a^{-1} \in G$*, it would certainly be commutative with the other*''	Action (R- & B-)
S4	Having stated she doubted the adequacy of this method, she abandoned it.	
A4	To understand better the relation between centralizer sets and their elements, she focused on a question.	
S5	«*If I select* a^{-1} *from C(a) and demonstrate that this element is commutative with all the elements of C(a), then I prove that C(a) set is also centralizer of the* a^{-1} *element.*»	Action (R- & B-)
A5	She answered the question asked in A4 action by using her pre-knowledge.	Action (R- & B-)
A6	She re-defined centralizer sets by using conclusion reached in A5 action.	Action (R- & B-)
S6	She stated that this approach made the relationship network more complicated and gave up using the definition she wrote in the last step.	

S7	She gave up her approach, which based on synthesizing two centralizer sets in single representation, and stated that she thought $C(a^{-1})$ as a simpler construct.	
A7	She thought about the properties of both centralizer sets and their elements.	
S8- A8	By considering S5 statement and A6 action, she formed following criterion to prove equality of the sets: *«If these two centralizer sets are sub-group of each other, then they must be equal.»*	Action (C-)
A9	She constructed the proof of $C(a) < C(a^{-1})$.	Action (R- & B-)
A10	She constructed the proof of $C(a^{-1}) < C(a)$ in a similar way.	Action (R- & B-)
S9	She stated that her proof was finished.	

Evaluation of Büşra's Proving Process

When cognitive and affective components taken into consideration, it could be said that Büşra had a proof image. The findings of the subcomponents will be exemplified below.

Cognitive Dimension

C_1. Personal Understanding: Because the proving process was shaped by Büşra's own preferences and her own actions, it can be interpreted that it includes a personal understanding which belongs to her. To illustrate, having considered using an approach based on finding a contradiction in the process, but then giving up on this approach with the impacts of her experiences and leaning towards a different approach can be interpreted as a reflection of her personal understanding giving direction to her proof. Personal understanding dimension expressed at this point can be said to provide an opportunity for presenting a flexible framework for herself. It can be expressed that this characteristic formed a branching construct rather than a linear proceeding.

On the other hand, it was observed that with the impact of Büşra's personal understanding, Büşra had difficulty in expressing her thoughts in the beginning stages and frequently hesitated in the communication process. To illustrate this, after having decided to define the elements of set C(a) with reference to the set $C(a^{-1})$, she remained silent for a while and then made the following explanation with a concerned face:

...I thought what I had at the beginning was logical for me but how can I express it?

It can be interpreted that at that moment the image was "silo thinking". On the other hand, with the impact of the dynamism provided in the next stages of the process, Büşra can be said to have managed to make contact with the outside, and thus she was able to express her thoughts in writing and orally in a more organized manner.

C_2. Including Logical Links: It can be interpreted that Büşra selected (R-) various mathematical constructs at several points and used them by establishing links most of which were based on logical justifications. To illustrate this, she focused on the relation between the centralizer sets and their elements to verify her initial intuition on the equality of the sets, and thus, she formed more formal framework between the sets by developing a mathematical definition which would correlate the elements of the set C(a) with the set of $C(a^{-1})$. Similarly, it can be interpreted that Büşra established logical links which enabled her to discuss different concepts such as equality, set, centralizer, group, and subgroup interactively at several points. Besides, it can be said that although some parts of those links which Büşra established in the process had correct justifications mathematically, the majority of the links were based on incorrect justifications.

On the other side, it can be said that the relation $C(a)<C(a^{-1})$ which Büşra expressed towards the last stages of the proving process was based on a mathematically inadequate justification process. Because she preferred to analyze the sets once more in terms of the characteristic of being a subgroup instead of analyzing their subgroup relations between them even though she knew that both sets were in a group structure. In this context, Büşra can be interpreted as having developed an inadequate understanding of the concept of the subgroup. On the other hand, because the subset relations between the sets weren't analyzed, a proof which could be valid for the proposition of $C(a)<G$ was put forward by Büşra. However, because she didn't question the operations adequately she put forward at the last stages of the proving process, she didn't realize this deficiency, and thus, any imbalance didn't emerge within her present knowledge construct. Therefore, Büşra stated that she produced the formal proof with the view that the operations she performed were correct.

C_3. Being Dynamic: Thanks to the logical justification networks among the mathematical constructs which were selected (R-) and used (B-), it can be stated that the proof made a dynamic progress from the backward form to the more developed form. Büşra illustrated this by managing to explain the equality, which was an abstract relation that she comprehended on merely concrete materials at the beginning of the process, within a mathematical form, thanks to the logical relation networks, which she established within the process. As in this example, thanks to the dynamism, it can be interpreted that the next stages within the proving process of

Büşra made progress in such a way that including the previous stages. Therefore, progressing from an intuitional characteristic to a formal framework was possible.

C_4. Giving Rise to an Entity: Although Büşra adopted different approaches methodologically and didn't proceed within the process linearly, she can be said to have a single and entire image in terms of her proof thanks to the emerged dynamism. In the most general sense, this characteristic allowed her to carry all steps of the process in her mind as a whole. By means of this integrity, Büşra can be said to have given direction to her proof by reviewing the results of previous experiences at the necessary points. For instance, when she foresaw that she would not be able to obtain the proof she wanted in the case of adopting the approach based on contradiction, she gave up this approach.

Insight Moments and Enlightenment Experiences: Thanks to the justified relation networks and the integrity based on this, Büşra can be said to have gone through insight (Aha! Experience) in the meaning by Liljedahl (2005) at three different points. First, two of these experiences enabled her to put forward proof approaches which would make it possible for her to overcome the difficulty resulting from dealing with the sets C(a) and C(a^{-1}) as separated constructs. In these moments, by taking into consideration of her dead-ends in proving, she produced new initiatives based on inferences of her previous experiences. The first method based on finding a contradiction and the second method grounded on expressing the sets under a single representation provided a beginning point for Büşra's proof approaches. However, these attempts could not provide enough sense making to her for continuing proving because of weakness and complexity. On the other side, following these experiences, the third insight moment occurred, which was a significant step in Büşra's proof. In this phase, she formed (C-) the following criterion confidently by binding the constructs of the equality, the centralizer and the subgroup, which comes into the forefront among the concepts:

$$C(a) < C(a^{-1}) \wedge C(a^{-1}) < C(a) \Rightarrow C(a) = C(a^{-1})$$

Although this criterion had inadequate links mathematically, this inadequacy was not questioned in detail because of the impact of Büşra's belief in her criterion. Because these inadequacies weren't realized, and any inconsistency didn't emerge within her knowledge construct. In other words, considering through Büşra's perspective, it could be said that there was no contradiction in terms of the relations hidden in the theorem. Thus, it can be said that Büşra could comprehend the relations among the concepts laying the basis of the theorem in the context of her understanding and she was enlightened in her present knowledge context.

Büşra's Feelings

When her proving process was analyzed, it can be said that she experienced various feelings such as the feeling of familiarity, the feeling of knowing, the feeling of being on the right track, and the feeling of certainty, which gave direction to the process. To illustrate this, after having read the theorem, she recognized (R-) the centralizer concept, and experienced the intense feeling of familiarity, as is seen in her explanations below:

> I am making assumptions right now, I mean the objects I used while comprehending the centralizer at the beginning are in my mind after all.

Along with this, she modelled the relations she mentioned within a concrete model and stated as follows that this model helped her comprehend the relations.

> Now, the centralizer isn't confusing for me any longer. What the centralizer is, is just a simple set, 'a' commutative one with 'a'...

Within this context, it can be said that the feeling of knowing of the concept of the centralizer is dominant in the explanations Büşra presented above. Besides, the existence of the feeling of being on the right track can be mentioned in some phases. The following explanation, while she was in search of a method to demonstrate the equality of the sets, can be interpreted as an example experience of this feeling.

> If I select the inverse of the element 'a' from the set of C(a) now and demonstrate that it is commutative with every element in C(a), I will have shown that this set is its centralizer... Okay, it made sense to me after all.

The moment that Büşra runs into a contradiction within the different methods she adopted, it can be said that the feeling of being on the right track was interrupted by the feeling of confusion at certain points as in the following example.

> ... I mean the thought I had at the beginning was logical for me but how can I express it? Because I am not sure about its correctness.

On the other side, it was observed that these interruptions didn't last long. Because, Büşra enriched the conceptual relation network at these points by different constructs and methods, and while doing this she strived to encourage herself at once with the explanations such as *"... I will do it now"* and *"...yes yes, I am doing it right now"*. Along with this, it can be said that Büşra experienced a feeling of certainty about "the centralizer sets were subgroups" as a result of actions that she had performed, thus she reached the feeling of rightness on her initial intuition. Therefore, it can be interpreted that although she didn't experience a feeling of rightness for some approaches, which they did not enable her to reach the point she wanted, she certainly had verified her intuition at the end of the process. In general, she had the feeling of completeness for the proof. On the other side, when her following statement considered, which she made when evaluating her proof in interview, it can be inferred that she was not adequately satisfied with the form of the proof despite having reached the feelings of rightness and completeness:

> ... now, I believe, okay, it might be long, I don't know, I may have gotten it very differently but I believe it is correct.

Discussion and Results

Based on the analysis of the presented case, some conclusions regarding the "proof image" and the "formal proof" are shared in this section.

Hierarchical Nature of Proof Image

When the proving process of the undergraduate in this study and two mathematicians presented by Kidron and Dreyfus (2014) have been evaluated together, it can be seen that a hierarchical relation is generally taking shape among the components of the cognitive dimension of the proof image. According to this, the individual realizing the proving process selects certain mathematical constructs by making an attempt on his/her own personal understanding to realize a certain purpose at any stage in the process, and establishes a relation among them which can be considered as intuitional or formal. If these established relations are consistent with the justification network adopted until the current stage, this stage is articulated with the previous stages of the process, and progress from a simple form to a more developed form in Davydov's (1990) sense could be possible. Furthermore, this dynamic development can lead to an entity between the present stage and the previous stages of the proof, and the individual gives direction to the process by making a new attempt considering the results of the previous steps (Pala, 2020).

Transition to Formal Proof In Terms of Sub-Components

It can be said that the construction of the image accompanying a proving activity provides an insight into the individual about why his or her claim is true thanks to the logical links. Along with this, an individual giving shape to a proof image can be said to be in need of obtaining more formal perspective by passing beyond the informal approach (Dreyfus & Kidron, 2014) with the certainty feeling which he/she reaches just as observed in the case Büşra. Moreover, the provided internal motivation encourages the individual to use formal constructs such as definitions (Weber, 2005). That is, the present formal knowledge constructs enable the individual to reach a more justified framework by contributing weaker constructs, just as expressed by Kidron and Dreyfus (2014). For example, after Büşra interpreted about the equality of the centralizer sets by the concrete model, which she formed through pencils, she sought to generalize her thoughts and formed a criterion for her judgement. This can be interpreted in the context of the transformational thought, which provides the transition from the image of proof to the formal proof. The importance of transformational thought in terms of constructing new mathematical situations has been also emphasized by Simon (1996) and has been closely related to the "dynamism" dimension of the proof image by Pala and Narlı (2020).

At this point, it can be interpreted that especially the justification dimension of the relation network in the proving process is an important element in both the dynamic progress of the proof and the individual's reaching the formal proof. Because it can be said that the relation networks established with insufficient justifications can be an obstacle against the meaningful progress (Duval, 2007), and as a result of this, it may not create an integrity. Moreover, dynamism dimension of the image includes "justification" within it, and thus consistent connections can be established between steps (Pala & Narlı, 2020). On the other side, it can be interpreted that the knowledge structure which can be synthesized (C-) in the circumstances in which the characteristic of the entity emerges, is strong within the context of its logical connections and accompanying epistemic actions; and plays an essential role in reaching the formal proof in this context. The dynamism in Büşra's image is parallel with Davydov's (1990) viewpoints on abstraction as expressed before. At this point, it can be said that the dynamism which was observed in Büşra's images enabled her to convey their intuitive approaches to a more formal mathematically framework. It can be said that the proving process of Büşra included the discovery of a new characteristic, which is a synthesis, by the intersection of the common characteristics of knowledge sets taking shape due to the gathering together of the different concepts. According to Kidron and Dreyfus (2014), when the image has the characteristic of giving rise to an entity, it includes whole mathematical circumstance within itself in full. It was clearly observed that the progress enabled by the dynamism occurred in the process had an important role in giving rise to the entity. It can be said that Büşra was able to carry consequences of previous stages continuously in her mind thanks to the entity they gave rise to and, thus experienced insightful moments due to their appropriate selections. Therefore, it can be interpreted that the entity characteristic of the proof image paves the way for the realization of important turning points which enables the revealing of a product in the proving process.

When the process had been analyzed in terms of the feeling dimension, it can be said that Büşra successively experienced some of the main cognitive feelings such as the feeling of familiarity, the feeling of knowing, the feeling of rightness, and the feeling of certainty. The experience of these feelings gave direction to her proving activity at various points, which in the end, allowed her to reach the feeling of "completeness" for the entire of the image. Moreover, it can be said that when the image is formed, cognitive and affective feelings reach in a specific step, give direction to the next step, and along with this, the product composed at the end of the process is reanalyzed with an integrated perspective in the context of the feelings of "completeness" and "satisfaction". It can be said that the occurrence of these feelings undertakes an important function in terms of termination of the proving activity (Selden & Selden, 2008).

Implications For the Further Studies

Kidron and Dreyfus (2014), made the following explanation while putting forward the analogy between the concept image and proof image:

> …while we do not have a specific example, we think that this might also occur in some cases where the proof image does not lead to a formal proof (Kidron & Dreyfus, 2014, p. 305)

Along with this, when the findings of this present study had been taken into consideration, it can be said that the foresight of Kidron and Dreyfus (2014) was verified by the case of Büşra. Because, despite the fact that she couldn't reach the formal proof, she had a proof image. On the other hand, the question of whether the individuals will be able to reach a formal proof even though they don't have any proof image is still pending.

This study was carried out with an undergraduate who can be considered as non-expert mathematicians unlike Kidron and Dreyfus (2014), and the analysis of proof image within the context of abstract algebra was managed by selecting the concept of the "centralizer". Along with this, understanding the nature of the proof image can be deepened by analysis of the proof image within the context of different age groups and different subject fields as suggested by Kidron and Dreyfus (2014).

Considering the findings of this study, it can be said that the relationships between mathematical concepts in the Abstract Algebra course should be taught by making formal justifications and by asking students for such justifications. It can be suggested that the logical connections that students establish between mathematical concepts should be frequently evaluated in the context of proving, and it should be ensured that they express these connections with formal justifications.

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Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi (EFMED)
Cilt 15, Sayı 1, Haziran 2021, sayfa 32-61. ISSN: 1307-6086

Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Vol. 15, Issue 1, June 2021, pp. 32-61. ISSN: 1307-6086

Araştırma Makalesi / Research Article

Öğrencilerin Süreç Diyagramlarında Öğrenme Stilleri, Öğrenme Aktiviteleri ve Öğrenme Çıktılarına Bir Bakış

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Gönderme Tarihi: 16.01.2021 Kabul Tarihi: 12.05.2021

Doi: 10.17522/balikesirnef.862572

Özet –Bilimsel metinlerde, öğrenenlerin bir konuyu öğrenmelerine yardımcı olmak için genellikle görsel sunumları (grafikler, diyagram, fotoğraflar, tablolar) kullanılır. Süreç diyagramları, uzun bir başlık, açıklayıcı etiketler, oklar ve renk kodlamalarından oluşan, her türden sürecin adım adım görselleştirilmiş biçimidir. Bu araştırmada, katılımcıların süreç diyagramlarında öğrenmeyi gerçekleştirirken kullandıkları öğrenme aktivitelerini ve öğrenme stillerini belirleyerek, öğrenme aktivitelerinin ve öğrenme stillerinin öğrenme başarısı üzerindeki etkisinin incelenmesi hedeflenmiştir. Araştırmaya, 23 katılımcı katılmıştır. Araştırma verilerin toplanması için ilk olarak katılımcılara Santa Barbara Öğrenme Stili Ölçeği'nin uyarlanmış hali uygulanmıştır. Daha sonra katılımcılara süreç diyagramları göz izleme tekniği ile gösterilmiştir. Aynı zamanda öğrenme aktivitelerini yorumlamak için katılımcılara yüksek sesle düşünme protokolü uygulanmıştır. Yapılan frekans analizi ve Mann Whitney U testi sonucunda başarılı öğrenme gerçekleştiren katılımcıların öğrenme aktivitelerinden okları anlamlandırma ve kendine soru sorma aktivitelerini kullandıkları tespit edilmiştir. Ayrıca, ana alana odaklanmak için daha fazla zaman harcayan katılımcıların öğrenmeyi başarılı bir şekilde gerçekleştirdikleri de bulunmuştur.

Anahtar kelimeler: öğrenme stili, öğrenme aktivitesi, öğrenme çıktısı, göz izleme, yüksek sesle düşünme protokolü.

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Geniş Özet

Giriş

Öğrenme aktif bir bilgi oluşturma sürecidir. Başarı ise, belirlenen bir hedefe ulaşma düzeyi olarak tanımlanabilir. Öğrenciyi bir diğerinden farklı kılan en önemli değişkenlerden biri öğrenme başarısıdır (Buluş , Duru, Balkıs, & Duru, 2011). Günümüzde yaygın bir şekilde ders kitaplarında kullanılan süreç diyagramları genellikle öğrenciler tarafından metinden bağımsız olarak incelenmekte ve öğretim tercihi olarak kullanılmaktadır (Kragten, Admiraal, & Rijlaarsdam, 2015; Reece, Urry, Cain, Wasserman, Minorsky, & Jackson, 2010). Peki, ne tür performanslar süreç diyagramlarından öğrenmede başarıyı arttırıcı etkiler yapar?

Öğrenme aktiviteleri öğrenenlerin yeni bir şeyi öğrenmek için kullandıkları bilişleri ve öğrencinin kendi öğrenme sürecini kontrol edip, düzenlemesine olanak tanıyan (ana noktaları ayırt etmek, önceki bilgilerle bağdaştırmak, kendine sorular sormak, konuyu tekrarlamak, bu aktiviteleri bilinçli bir şekilde kullanmak gibi) becerilerini içerir. Bu becerilere sahip olmak öğrenme başarısını etkileyen temel faktörler arasında yer alır. Ayrıca süreç diyagramları resim-metin kombinasyonlarını içerirler. Bu bağlamda öğrenenlerin öğrenme stillerini bilmesi, öğrenme sürecinde bu stili devreye sokması başarıyı arttırıcı etki yapar (Koc-Janutha, Höffler, Thoma, Prechtl, & Leutner, 2017).

Bu araştırmadaki amaç; katılımcıların süreç diyagramlarında öğrenmeyi gerçekleştirirken kullandıkları öğrenme aktivitelerini ve öğrenme stillerini belirleyerek, öğrenme aktivitelerinin ve öğrenme stillerinin öğrenme başarısı üzerindeki etkinin incelenmesidir. Bu yüzden aşağıdaki sorulara cevap aranmıştır.

1. Süreç diyagramında katılımcılar görsel alana mı yoksa sözel alana mı daha çok odaklanırlar?
2. Odaklanma Süreleri (fixation duration) ve Santa Barbara Ölçek puanları Hatırlama ve Etki Değerlendirme Formu (HEDF) puanlarını ne düzeyde yordamaktadır?
3. Katılımcılar süreç diyagramlarını kullanırken öğrenme aktivitelerini ne düzeyde kullanırlar?
4. Katılımcıların öğrenme aktiviteleri ve öğrenme çıktıları arasında anlamlı bir ilişki var mıdır?

Yöntem

Araştırmada süreç diyagramlarında katılımcıların öğrenme stilleri, öğrenme aktiviteleri ve öğrenme çıktıları üzerine odaklanılmıştır. Süreç diyagramları sistemlerin işleyişini daha somut bir şekilde anlaşılır hale getirdikleri için biyoloji dersinde; fotosentez, solunum, protein sentezi gibi konularda kullanılmaktadır. Bu yüzden 'Kemiozmotik Teori' ile ilgili iki süreç diyagramı Taiz ve Zeiger (2002)'nin Bitki Fizyolojisi kitabından seçilmiştir. Bu araştırmada iki süreç diyagramı seçilmesinin asıl nedeni ise süreç diyagramlarındaki tasarımdan kaynaklanacak farklıların olmasını engellemektir.

Araştırmanın araştırma grubu, amaçlı örnekleme yönteminden ölçüt örnekleme yöntemi kullanılarak belirlenmiştir. Katılımcıların seçiminde ölçüt biyoloji dersinde kemiozmotik teoriyi görmüş olmasıdır. Bu yüzden araştırma grubu, liseden sonra sınavla ve bulunduğu ilde kendi kategorisinde en yüksek puanla öğrenci alan bir devlet üniversitesinin Biyoloji Eğitimi Anabilim Dalından seçilen 23 öğretmen adayından oluşturulmuştur. Araştırmanın katılımcıları gönüllülük esasına göre belirlenmiştir. Araştırmanın etik izni araştırmanın yapıldığı üniversitenin Etik Komisyonu tarafından (Sayı: 35853172/433-2465) onaylanmıştır.

Uygulama için her bir katılımcı sessiz bir test odasında 10-15 dakikalık bir öğrenme görevini gerçekleştirmiştir. Katılımcıların öğrenme stillerini belirlemek için ilk önce Santa Barbara Öğrenme Stili Ölçeği uygulanmıştır. Süreç diyagramları gösterilirken göz izleme tekniği ve yüksek sesle düşünme protokolü veri toplama aracı olarak kullanılmıştır. Göz izleme tekniği ile katılımcıların süreç diyagramlarında nereye, ne kadar süre ve kaç kere baktığına dair bilgi elde edilmektedir. Yüksek sesle düşünme protokolü ise , katılımcıların bilişsel görev esnasında zihninden geçirdikleri sesli bir şekilde ifade etmelerinden elde edilen verileri içerir. Bu sayede araştırmada katılımcıların öğrenme aktiviteleri gözlemlenerek analiz edilmektedir. Araştırmada katılımcıların ses kayıtları ve göz hareketleri Tobii Studio programı tarafından kaydedilmiş ve içerik analizi yapılmıştır. Ayrıca katılımcıların süreç diyagramlarından anlama derecelerini ölçmek için Hatırlama ve Etki Değerlendirme Formu (HEDF) uygulanmıştır.

Verilerin Analizi

Birinci problem için iki süreç diyagramının da ilgi alanları (AOI) görsel ve metin alanı olmak üzere iki bölgeye ayrılmıştır. Tobii Studio yazılımı kullanılarak katılımcıların Süreç Diyagramı 1 ve Süreç Diyagramı 2 için görsel ve metin alanlarında geçirdikleri ortalama ve toplam süreleri saniye cinsinden hesaplanmıştır.

İkinci problem için Santa Barbara Öğrenme Stili ölçeği kullanılarak katılımcıların öğrenme stilleri belirlenmiştir. Ayrıca öğrenme problemine etki eden göz hareketlerini belirlemek için süreç diyagramlarının ilgi alanları (AOI); başlık, ana alanlar ve açıklama olmak üzere ayrılmıştır (Kragten, Admiraal, & Rijlaarsdam, 2015). Süreç Diyagramı 1 ve Süreç

Diyagramı 2'nin Açıklama, Ana Alanlar ve Başlık ilgi alanları için katılımcıların toplam odaklanma süreleri ve toplam geçiş sayılarının verileri uygulama sırasında elde edilmiş; ortalamaları hesaplanmıştır. Bu verilerle birlikte, Santa Barbara ölçeğinden elde edilen görsel ve sözel puanlar bağımsız değişkenler olarak; HEDF'den alınan puanlar ise bağımlı değişken olarak ele alınmış; çoklu regresyon analizi ile bağımsız değişkenlerin bağımlı değişkeni ne düzeyde yordadığı incelenmiştir.

Üçüncü problem için katılımcıların ses kaydının transkripsiyonu kullanılmıştır. Katılımcıların öğrenme aktiviteleri yapılan literatür taraması (Azevedo & Cromley, 2004; Kragten, Admiraal, & Rijlaarsdam, 2013; Kragten, Admiraal, & Rijlaarsdam, 2015) ve elde edilen yüksek sesle düşünme protokolü verilerine göre aşağıda ki gibi 3 kategoriye ve bu kategorilerde toplamda 10 alt kategoriye ayrılmıştır.

1. Bilişsel Öğrenme Aktiviteleri; okları anlamlandırma, yorumlama, once bilgilerle bağdaştırma, hipotez üretme, ilgi alanlarını (AOI) karşılaştırma.
2. Biliş Ötesi Öğrenme Aktiviteleri; kendine soru sorma, diyagramı yeniden okuma.
3. Diyagram Öğrenme Aktiviteleri; başlığı okuma, organizasyon etiketlerinin okunması, içeriğin kullanılması.

Dördüncü problem için katılımcıların en sık kullandıkları öğrenme aktiviteleri ile Hatırlama-Etki Değerlendirme Formu (HEDF) toplam puanları arasındaki ilişki incelenmiştir. Bu amaçla katılımcıların öğrenme aktivitelerindeki frekanslarının ortalamaları dikkate alınarak katılımcılar her bir öğrenme aktivitesi için yapay iki alt gruba ayrılmıştır: 1. alt grup belirli öğrenme aktivitesini az sıklıkla kullanan ya da hiç kullanmayan katılımcılardan oluşurken; 2. alt grup daha sık kullanan katılımcılardan oluşturulmuştur.

Sonuçlar

Araştırmanın alt problemleri bağlı olarak elde edilen bulgular 4 alt başlık halinde sunulmuştur.

Süreç Diyagramında Katılımcılar Görsel Alana mı Yoksa Sözel Alana mı Daha Çok Odaklanırlar?

Katılımcıların süreç diyagramlarında öğrenme tercihi olarak daha çok görsel alana yoğunlaştığı veriler elde edilmiştir.

Odaklanma Süreleri ve Santa Barbara Ölçek Puanları Hatırlama Hedef Puanlarını Ne Düzeyde Yordamaktadır?

Ana alanda odaklanma gösteren katılımcıların öğrenme çıktılarında başarılı olduğunu göstermiştir.

Katılımcılar Süreç Diyagramlarını Yorumlarken Hangi Öğrenme aktivitelerini Daha Sık Kullanırlar?

Yapılan araştırma sonuçlarına göre öğrenme başarısı yüksek katılımcılar Bilişsel Öğrenme Aktivitelerinden okları anlamlandırma aktivitesini; Biliş ötesi Öğrenme Aktivitelerinden kendine soru sorma öğrenme aktivitesini; Diyagram Öğrenme Aktivitelerinden içeriği kullanma öğrenme aktivitesini daha sık kullanmışlardır.

Katılımcıların Öğrenme aktiviteleri ve Öğrenme Çıktıları Arasında Anlamlı Bir İlişki Var Mıdır?

Elde edilen verilere bakıldığında Bilişsel Öğrenme Aktivitelerinden okları anlamlandırma öğrenme aktivitesini; Biliş ötesi Öğrenme Aktivitelerinden kendine soru sorma öğrenme aktivitesini daha sık kullanan katılımcıların Hatırlama Etki Değerlendirme Formundan (HEDF) daha yüksek puan alması istatiksel olarak anlamlı çıkmıştır.

Tartışma ve Öneriler

Birçok bilim kitabına baktığımız zaman süreç diyagramları için konulan açıklamaların konu ile ilgili ayrıntılı bilgiler içerdiği görülmektedir. Ancak araştırmada görüldüğü üzere katılımcıların sık kullandığı öğrenme aktivitelerinden içeriği kullanma aktivitesi başarılı öğrenme gerçekleştirme için ayırt edici bir özellik olarak bulunmamıştır. Çünkü katılımcılar içerikteki konuya ait her bilgiyi eşit derecede önemli bulabilir ya da önemli kısımları ayırt etmede zorlanmış olabilir ya da araştırma materyalindeki içerik konunun her detayının hatırlanamayacağı kadar fazla olabilir. Bu yüzden süreç diyagramlarındaki açıklama içerikleri sadece konunun önemli kısımları içerecek şekilde düzenlenmelidir. Böylelikle öğrenciler konunun önemli kısımları ayırt etmede zorlanmayacak ve bu bilgilerin hatırlanması kolay olacaktır.

A View of Students' Learning Styles, Learning Activities, and Learning Outcomes in Process Diagrams

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Received : 16.01.2021 Accepted : 12.05.2021

Doi: 10.17522/balikesirnef.862572

Abstract –Scientific texts generally use visual presentations (graphs, diagrams, photos, tables, etc.) to help learners to learn a subject. Process diagrams are the effective learning tools containing long headings, explanatory labels, arrows and coding in colors. This research aims to determine the learning activities and learning styles students use in learning through process diagrams and to analyze the effects of learning activities and learning styles on learning achievement. 23 participants were included in the research. Santa Barbara Learning Style Questionnaire, eye tracking technique, think aloud protocol and Remembering and Effect Evaluation Form were applied to the participants for data collection. As a result of the frequency analysis and Man Whitney U test, it was found that the participants used such learning activities as giving meaning to process arrows and self-questioning. It was also found that the participants who spent more time in fixation time main achieved more success in learning.

Key words: learning styles, learning activities, learning outcomes, eye-tracking, think-aloud protocol.

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Introduction

Learning is an active process of knowledge construction. Success can be defined as the extent to which one attains the goals set (Buluş , Duru, Balkıs, & Duru, 2011). Students differ in terms of levels of achievement. When evaluated in this respect, one of the most important factors that make a student different from another is his achievement in learning. So, what type of performance is influential in promoting success in learning through process diagrams?

Scientific texts generally use visual presentations (graphs, diagrams, photos, tables, etc.) to help learners to learn a subject. Diagrams are effective learning tools containing long headings, explanatory labels, arrows and coding in colours (Winn, 1991). They help learners create mental models and make abstract ideas concrete by encouraging them to use their spatial skills. Research has demonstrated that schemata support learners' explanations, inferences and integration of knowledge and reduce their misunderstanding (Ainsworth & Loizou, 2003). Therefore, diagrams are used as instructive elements more commonly in the present day's scientific books (Reece et al., 2010). Process diagrams, on the other hand, are the visualized forms of processes of all types as stages. The stages in a process diagram are composed of simplified symbolic representations. The stages are clustered and connected to each other with arrows and thus, how the system works is shown. Process diagrams are used in such subjects as photosynthesis, protein synthesis and respiration in biology classes because they make the functioning of those systems more comprehensible.

Students need to know whether or not they use strategies that facilitate them to reach knowledge while learning and activities which help them internalise the knowledge because the learning activities students use to influence the quality of learning outcomes substantially. Besides, diagrams also contain picture-text combinations. That is why learning styles are also helpful in learning from diagrams. Hence, this paper investigates the learning activities and learning styles that lead learners to success in learning.

Learning Styles

One of the characteristics that individuals have inherently is their learning styles. Learning style is the actualisation of learning through personal choices. That is to say, learners learn through their individual choices while receiving and processing the knowledge in teaching. Learning styles occupy an important place in individuals' lives because knowing of one's own learning style and putting it into action in the learning process affects his or her learning achievement. For this reason, many studies emphasise the importance of taking individual choices into consideration in choosing the teaching content and teaching methods and techniques and in teaching (Mayer & Massa, 2003; Riding, 1997; Witkin, 1973).

A review of literature demonstrates that learning styles are divided into two as visualiser and verbaliser learning styles. Individuals who learn better through visual presentation of knowledge in maps or diagrams have visual learning styles (visualisers). What is important to them is colour and images. They learn more easily through visual materials such as maps, diagrams and graphs and they remember more easily what they have learnt through such materials. Those who have verbal learning style (verbalisers), however, are inclined towards verbal elements such as sound and words in the process of teaching. They learn better if knowledge is presented verbally (Koc-Janutha, Höffler, Thoma, Prechtl, & Leutner, 2017; Mehigan, Barry, Kehoe, & Pitt, 2011).

Several studies have demonstrated that learning styles affect where learners look at in picture-text combinations. Mehigan, Barry, Kehoe and Pitt (2011), for instance, found that visualisers spent more time in areas containing pictorial knowledge than verbalisers did. Plass, Chun, Mayer and Leutner (1998), on the other hand, found that in picture and text combination cases, when visualisers needed to use pictorial content learning consequences were better for them.

Learning Activities

Learning is an active process in the formation of knowledge. It is necessary to force the use of mental abilities to learn (Azevedo & Cromley, 2004; Boekaerts, 1997; Butcher, 2006; Canham & Hegarty, 2010; Cook, Carter, & Wiebe, 2008; Hegarty, 2005; Kriz & Hegarty, 2007; Pressley & Afflerbach, 1995). Therefore, students have to regulate the formation of learning activities when they study diagrams on their own. In this way, the learning process will be more effective, and students will attain learning objectives. A review of the literature demonstrates that learning activities are divided into three as cognitive learning activities, meta-cognitive learning activities and domain knowledge.

Cognitive learning activities are the changes occurring in systems of thinking, reasoning, memory and comprehension enabling students to understand, acquire and use the knowledge. Cromley, Snyder-Hogan and Luciw-Dubas (2010) investigated whether students employed different cognitive learning activities while analysing diagram-text combinations or texts. They offered a taxonomy of cognitive learning activities as relating to previous knowledge, explaining, summarizing and inferring.

Metacognitive learning activities are the regulations of the functioning of individuals' cognitive learning activities. That is to say, they mean individuals' becoming aware of their own cognitive processes and being able to control them. Metacognition allows students to discover problem-solving processes, to use the processes in different situations and thus it enables them to reach an upper order cognitive process. Meijer, Veenman and Van Hout-Wolters (2006) concluded that the students who displayed activities such as orientating, planning, executing, monitoring, evaluating and detailing were the students who had upper order cognitive skills.

Domain knowledge is important in interpreting scientific pictographic presentations. Kriz and Hegarty (2007), for instance, evaluated learning in animations. They classified learners into two groups as learners with high prior knowledge and learners with low prior knowledge. As a result, they found that the participants with high domain knowledge made more accurate interpretations than those with low domain knowledge.

Eye-tracking and Learning

Biometrical methods enabling researchers to analyse the cognitive and metacognitive reactions underlying behaviours have been used in several studies for a long time. One of the biometrical methods is eye-tracking. Data such as how long and on what points on the screen are focussed can be obtained through eye-tracking technique. An important and difficult step in eye-tracking data is to determine the learning activities done during eye movements. The change of focus from one point to another can indicate ineffective behaviour of searching as well as indicating that students set up connections between what is shown. For this reason, several studies made comparisons between eye-tracking and learning outcomes. To exemplify, Mason, Pluchino, and Tornatora (2013) analysed how students learnt from scientific texts which contained abstract and concrete drawings. Consequently, they found that learning performance was directly related to long fixation time and to transitions between graphs and texts. The Eye-memory hypothesis argues that there are positive correlations between cognitive operations and cognitive operations performed. In other words, long fixation time is an indicator of more comprehensive cognitive operations (Just & Carpenter, 1976; She & Chen, 2009). The eye is fixed on a certain point for 250-300 milliseconds at the maximum when there is no conscious fixation. It was demonstrated by scientific research that increase in fixation time meant increase in cognitive load (Batı & Erdem, 2016). Rayner (1998) also found that the number of fixations, average length of fixation and total length of analysis were correlated to learning. Cook et al. (2008) made a pictographic demonstration about cellular transport mechanisms to the participants and they collected data about the participants' eye-tracking. They found in consequence that the participants with low prior knowledge had tendency to focus on different properties, such as colours, while the participants with high prior knowledge had tendency to the content.

Present Research and Research Question

Process diagrams, which are commonly used today, are generally examined independently of texts by students and are used as a choice of teaching (Kragten, Admiraal, & Rijlaarsdam, 2015). This paper aims to identify the learning activities and learning styles the participants use while learning and to investigate the effects of learning activities and learning styles on learning achievement. In this way, an overview of the learning preferences and processes used by students while examining the process diagrams is provided. By analysing the factors affecting students' understanding levels in the process diagram, we can determine which activities and styles are acceptable or not. Hence, answers were sought to the following questions.

1. Do participants focus on visual areas or verbal areas more in process diagrams?
2. To what extent do fixation duration and Santa Barbara learning style questionnaire scores predict the Remembering and Effect Evaluation Form (REEF) scores?
3. To what extent do the participants use the learning activities while using the process diagram?
4. Are there any significant correlations between learning activities used by participants and their learning outcomes?

Method

Participants and Assignment to Treatment

The study group was formed by using criterion sampling method- a purposeful sampling method. The criterion in choosing the participants was to have received education in biology. As is apparent from literature review, domain knowledge is influential in participants' learning outcomes, areas of fixation and fixation duration. To eliminate this effect in research data, the study group was composed of 23 prospective biology teachers attending the Science Education department of a state university that accepted students with the highest scores in its category in the city where it was located.

Measures

This study concentrates on the learning styles, learning activities and learning outcomes used by the participants in process diagrams. Therefore, two process diagrams related to "Chemiosmotic Theory", were taken from the book Plant Physiology written by Taiz and Zeiger (Taiz & Zeiger, 2002). The main reason for choosing the two process diagrams is to hinder the differences that can stem from the design of process diagrams. Then, the process diagrams were turned into slides. A pilot scheme was done with two participants to check the suitability of the slides.

The participants in the research were chosen on the basis of volunteering. The ethical permission for the research was approved by the ethical commission of the university where the research was conducted. The research data were collected in 2017-2018 academic year. Suitable time was determined with the participants to employ eye-tracking technique and think aloud-protocol. Each participant fulfilled the 10-15-minute learning task in a silent test room for the application at the time determined.

Primarily, the Santa Barbara Learning Style Questionnaire was given to the participants to determine their learning styles. One of the data collection tools used in the research which demonstrated the differences between visualisers and verbalisers is the Santa Barbara Learning Style Questionnaire (SBLSQ). The questionnaire, which consists of six items evaluates verbal-visual cognitive styles. Eye-tracking technique and think aloud protocol were used as the tools of data collection in showing the process diagrams (Appendices A-B). Eye-tracking provides information about what area of the screen users look at, for how long and how many times they look at the area, on what area they focus their instant and past attention and about their mental states. The users' eye movements were recorded with Tobii T120 eye tracking equipment and were evaluated by using Tobii Studio data collection and analysis programme in this study. Think aloud protocol, a synchronic measure, involves data collected from verbal expressions of what participants have in their mind during their cognitive task. The technique enables participants to state their thoughts verbally while solving a problem or fulfilling a task or to ask questions so that they can think aloud and to analyse the verbal protocols emerging. Participants' process of fulfilling their task is observed and is analysed in this way. In this way, the learning activities of the participants in research are observed and analysed. The participants' voice was recorded on Tobii Studio programme in this study. After that, the voice records were transcribed and were put to content analysis. In addition to that, the Remembering and Effect Evaluation Form (REEF) was given to find the degree to which the participants understood from the process diagrams (Appendix C). The form contains open-ended questions, True-False questions and a section in which participants are expected to complete the lacking parts in drawings in the process diagrams. The participants were asked to complete the form after eye-tracking and think aloud-protocol data were recorded. The data coming from the form were assessed at two levels as True-False=1 and incomplete answer-no answer=0. Inappropriate evaluations were discussed by the observers until they are fully appropriate and then they were regarded as data. Table 1 below shows which data collection tool is used for which research question while seeking answers to the research problems.

Table 1 The Connection Between the Research Problems and the Data Collection Tools

Research problems	Data collection tools
Research problem 1	Eye tracking
Research problem 2	Santa Barbara Learning Style Questionnaire, Remembering and Effect Evaluation Form
Research problem 3	Think aloud protocol
Research problem 4	Think aloud protocol, Remembering and Effect Evaluation Form

Data Analysis

Do participants focus on visual areas or verbal areas more in process diagrams?

For the answer to the problem, the areas of interest in the two process diagrams were divided into two as the visual area and the textual area, as shown in the Figure 1. Of the areas of interest, the visual area was shown in pink whereas the textual area was shown in purple. The mean and total time the participants spent in the visual and the textual areas of the process diagrams were calculated by using Tobii Studio software and the data concerning which areas of interest the participants focused on more in Process Diagram 1 and Process Diagram 2 were collected.

To what extent do fixation duration and Santa Barbara learning style questionnaire scores predict the remembering and effect evaluation form (REEF) scores?

The participants were administered the Santa Barbara Learning Style Questionnaire to find which of the visual and verbal learning styles they had. The participants were asked to complete the questionnaire before entering the eye-tracking laboratory. The data coming from the questionnaire were analysed by using a SPSS for statistics. The mean for the questions measuring the visual learning style and the mean for the questions measuring the verbal learning style were found and thus the learning styles were determined. Besides, the areas of interest (AOI) were identified in the process diagrams as headings, main areas and descriptions to determine the eye movements influential in the learning problem. The headings were given in orange, descriptions were given in green and the main areas were given in yellow (see Fig. 2).

The data on participants' total fixation duration and total visit count for the descriptions, main areas and headings of Process Diagram 1 and Process Diagram 2 were obtained during the application and the averages were calculated. In addition to that, the visual and verbal scores received from the Santa Barbara learning style questionnaire were regarded as independent variables while the scores received from the Remembering Effect Evaluation Form (REEF) were regarded as dependent variables, and efforts were made to find the degree to which the independent variables predicted dependent variables through multiple regression analysis.

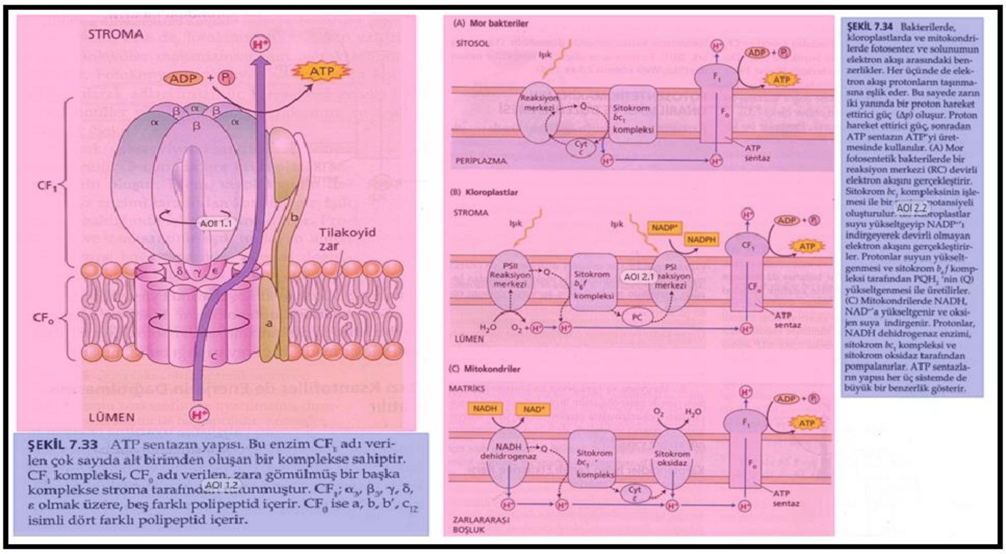

Figure 1 The Visual-Textual Distinction in the Process Diagrams

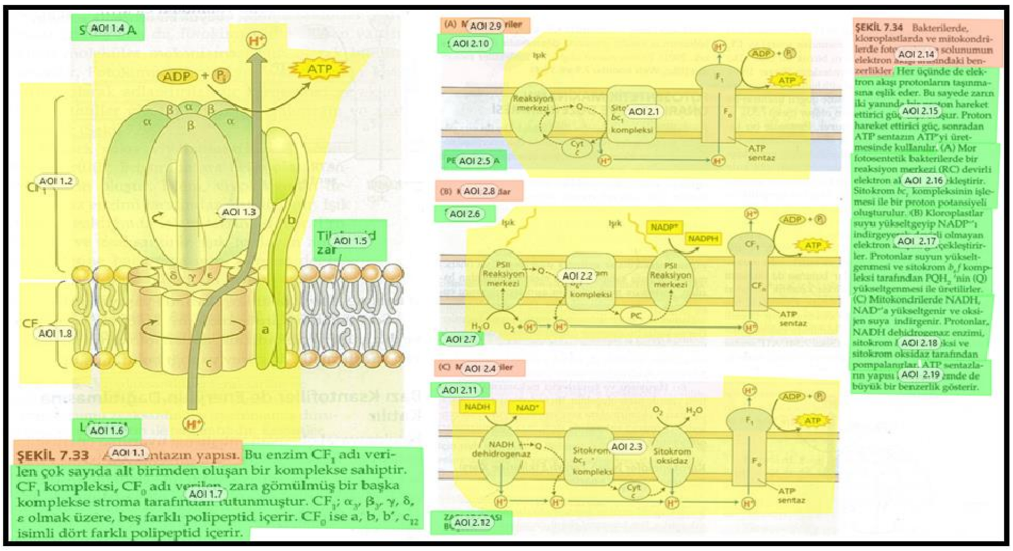

Figure 2 Distinguishing the Areas of Interest (AOI) in the Process Diagrams

What Learning Activities Do Students Use More Frequently While Interpreting Process Diagrams?

The transcription of the participant’s voice recordings was used in solving this research problem. The learning activities the participants used were divided into three categories and ten sub-categories in accordance with literature review (Azevedo & Cromley, 2004; Kragten, Admiraal, & Rijlaarsdam, 2013; Kragten, Admiraal, & Rijlaarsdam, 2015) and retrospective think-aloud protocols data- as is shown in Table 2.

Table 2 Categorising the Learning Activities And Participants Verbal Reports Example

Cognitive Learning Activities
Learning Activities: Giving meaning to process arrows
Example: ‘ADP combines with other P_i and makes up ATP. . H^+ ions come from above, they come out of stroma
‘ATPsynthesis enzyme is activated by H^+ ions.’
‘Those polypeptides rotate within each other, they seem to move.’
Learning Activities: Inference
Example: ‘proton flow was enabled in purple bacteria’
‘That is to say, it occurs in the stroma of chloroplast.’
Learning Activities: Relating to prior knowledge
Example: ‘Cell membrane has a phospholipid layer. It has hydrophilic and hydrophobic parts.
‘Chloroplasts are the part through which light comes.’
Learning Activities: Alternative hypothesis
Example: (No data)
Learning Activities: Comparing elements across AOIs
Example: ‘Now I’m comparing the figures.’
‘NADs are reduced in different places- in chloroplast and in mitochondrion. There are no NADs in bacteria.’
Meta-Cognitive Learning Activities
Learning Activities: Self-questioning
Example: ‘Is NADP reduced to NADPH’ here?’
‘CF0 partial double membrane lipids structure. What do we call it?’
Learning Activities: Rereading parts of the diagram
Example: (No data)
Diagram Learning Activities
Learning Activities: Reading the title
Example: ‘Similarities between bacteria, chloroplasts and mitochondrion in photosynthesis and respiration and electron flow.’
‘The structure of ATPsynthesis ’
Learning Activities: Reading the labels regarding the organizational level
Example: (No data)
Learning Activities: Using the legend
Example: ‘He says CF1 enzyme contains five different polypeptides.’
‘He said proton transfer accompanied in all three.’

Are There Any Significant Correlations Between Learning Activities Used by Participants and Their Learning Outcomes?

The correlations between the learning activities most frequently used by participants and the total scores they received from the Remembering Effect Evaluation Form (REEF) were analysed in this research problem. The averages for the frequencies in the participants' learning activities were considered for this purpose and the participants were divided into two sub-groups. Accordingly, sub-group one contained participants who used a certain learning activity less frequently or who never used the activity while sub-group two contained participants who used the activity more frequently.

The differences between the REEF scored received by the group of participants who used the learning activities which were suggested with the second research question the most frequently and the group of participants who used those activities the least frequently or who never used them were tested through Mann-Whitney U test, which did not require normality assumption and which was a non-parametric method.

Results

This section presents the results concerning the research problems.

Do Participants Focus on Visual Areas or Verbal Areas More in Process Diagrams?

The participants were shown two different Process Diagrams- Process Diagram 1 and Process Diagram 2- in accordance with the purpose of this study. The mean fixation durations and total fixation durations for the visual and the verbal areas of interest in Process Diagram 1 and Process Diagram 2 were found through Tobii Studio programme. The averages for the participants' fixation duration in visual and verbal areas were calculated for both data. The results are shown in Table 3. Accordingly, 18 participants were found by setting out from the averages for Process Diagram 1 and Process Diagram 2 to focus on visual areas more. The remaining 5 participants (Ayşe, Mahmure, Canan, Sevgi, Selin) were found based on the averages for Process Diagram 1 and Process Diagram 2 to focus more on the textual areas.

Table 3 Participants' Fixation Duration In The Process Diagrams

Participants	Visual-1 total	Textual-2 total	Visual-2 total	Textual-2 total	Visual total mean	Textual total mean
Ayşe	32.98	44.70	25.50	36.40	29.24	40.55
Ahmet	66.05	20.80	51.44	39.10	58.75	29.95
Fatma	58.55	43.29	89.28	40.81	73.92	42.05
Abdullah	67.40	38.49	72.70	34.31	70.05	36.40
Mahmure	40.02	28.10	26.55	39.27	33.29	33.69
Meliha	52.00	58.09	65.30	38.49	58.65	48.29
Sevil	50.30	32.09	56.40	52.66	53.35	42.38
Serpil	68.78	34.18	74.91	46.82	71.85	40.50
Mehtap	77.40	16.05	76.99	18.02	77.20	17.04
Sevcan	71.97	23.93	115.82	0.00	93.90	11.97
Bahar	79.19	21.82	132.96	2.22	106.08	12.02
Elif	59.73	36.42	68.84	63.25	64.29	49.84
Damla	58.64	35.19	56.64	37.79	57.64	36.49
Canan	24.54	82.34	84.86	37.59	54.70	59.97
Sevgi	37.00	51.83	41.64	59.17	39.32	55.50
Ebrar	70.79	28.10	65.87	50.41	68.33	39.26
Evliyan	58.63	33.78	100.99	25.92	79.81	29.85
Melike	89.35	53.03	88.70	65.79	89.03	59.41
Burçin	90.02	33.81	92.98	6.99	91.50	20.40
Selin	55.87	40.42	42.09	77.23	48.98	58.83
Pınar	76.19	44.72	58.61	55.50	67.40	50.11
Şule	62.92	33.88	88.50	9.73	75.71	21.81
Özgür	55.99	63.42	99.19	27.13	77.59	45.28
All participants	140.31	89.47	1676.75	864.59	1540.53	881.53

To What Extent Do Fixation Duration and Santa Barbara Learning Style Questionnaire Scores Predict The Remembering and Effect Evaluation Form (REEF) Scores?

The data set was prepared for the analysis prior to multiple regression analysis and whether or not it satisfied the assumptions of multiple regression analysis was checked. First, whether or not there were any losses in this data set for 23 participants was examined and it was found that there were no losses in the data. The Z scores were calculated to examine one-way extreme values; consequently, it was found that there were no Z values in -3-+3 range. descriptive statistics were calculated to check the normality assumption of the variables and one sample Kolmogorov-Smirnov test was employed.

Table 4 Descriptive Statistics and the Results for Kolmogorov-Smirnov Test

	REEF	**Fixation Time Legend**	**Transitions Legend**	**Fixation Time Main**	**Transitions Main**	**Fixation Time Title**	**Transitions Title**	**Visual scores**	**Verbal scores**
N	23	23	23	23	23	23	23	23	23
Loss	0	0	0	0	0	0	0	0	0
Mean	0.57	7.64	4.56	20.96	18.25	244	4.79	6.04	4.26
Median	0.60	7.59	4.40	20.18	16.66	2.13	4.3	6	4
Mode	0.35	3.60	4.05	11.72	14.83	0.74	2.13	6	5
Standard deviation	0.25	2.56	1.12	5.10	4.50	1.34	2.1	0.63	1.09
Skewness	-0.47	0.10	0.24	0.23	1.25	0.88	0.47	-1.18	-0.57
Standard error	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Kurtosis	-0.80	-0.44	-1.04	0.33	1.59	-0.30	-0.57	4.46	-0.11
Standard error	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Ko-S Z	0.61	0.47	0.54	0.39	0.91	0.87	0.48	1.85	1.09
P	0.85	0.97	0.92	0.99	0.38	0.42	0.97	0.00	0.18

It may be said according to the descriptive statistics in Table 4 that the variables have almost normal distribution due to the fact that the mean, mode and median for the variables are very similar. It became apparent that the skewness and kurtosis coefficients for the variables mostly took on values between -1 and +1 and that only fixation time main and visual scores had skewness coefficients outside the ± 1 range. according to Kolmogorov-Smirnov test results, however, only visual scores deviated significantly from normal distribution. Based on this information, square root was applied to the variable of fixation time main and reflection and square root change was applied to the variable of visual scores. Mahalonobis distance was calculated to examine multivariate extreme values and the correlations between the variables were analysed with Pearson' correlations coefficient to check multiple regression because there were no values exceeding the critical value.

Table 5 shows that a high correlation of 0.86 ($p<0.01$) between fixation duration heading and transitions heading can indicate a problem of multiple regression and that the other variables do not have any problems. On examining the tolerance and Variance Inflation Factor (VIF) values obtained as a result of multiple regression, it was found that the VIF values were smaller than 10 and that the tolerance values were bigger than 0.10. Yet, these two variables with high correlations were excluded from the analysis and the analysis was repeated because the Condition Indices (CI) values were bigger than 30. On including any of the variables in the analysis, it was found that the CI values became bigger than 30 again; and decision was made to exclude both variables from the analysis to satisfy the assumptions of the regression analysis.

Table 5 Correlations Between The Variables

		Fixation duration legend	Transitions legend	Fixation time main	Fixation duration heading	Transitions heading	Visual scores	Visual scores transformation	Transitions main transformation
Fixation duration legend	Pearson Correlation	1	0.414*	-0.518	0.339	0.286	0.04	-0.51	0.011
	Sig. (2-tailed)		0.049	0.011	0.113	0.185	0.858	0.817	0.961
	N	23	23	23	23	23	23	23	23
Transitions legend	Pearson Correlation	0.414*	1	-0.239	0.421*	0.428*	-0.147	0.209	0.409
	Sig. (2-tailed)	0.049		0.272	0.045	0.042	0503	0.338	0.053
	N	23	23	23	23	23	23	23	23
Fixation time main	Pearson Correlation	-0.518	-0.239	1	-0.342	-0.296	0.158	-0.155	0.358
	Sig. (2-tailed)	0.011	0.272		0.11	0.17	0.47	0.48	0.093
	N	23	23	23	23	23	23	23	23
Fixation duration heading	Pearson Correlation	0.339	0.421*	-0.342	1	0.860**	0.013	0.022	-0.13
	Sig. (2-tailed)	0.113	0.045	0.11		0	0.952	0.921	0.553
	N	23	23	23	23	23	23	23	23
Transitions heading	Pearson Correlation	0.286	0.428*	-0.296	0.860**	1	0.045	0.087	0.011
	Sig. (2-tailed)	0.185	0.042	0.17	0		0.837	0.692	0.961
	N	23	23	23	23	23	23	23	23
Visual scores	Pearson Correlation	0.04	-0.147	0.158	0.013	0.045	1	-0.108	-0.178
	Sig. (2-tailed)	0.858	0.503	0.47	0.952	0.837		0.625	0.416
	N	23	23	23	23	23	23	23	23
Visual scores transformation	Pearson Correlation	-0.051	0.209	-0.155	0.022	0.087	-0.108	1	0.057
	Sig. (2-tailed)	0.817	0.338	0.48	0.921	0.692	0625		0.796
	N	23	23	23	23	23	23	23	23
Fixation time main transformation	Pearson Correlation	0.011	0.409	0.358	-0.013	0.011	-0.178	0.057	1
	Sig. (2-tailed)	0.961	0.053	0.093	0.553	0961	0.416	0.796	
	N	23	23	23	23	23	23	23	23

It was summarised in Table 6 below that fixation time legend, transitions legend, fixation time main, verbal scores and visual scores were the independent variables and that the REEF scores were the predicted dependent variables. An examination of Table 6 showed that the model created was significant and that the independent variables predicted the dependent variables significantly (F (6, 16) = 3.615; $p < 0.05$). according to Table 6, the independent variables explain the independent variable at the rate of 0.76 approximately. Thus, approximately 58% of the total variance in REEF is explained by independent variables.

Table 6 Regression Analysis Results

Components	**B**	**Standard error (B)**	**B**	**t**	**P**
Constant	-0.018	0.529	-	-0.035	0.973
Fixation Time Legend	-0.003	0.021	- 0.025	-0.118	0.907
Transitions Legend	0.042	0.048	0.186	0.876	0.394
Fixation Time Main	0.034	0.012	0.686	2.931	0.010
Verbal scores	0.070	0.041	0.300	1.714	0.106
Visual scores	-0.143	0.196	-0.126	-0.728	0.477
Transitions time main	-0.094	0.109	-0.186	-0.861	0.402

R = 0.759, R^2 = 0.575, F (6. 16) = 3.615, P = 0.018

According to Table 6, only fixation time main- of the independent variables- predicted the dependent variable significantly ($p<0.05$). The order of importance of the predictive variables in the REEF was as fixation time main, verbal scores, transitions legend, fixation time main, visual scores and fixation time legend according to standardised regression coefficients(β). In the light of these findings, the regression equation can be formed as in the following:

REEFscores = -0.018 + (-.003*fixation time legend) + (0.042*transitions legend) + (0.034*fixation time main) + (0.070*verbal scores) + (-0.143*visual scores) + (-0.094*Transitions time main)

What Learning Activities Do Participants Use while Interpreting Process Diagrams?

The participants' frequencies in each sub-category in both process diagrams were calculated within the scope of the research problem. The frequencies found for Process Diagram 1 were shown in Table 7 and the frequencies found for Process Diagram 2 were shown in Table 8. Setting out from the frequencies and mean frequencies calculated from the two process diagrams, the learning activities that the participants used more often were determined.

Table 7 Frequencies Obtained From Process Diagram 1

	Cognitive Learning Activities					Metacognitive Learning Activities		Diagram Learning Activities		
Participants	Giving meaning to a process arrow	Inference	Relating prior knowledge	Alternative hypothesis	Comparing elements across AOIs	Self-questioning	Rereading parts of the diagram	Reading the title	Reading the labels regarding the organizational level	Using the legend
Ayşe	2	0	0	0	0	0	0	1	0	1
Ahmet	2	0	1	0	0	0	0	1	0	1
Fatma	2	1	1	0	0	0	0	1	0	2
Abdullah	2	2	0	0	0	0	0	0	0	0
Mahmure	1	2	1	0	0	0	0	0	0	1
Meliha	2	1	0	0	0	0	0	1	0	1
Sevil	2	2	0	0	0	0	0	0	0	2
Serpil	1	0	2	0	0	2	0	0	0	3
Mehtap	2	0	3	0	0	1	0	0	0	1
Sevcan	5	0	2	0	0	2	0	0	0	2
Bahar	2	0	4	0	0	0	0	0	0	0
Elif	0	0	2	0	0	0	0	0	0	2
Damla	1	0	1	0	0	0	0	0	0	2
Canan	0	0	1	0	0	0	0	1	0	1
Sevgi	0	0	0	0	0	0	0	0	0	3
Ebrar	2	2	2	0	0	1	0	0	0	1
Evliyan	3	0	0	0	0	0	0	1	0	2
Melike	3	3	1	0	0	1	0	1	0	4
Burçin	1	2	0	0	0	0	0	0	0	3
Selin	0	2	0	0	0	1	0	1	0	1
Pınar	4	2	0	0	0	0	0	0	0	1
Şule	2	1	0	0	0	0	0	1	0	3
Özgür	2	1	0	0	0	0	0	1	0	3

Table 8 Frequencies Obtained From Process Diagram 2

	Cognitive Learning Activities					Metacognitive Learning Activities	Diagram Learning Activities			
Participants	Giving meaning to a process arrow	Inference	Relating prior knowledge	Alternative hypothesis	Comparing elements across AOIs	Self-questioning	Rereading parts of the diagram	Reading the title	Reading the labels regarding the organizational level	Using the legend
Ayşe	2	3	0	0	0	0	0	1	0	0
Ahmet	2	4	0	0	2	0	0	0	0	0
Fatma	1	6	1	0	1	0	0	0	0	0
Abdullah	0	4	0	0	0	0	0	0	0	0
Mahmure	1	1	0	0	0	0	0	0	0	6
Meliha	1	1	0	0	0	1	0	1	0	4
Sevil	3	1	0	0	1	0	0	0	0	0
Serpil	4	2	0	0	2	0	0	0	0	1
Mehtap	2	1	1	0	3	0	0	0	0	0
Sevcan	9	1	0	0	0	1	0	0	0	0
Bahar	4	3	2	0	2	0	0	0	0	0
Elif	3	1	0	0	2	0	0	0	0	0
Damla	1	1	0	0	2	0	0	0	0	1
Canan	4	0	0	0	0	1	0	0	0	0
Sevgi	0	1	0	0	1	0	0	0	0	1
Ebrar	4	3	0	0	1	0	0	0	0	0
Evliyan	8	3	1	0	2	0	0	0	0	0
Melike	4	3	2	0	2	0	0	1	0	1
Burçin	9	1	0	0	0	0	0	0	0	0
Selin	3	1	0	0	3	0	0	0	0	0
Pınar	3	1	0	0	2	0	0	0	0	0
Şule	6	4	0	0	1	0	0	1	0	4
Özgür	3	2	0	0	2	4	0	0	0	0

Table 9 Frequencies Calculated From Both Process Diagrams

	Cognitive Learning Activities					**Metacognitive Learning Activities**	**Diagram Learning Activities**			
	Giving meaning to a process arrow	Inference	Relating prior knowledge	Alternative hypothesis	Comparing elements across AOIs	Self-questioning	Rereading parts of the diagram	Reading the title	Reading the labels regarding the organizational level	Using the legend
Total frequencies in process diagram one	41	21	21	0	0	7	0	10	0	40
Total frequencies in process diagram two	80	42	42	0	0	14	0	19	0	79
Mean frequencies	60.5	31.5	31.5	0	0	10.5	0	14.5	0	59.5

According to Table 9, participants use giving meaning to a process arrow in cognitive learning activities, self-questioning in meta-cognitive learning activities and using the legend in diagram learning activities the most frequently.

Are There Any Significant Correlations Between Learning Activities Used by Participants and Their Learning Outcomes?

Finally, this paper analysed the correlations between learning activities that the participants used the most frequently and the total scores they had received from Remembering and Effect Evaluation Form (REEF) within the scope of research problem four. The results for the analysis are presented below according to the sub-categories of the most frequently used learning *activities*.

Cognitive Learning Activities

It was demonstrated in Research Problem Three that giving meaning to process arrows was the most frequently used sub-category of cognitive learning activities. Whether or not the total REEF scores differed statistically significantly was examined through Mann Whitney U test. The results for the analysis are shown in Table 10 below.

Table 10 The U Test Results for Giving Meaning to Process Arrows in the REEF

Groups	**N**	**Mean Rank**	**Rank total**	**U**	**P**
1	12	7.96	95.50	17.50	0.003
2	11	16.41	180.50		

Accordingly, it was concluded that the REEF scores differed significantly at the level of 0.01 error ($U=17.5$; $p<0.01$). Considering the mean ranks, it is clear that Group 2 has higher average than Group 1. Thus, it can be said that the group which uses the activity of giving meaning to process arrows has received statistically significantly higher scores from the REEF than the group which has used it less or which has never used it.

Metacognitive Learning Activities

It was demonstrated in Research Problem Three that self-questioning was the most frequently used sub-category of metacognitive learning activities. Whether or not the participants' scores from the REEF differed statistically significantly on grouping according to the frequency of self-questioning was analysed through Mann Whitney U test. The analysis results are shown in Table 11.

Table 11 The U Test Results for Self-Questioning in the REEF

Groups	N	Mean Rank	Rank total	U	P
1	15	9.53	143.00	23.00	0.016
2	8	16.63	133.00		

It is apparent from Table 11 that the REEF scores differed significantly at the level of 0.05 error (U=23.0; p<0.05). considering the mean ranks, it is clear that Group 2 has higher average than Group 1. Accordingly, it can be said that the group using self-questioning activity more frequently has received statistically significantly higher scores from the REEF than the group which has used it less or which has never used it.

Diagram Learning Activities

It was demonstrated in Research Problem Three that using the legend was the most frequently used sub-category of diagram learning activities. Whether or not the participants' scores from the REEF differed statistically significantly on grouping them according to the frequency of using the legend was analysed with Mann Whitney U test. The analysis results are shown in Table 12 below.

Table 12 The U Test Results for Using the Legend in the REEF

Groups	n	Mean Rank	Rank total	U	P
1	14	12.32	172.5	58.5	0.776
2	9	11.50	103.5		

As is clear from Table 12, the total scores received from Remembering and Effect Evaluation form do not differ significantly according to the frequency of participants' sing the legend (U= 58.5; p>0.05). considering the mean ranks, it is apparent that Group 1 has higher average than Group 2. However, the difference is not statistically significant.

It was found that the participants who used the activity of giving meaning to process arrows -a cognitive learning activity- more frequently had received statistically significantly higher scores from the REEF. The arrows are shown in the process diagrams set up ties between the stages of the process. It also represents the turning of ATP synthase just like a motor depending on changes in electrical charge. The participants who predict successfully the ties and moves in the process diagrams can be said to have understood the diagrams intend to explain. It, in turn, helps participants to see an abstract idea concretely and to understand it. Thus, they comprehend how processes function. It was also found in this study that the participants who had understood the ties between the stages of the process had higher degrees of remembering.

Thus, it became apparent that the participants who had used self-questioning activity- a metacognitive learning activity- more frequently received statistically significantly higher scores than the REEF. It was also found in the data analysis results that the participants used the activity of giving meaning to process arrows more frequently. The mind of the participants who are good at giving meaning to process arrows is full of questions. Asking the questions and searching for answers is important in understanding the processes better. The participants who ask questions and who look for answers to the questions remember a subject better.

The fact that the participants using the legend more frequently had higher REEF scores were not found to be statistically significant. Participants spend time on legends- which have explanatory functions- and they use them as learning activities. Yet, the fact that they contain more information and that participants have difficulty in discriminating what information is important can cause them not to remember well.

Discussion

The results obtained in relation to research problem two demonstrated that the participants who focused on the main area of interest had good learning outcomes. That is to say, the participants who focused on the main areas learnt better. As it was also found in research into fixation duration, the students who spent more time on main areas have better achievement in learning (Mason et al., 2013; She & Chen, 2009; Schwonke, Berthold, & Renkl, 2009). They are supportive of the findings obtained in this study.

Analyses were carried out on the learning activities that the participants who learnt from the process diagrams used in relation to research problem three. The results indicated that the participants with high learning achievement used the activity of giving meaning to process arrows among cognitive learning activities, the activity of self-questioning among metacognitive learning activities and the activity of using the legend among diagram learning activities more frequently. Larkin and Simon (1987) demonstrated that clustering the process step by step and placing it in diagrams facilitated finding the information and using it effectively. It is probable to find the next step after finding the first step in a process diagram. It is made possible by connecting the process with arrows which represent the steps of the process and thus by showing the next step. Arrows can have several meanings such as pointing, setting up ties, ordering and moving (Heiser & Tversky, 2006). Process diagrams describe how systems function in this way. Arrows function as the keys in process diagrams. The students who understand the meaning of arrows and comprehend the process have questions in their mind. When they look for answers to their questions, they activate their prior knowledge and thus they learn.

The correlations between those learning activities and learning outcomes were examined in relation to research problem four. The data showed that the participants who used the learning activity of giving meaning to process arrows among cognitive learning activities and the learning activity of self-questioning among metacognitive learning activities more frequently received higher scores from the Remembering and Effect Evaluation Form (REEF)- which was statistically significant. It means that the participants who use the activities of giving meaning to process arrows and self-questioning more frequently learn better. The results obtained in previous studies demonstrated that the students who achieved learning used such learning activities as activating their prior knowledge (Presley, 2000; Pressley & Afflerbach, 1995) and self-questioning (Azevedo & Cromley, 2004). It is apparent that the findings obtained in this study are not conflicting with the findings obtained in studies so far.

Conclusions

It was found with data concerning research problem one that the participants focused more on the visual areas in process diagrams. The results obtained in relation to research problem two demonstrated that the participants who focused on the main area of interest had good learning outcomes. That is to say, the participants who focused on the main areas learnt better. Analyses were done on the learning activities that the participants who learnt from the process diagrams used in relation to research problem three. The results indicated that the participants with high learning achievement used the activity of giving meaning to process arrows among cognitive learning activities, the activity of self-questioning among metacognitive learning activities and the activity of using the legend among diagram learning activities more frequently. Process diagrams describe how systems function in this way. Arrows function as the keys in process diagrams. The students who understand the meaning of arrows and comprehend the process have questions in their mind. When they look for answers to their questions, they activate their prior knowledge and thus they learn. The correlations between those learning activities and learning outcomes were examined in relation to research problem four. The data showed that the participants who used the learning activity of giving meaning to process arrows among cognitive learning activities and the learning activity of self-questioning among metacognitive learning activities more frequently received higher scores from the Remembering and Effect Evaluation Form (REEF) which was statistically significant. It means that the participants who use the activities of giving meaning to process arrows and self-questioning more frequently learn better.

It is apparent that the activities the participants use are sometimes not influential in their learning achievement. Of diagram learning activities, for instance, participants used the activity of using the legend frequently. However, the use of the activity was not found to be a discriminating feature for successful learning. It is because students can find all the information in the legend equally important, they can have difficulty in distinguishing the important parts or the content can be too large to remember. Thus, it affects remembering in negative ways. An examination of many books on science makes it clear that the explanations offered for process diagrams contain detailed information about the subject. The findings obtained in this paper demonstrate that the content for explanations about process diagrams should include only important information. In this way, learners will not have difficulty in discriminating between important and unimportant and they will remember the information more easily.

Learning activities are used in learning a subject. What teachers do to teach learners a subject is also described in the same word. For example, teachers can make use of process diagrams as materials in teaching an abstract subject. In that case, teachers explain the relationships between process to students, they try to set up ties between students' previous knowledge and new knowledge and they ask questions to make students search for answers to the questions. This example shows that learning and teaching activities are the different manifestations of the same thing and can be described in similar ways (Vermunt, 1996). Teachers should employ the use of learning activities that students already have when they use those materials. They should set models to students and encourage students to use those activities; because it was found in this study that students do not use all learning activities in learning.

Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Notes

Ethical approval for this study was obtained from Ethics Committee of Hacettepe University (11.07.2017 / 35853172/433-2465).

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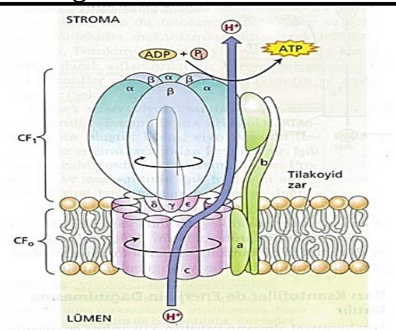
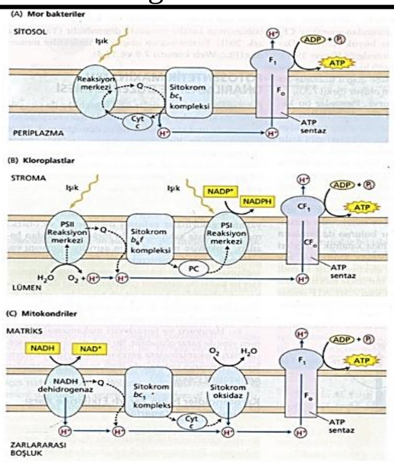
Appendix A. Process Diagram 1



ŞEKİL 7.33 ATP sentazın yapısı. Bu enzim CF_1 adı verilen çok sayıda alt birimden oluşan bir komplekse sahiptir. CF_1 kompleksi, CF_0 adı verilen, zara gömülmüş bir başka komplekse stroma tarafından tutunmuştur. CF_1; α_3, β_3, γ, δ, ε olmak üzere, beş farklı polipeptid içerir. CF_0 ise a, b, b′, c_{12} isimli dört farklı polipeptid içerir.

Appendix B. Process Diagram 2



ŞEKİL 7.34 Bakterilerde, kloroplastlarda ve mitokondrilerde fotosentez ve solunumun elektron akışı arasındaki benzerlikler. Her üçünde de elektron akışı protonların taşınmasına eşlik eder. Bu sayede zarın iki yanında bir proton hareket ettirici güç (Δp) oluşur. Proton hareket ettirici güç, sonradan ATP sentazın ATP'yi üretmesinde kullanılır. (A) Mor fotosentetik bakterilerde bir reaksiyon merkezi (RC) devirli elektron akışını gerçekleştirir. Sitokrom bc_1 kompleksinin işlemesi ile bir proton potansiyeli oluşturulur. (B) Kloroplastlar suyu yükseltgeyip $NADP^+$'ı indirgeyerek devirli olmayan elektron akışını gerçekleştirirler. Protonlar suyun yükseltgenmesi ve sitokrom b_6f kompleksi tarafından PQH_2'nin (Q) yükseltgenmesi ile üretilirler. (C) Mitokondrilerde NADH, NAD^+'a yükseltgenir ve oksijen suya indirgenir. Protonlar, NADH dehidrogenaz enzimi, sitokrom bc_1 kompleksi ve sitokrom oksidaz tarafından pompalanırlar. ATP sentazların yapısı her üç sistemde de büyük bir benzerlik gösterir.

Appendix C. Remembering and Effect Evaluation Form

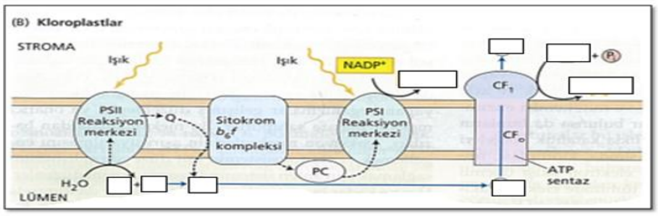
Please explain below term.

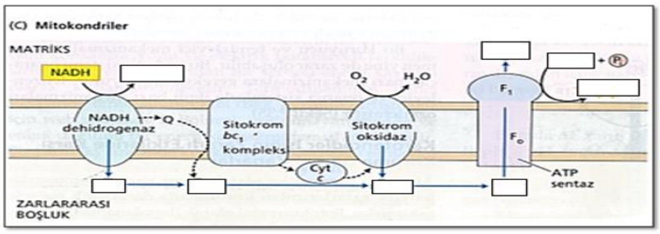
1. Explain Chemiosmosis Theory.

Are the following statements True (T) or False (F)?

1. ( ) Photosynthesis and cellular respiration have similar electron flow at Bacterias, Chloroplasts and Mitochondria.
2. ( ) Thylakoid membrane at chloroplast and mitochondrial cristae membrane are direct transparent for hydrogen ions.
3. ( ) ATP synthase is actually a small molecular engine that hydrolysis ATP.

Please fill blanks in below given diagrams with suitable terms.





Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi (EFMED)
Cilt 15, Sayı 1, Haziran 2021, sayfa 62-94. ISSN: 1307-6086

Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Vol. 15, Issue 1, June 2021, pp. 62-94. ISSN: 1307-6086

Araştırma Makalesi / Research Article

Matematiksel Modelleme Etkinliklerine Dayalı Öğrenme Ortamının İncelenmesi

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Gönderme Tarihi: 12.03.2021 Kabul Tarihi: 03.06.2021

Doi: 10.17522/balikesirnef.896038

Özet – Bu araştırma, matematiksel modelleme etkinliklerine dayalı öğrenme ortamında öğrencilerin matematiksel bilgilerindeki değişime ilişkin sonuçlar sunmaktadır. Yedinci sınıfta öğrenim gören 6 öğrenciyle (13 yaş) yürütülen araştırmada, alan ölçme konusunun kazanımlarına yönelik olarak hazırlanan 8 adet matematiksel modelleme etkinliği uygulamaları, video ve ses kayıtları, öğrenci çözüm raporları ve araştırmacı notları aracılığıyla incelenmiştir. Uygulama sürecindeki verileri desteklemek amacıyla, öncesinde ve sonrasında öğrencilerle bireysel görüşmeler gerçekleştirilmiştir. Araştırmada elde edilen sonuçlar, matematiksel modelleme yöntemiyle yapılan öğretimin öğrencilerin alan ölçme bilgi ve becerilerini önemli ölçüde desteklediği yönündedir. Söz konusu gelişimin, matematiksel modelleme sürecinde ortaya çıkan öğrenme fırsatları yoluyla desteklendiği sonucuna ulaşılmıştır. Öğrencilerin alan ölçme bilgi ve becerilerinin gelişiminde birim kare kavramının oluşması ve alan ölçme bağıntısının birim kareyle ilişkilendirilerek açıklanması, bir lokomotif etkisi oluşturmuştur. Sonuçlar, matematiksel modelleme uygulamalarının öğretim programında yer alması gerektiğini gösterir niteliktedir.

Anahtar kelimeler: alan ölçme, matematiksel modelleme, öğrenme ortamı

Sorumlu yazar: Zeynep Çavuş Erdem, zcavuserdem@hotmail.com. Bu araştırma birinci yazarın “Matematiksel modelleme etkinliklerine dayalı öğrenim sürecinin alan ölçme konusu bağlamında incelenmesi” isimli doktora tezinden üretilmiştir. Aynı zamanda ‘4. Uluslararası Türk Bilgisayar ve Matematik Eğitimi Sempozyumu’nda sözlü bildiri olarak sunulmuş ve tam metin formatında yayınlanmıştır.

Geniş Özet

Giriş

Matematik öğretimin amacı, sadece okul ortamı değil, okul ortamının dışında da matematiği kullanabilen, uygulayabilen ve sorgulayabilen öğrencilerin yetiştirilmesini sağlamaktır (MEB, 2018). Bunu sağlamanın yollarından biri ise matematiksel modellemedir. Matematiksel modelleme, gerçek yaşamda karşılaşılan bir problem durumunun matematiksel yollarla çözüme ulaştırılıp elde edilen çözümün yorumlandığı ve değerlendirildiği bir süreçtir (Lesh ve Doerr, 2003). Matematiksel modelleme yoluyla öğrenciler, gerçek yaşamdaki matematiği keşfederek, matematiğin yaşamdan ayrı bir disiplin olmadığını, yaşamla iç içe olduğunu görme fırsatı yakalar. Matematiğe gerçek hayatta nasıl ihtiyaç duyulduğunu fark eder (Borromeo Ferri, 2018). Bu nedenle son yıllarda matematiksel modelleme uygulamalarının öğretim programlarında yer almasının önemi sıkça vurgulanmaktadır. Ortaokul matematik öğretim programında matematiksel modellemenin yer almadığı, modellemenin somutlaştırma ve görselleştirme olarak ifade edilen "matematiği modelleme" olarak yorumlandığı görülmektedir (MEB, 2018; Çavuş Erdem, Doğan, Gürbüz ve Şahin, 2017). Matematiksel modellemenin ülkemiz öğretim programlarında yer alması ve doğru bir şekilde ele alınması için matematiksel modellemenin öğrencilerin matematiksel gelişimlerine etkisini araştıran çalışmaların yapılması önem kazanmaktadır. Bu nedenle matematiksel modelleme etkinlikleri dayalı öğrenme ortamının incelendiği bu çalışmanın, bu anlamda literatüre katkı sağlayacağı düşünülmektedir.

Yöntem

Durum çalışması yöntemiyle yürütülen araştırmanın çalışma grubunu, araştırmacı tarafında kolay ulaşılabilir olması yönüyle belirlenen bir okulda öğrenim gören ve amaçlı örneklem yöntemiyle seçilen 6 tane yedinci sınıf öğrencisi oluşturmaktadır. Tüm veri toplama araçları öğretim programda yer alan, alan ölçme konusunun kazanımları dikkate alınarak geliştirilmiştir. Çalışmada, öğrencilerin bilgilerinde değişim olup olmayacağını net bir şekilde gözlemlemek için öğrencilerle uygulama öncesi ve sonrası bireysel görüşmeler gerçekleştirilmiştir. Uygulama süreci 8 adet matematiksel modelleme etkinliği ile yürütülmüştür. Verilerin analizinde gömülü teori kodlama (grounded coding) yöntemi kullanılmış ve rubrikle değerlendirme yapılmıştır. Araştırmada tüm veriler toplandıktan sonra, verilerin tamamı transkript edilmiştir. Transkriptlerin tamamlanmasının ardından kodlama sürecine geçilmiştir. Öncelikle toplanan veriler araştırmacılar tarafından ayrı ayrı kodlanmış, sonrasında kodlar karşılaştırılarak kod birliğine varılmış ve kodlama sürecine devam edilmiştir.

Bulgular

Araştırmada uygulama öncesi bazı öğrencilerde alan kavramının iki uzunluğun (en ve boy) çarpımı sonucunda elde edilen sayısal bir değer olarak oluştuğu, alan ölçmenin temel kavramlarından biri olarak birim kare kavramının oluşmadığı, bunun sonucu olarak öğrencilerin alan ölçme birimlerini tanımlamada ve birimler arası dönüşümde eksiklikleri bulunduğu belirlenmiştir. Üçgen (dik açılı üçgen hariç) ve paralelkenarın alanını hesaplarken, yanlış stratejiler kullanan ve hatalı işlemler yapan öğrencilerin, aynı zamanda, kenar uzunluğu ile alan arasındaki ilişkiyi fark edemedikleri belirlenmiştir. Uygulama sonrası öğrencilerin alan kavramını doğru bir şekilde açıkladığı ve alanı kaplama olarak ifade ettikleri belirlenmiştir. Tüm öğrencilerin çokgenlerin alanı doğru bir şekilde hesaplayabildiği, hatta kare, dikdörtgen ve üçgenin alan bağıntısını birim kare yardımıyla açıkladığı, bazı öğrencilerin ise bunlara ek olarak paralelkenar ve yamuğun alan bağıntısını da açıklayabildiği belirlenmiştir. Öğrencilerde yaşanan gelişmenin, matematiksel etkinlikleriyle meşgul olurken gerçekleştiği ve bu gelişmenin bilgilerin hatırlanması (çağrılması), modelleme sürecinde ortaya çıkan öğrenme fırsatları yoluyla değerlendirilmesi ve bunun sonucu olarak bilginin değiştirilmesi veya pekiştirilmesi şeklinde gerçekleştiği bulgularına ulaşılmıştır.

Tartışma, Sonuç ve Öneriler

Araştırmada matematiksel modellemeye dayalı öğrenme ortamında, öğrencilerin öğrenme fırsatları yoluyla gelişme sağladığı sonucuna ulaşılmıştır. Öğrencilerin bilgilerini değerlendirmesine ortam sağlayan öğrenme fırsatları bireysel keşifler, akran iş birliği veya rehberliği ya da öğretmen rehberliği şeklindedir. Öğrencinin dışardan hiç biri müdahale olmadan sadece model oluşturma sürecinde keşfettiği matematiksel anlayışlar araştırmada bireysel keşif olarak ifade edilmiştir. Lesh ve Doerr (2003), öğrencilerin güçlü, paylaşılabilir modeller oluştururken kavramsal yapılarını farkında olamadan gözden geçirdiğini ifade etmektedir. Öğrencilerin bilgileri sınamalarındaki bir diğer etken akran faktörüdür. Matematiksel modelleme etkinliklerinde, grup içinde öğrencilerin bilgileri sunması ve karşısındaki bireyin bilgilerine ulaşması, model oluşumu için bilginin grup üyelerinin onayından geçerek kullanılması doğal bir karşılaştırma ve değerlendirme sürecini barındırır. Akran değerlendirmesi olarak ifade edebileceğimiz bu durum öğrenciye rehberlik etmesi konusunda oldukça önemlidir (Lesh ve Harel, 2003). Bu çalışmada da grup üyelerinin, model oluşturma sürecindeki açıklamaları ve modeli değerlendirme basamağında diğer grup üyelerinin açıklamalarının öğrencilerin öğrenmelerinde etkileyici olduğu tespit edilmiştir. Çalışma bulguları ayrıca öğrencilerin gelişimlerini ve öğrenmelerini destekleyen bir diğer faktörün öğretmen rehberliği olduğunu göstermiştir. Modelleme etkinliklerinde öğretmen, bilgiyi aktaran bir kaynak olmanın ötesinde, bir rehber görevi üstlenmektedir (Dunne ve Galbraith, 2003; Ärlebäck, Doerr ve O’Neil, 2013). Modelleme etkinlikleri, gerek geleneksel olmayan çözümler gerektirdiğinden, gerek çözüm esnasında ortaya çıkan öğrenci diyaloglarından dolayı, öğrencilerin hem matematiksel bilgileri hem de matematik anlayışları hakkında derinlemesine bilgi çıkarmaya destektir (Brown ve Edwards, 2011). Burada öğretmenin doğru zamanda doğru sorularla öğrenci açıklamalarına ulaşması, derin bir değerlendirmenin yanı sıra öğrencilerin bilgilerini gözden geçirmelerine ve hatalarını fark etmelerine olanak tanımaktadır. Çalışmada öğrencilerin durumu gözlemleyen ve gerektiğinde kritik sorularla öğrencilerin muhakemelerini harekete geçiren araştırmacı, benzer bir öğretmen rolü üstlenmiştir. Araştırmacının öğrencilere yönlendirdiği kritik sorular, hem öğrencilerin düşüncelerini daha derin bir şekilde açığa çıkarmaya ve öğrenmenin ne düzeyde oluştuğunu belirmeye yardımcı olmuş, hem de etkinlikte fark edilmeyen noktaları ve matematiksel ilişkileri görmede tetikleyici bir rol üstlenmiştir.

Çalışmadan elde edilen sonuçlar matematiksel modelleme etkinliklerine dayalı öğrenme ortamının öğrencilerin öğrenmeleri destekleyici fırsatlar sunduğunu göstermiştir. Matematiksel modellemenin sağladığı katkıdan faydalanabilmek ve uygulamaları öğrenme ortamına taşıyabilmek için, öğretim programında matematiksel modelleme uygulamalarına yer verilmesi önemlidir. Bu anlamda matematiksel modellemenin öğrenmeye etkisini araştıran çalışmaların, bununla birlikte modelleme sürecinde öğrenmenin nasıl gerçekleştiği, matematiksel kavramların oluşumunu nasıl etkilediğiyle ilgili araştırmaların artırılması önem kazanmaktadır. Bu nedenle araştırma sonuçları dikkate alınarak, matematiksel modellemenin matematik öğrenimindeki etkisini araştıran çalışmaların artırılması ve öğretim programında modelleme uygulamalarına yer verilmesi gerektiği önerilebilir.

Investigation of Learning Environment Based on Mathematical Modelling Activities

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Received: 12.03.2021 Accepted: 03.06.2021

Doi: 10.17522/balikesirnef.896038

Abstract – This study aimed to examine change in students' mathematical knowledge in a learning environment based on mathematical modeling activities. The study conducted with six students (13-year-old) and examined the seventh graders' eight mathematical modeling activities prepared for the acquisition of the area measurement subject through applications, video and sound recordings, student solution reports, and researcher notes. To support the data in the implementation process, individual interviews were held with the students. The findings of the study revealed that teaching through mathematical modeling method supports students' area measurement knowledge and skills significantly. This development is supported through learning opportunities that arise in the mathematical modeling process. The formation of the unit square concept in the development of students' area measurement knowledge and skills and the explanation of the area measurement relation by associating it with the unit square created a locomotive effect. The findings of the study showed that mathematical modeling applications should be included in the curriculum.

Key words: area measurement, learning environment, mathematical modeling.

Corresponding author: Zeynep Çavuş Erdem, zcavuserdem@hotmail.com. This paper, has been produced from the first author's doctoral dissertation titled “Investigation of the learning process based on mathematical modeling activities in the context of area measurement”.The paper was previously presented orally in the "4th International Symposium of Turkısh computer and Mathematics Education" and and it has been published in the proceedings.

Introduction

The purpose of teaching mathematics is to train students who can use, apply, and question mathematics in and out of school environment (Ministry of National Education [MEB]), 2018). One of the way to achieve this aim is mathematical modeling. In its most general form, mathematical modeling can be defined as the process of solving real-life problems using mathematics (Niss, Blum & Galbraith,2007). In this process, which involves creating a solution using mathematical structures and operations and evaluating the functionality of the solution, an individual can see the opportunity to comprehend that mathematics is not a discipline separate from life but is intertwined with life itself, and realizes how mathematics is needed in real life (Borromeo Ferri, 2018). Therefore, the importance of mathematical modeling applications has frequently been emphasized in the curriculum, international reports recently and research articles (National Council of Teachers of Mathematics [NCTM], 2000; Common Core State Standards for Mathematics [CCSM], 2011, Kaiser, 2020). It is also seen that mathematical modeling is handled as concrete material usage in some curricula and textbooks (Çavuş Erdem, Doğan, Gürbüz, Şahin, 2017). However, mathematical modeling consists of a much more comprehensive structure. Mathematical modeling needs to be handled correctly in the curriculum. Because the goals in mathematics education programs can be achieved through mathematical modeling, it is expressed in modeling studies (Author, 2018). Besides, it is emphasized in studies that mathematical modeling has effect on the creation and deepening of mathematical concepts and information (Ottesen, 2001; Blum & Borromeo Ferri, 2009; Park, Park, Park, Cho & Lee, 2013). Thus, it is important to conduct studies investigating the effect of mathematical modeling on students' mathematical development to include and address mathematical modeling in the curriculum correctly.

There are few studies examining the effect of mathematical modeling on individuals' mathematical knowledge and skills (Stohlmann , DeVaul, Allen, Adkins, Ito, Lockett & Wong, 2016). The literature review shows that the majority of studies conclude that mathematical modeling affects students' learning positively (Harel & Lesh, 2003; Park et al.2013). Dunne and Gabraith (2003) examined the effect of a curriculum created with mathematical modeling activities on the development of students' mathematical concepts and skills. The researchers argued that mathematical modeling provides students with important opportunities to know how it is beyond knowing something and is a very effective tool to test the accuracy of students' knowledge gained through traditional teaching methods. Harel and Lesh (2003), in their study with three students with low academic success, examined conceptual changes of students during the application process of modeling activity in mathematics.

Their findings revealed that there were conceptual change and development in students and mathematical modeling effectively served this purpose. Park et al. (2013) argued that mathematical modeling activities provided discovery and conceptual developments related to the subject in their research and claimed that mathematical modeling has a facilitating role in learning. Ärlebäck, Doerr & O'Neil (2013) claimed that students provided improvement on the subject but had difficulty interpreting some situations. The researchers, addressing the difficulties experienced conceptually and contextually, stated that mathematical modeling activities contribute to the mathematical development of the students, and therefore suggested that further explanatory research should be conducted, especially on the subject. Freeman (2014) argued that mathematical modeling activities do not make a big difference compared to traditional teaching and do not affect students' attainment significantly. According to the findings of these studies, it would be safe to say that the algebraic issues are prioritized. More studies are required to examine the effect of mathematical modeling on mathematics teaching (Stohlmann et al., 2016). This study, in this sense, aimed to examine the learning environment based on mathematical modeling activities, including one of the areas of geometry sub-learning. Therefore, the study aimed to answer the following research question: "Are mathematical modeling activities an effective method in teaching the subject of field measurement?". This study investigated students' knowledge of area measurement at pre-implication and post-implication and their explanations during the implementation of activities.

Theoretical Framework

Mathematical Modeling as a Tool for Teaching Mathematics

Studies on mathematical modeling showed that modeling is defined differently and used for different purposes (Galbraith, 2012; Kaiser & Sriraman, 2006). The use of mathematical modeling to teach and reinforce mathematical concepts is the approach in which modeling is considered a tool (Galbraith, 2012). As the mathematical structures and concepts targeted in the problems used in this approach create a requirement for students, it is aimed to provide more meaningful learning. Examples of perspectives adopting this approach in the literature are educational modeling and contextual modeling (model and modeling perspective [MMP]) perspectives defined by Kaiser and Sriraman (2006). Although there are fundamental differences in the meaning attributed to modeling activities between these two perspectives, both include the idea that mathematical concepts can be taught through mathematical modeling activities (Abassian, Safi, Bush & Bostic, 2020).

In this research, the approach in which mathematical modeling is adopted as a tool and some issues highlighted in the aforementioned approaches were taken into consideration in research design. Mathematical modeling activities are considered realistic, complex, and open-ended problems with a set of principles (Lesh & Zawojewski, 2007; Şahin, 2019), however, it might be simpler and closed-ended when it is used as a tool for teaching mathematics (Bukova Güzel, Dede, Hıdıroğlu, Kula Ünver & Özaltun Çelik, 2016). This issue adopted by the educational modeling approach was considered while designing activities in the research, and mathematical modeling activities were designed in a more structured way (Table 2). Another approach proposed by Lesh and Doerr (2003), the MMP, takes mathematical modeling as a tool. According to this approach, students develop important mathematical and conceptual structures while engaging in modeling activities. The features emphasized by the researchers dealing with the topics mentioned in their research in a much deeper way and the features taken into consideration in this research design can be listed as follows:

According to MMP, an individual in mathematical modeling activities explains the problem's situation with his own experiences and creates his/her model with his conceptual structures. If a person first creates the model and then examines it, his/her thinking can be changed in basic ways, and this change in the individual can be observed through external representations and models used in the modeling process. This study, in this sense, examined mathematical structures and models in the modeling processes to determine how the students achieved the desired goals with modeling activities.

MMP proposes applying mathematical modeling activities with groups of three or four students, explaining this on cognitive and social bases. In any case, it is not always possible for an individual to handle and interpret a subject with all its components. Researchers argued that it would be appropriate to carry out applications by forming groups because of the same concept being perceived and interpreted differently by different people and the individual not being aware of the details while looking at the big picture or not being able to see the big picture while focusing on the details. Based on this idea, mathematical modeling activities in this study were applied to groups of three students.

Concept of and Measurement of Area

In this study, mathematical modeling activities are designed to include the gains of the measurement subject. The area measurement, which is considered one of the important topics of the geometry-learning field, determines how many of a limited plane will be covered by the same type and appropriate measurement unit (Reynolds & Wheatley, 1996). To understand area measurement, it is essential to comprehend the area and measurement correctly, as these two concepts are different from each other in the area measurement, and two concepts can be mixed and the students with no sufficient knowledge about the area interpret the area concept as the area measurement (Dickson, 1989; Huang & Witz, 2013). The area is a certain amount that covers the surface of a limited area, and the purpose of area measurement is to determine this amount (Baturo & Nason, 1996). Simon and Blume (1994) stated that the area measurement should be handled in two different stages as evaluating the area as a limited region and determining the amount of this area. The first stage involves understanding that the area is a planar region and conceptually interpreting the area. The second stage includes being able to determine the amount of the region. Baturo and Nason (1996) emphasized that it is very important to correctly understand the measurement tool, the unit, in determining this amount. Likewise, Outhred and Mitchelmore (2000) stated that systematic counting comes to the fore in covering the region with the same type of unit and determining the unit amount. As a result of covering a rectangle with a suitable and identical unit, it is necessary to turn it into a systematic count to calculate how many units are on each line and how many lines are available, because it is very important to see the column-row coordination and correlate this with the product of the edge lengths in the transition of the area measurement to the product (Huang & Witz, 2013). Thus, students can understand the multiplication process in the area formula conceptually (Outhred & Mitchelmore, 2000).

Another important concept in learning area measurement at a conceptual level is conservation. Conservation includes information on how changing the shape and dimensions of a surface will change the surface area. The concept of field conservation is generally neglected in teaching (Stephan & Clements, 2003). However, ensuring conservation in measurement is very important for conceptual development (Lesh & Carmona, 2003). Studies reported that students have difficulty in accepting that the area remains the same when they cut a certain area and rearrange it to create another shape (Lehrer, 2003). Therefore, the concept of the area, the concept of the unit, and the conservation of the area should be gained basically for the teaching of the subject measurement. Then, teaching the area relations by repeating the units should be targeted. In this research, while the mathematical modeling activities were being designed and the order of implementation of the activities, the aforementioned issues were being taken into consideration, an application aimed at creating the perception for the students that the area is a region, covering this region with standard and non-standard units, and then the transition to the area relation.

Method

Research Method

Due to the in-depth analysis of the learning environment, a case study method is adopted in this study. In the most general sense, the purpose of a case study is to examine and describe a case in its real context (Yin, 2009). In this study, a case study is considered an instrumental case. The instrumental case study aims to provide an idea about a subject and make a generalization, and a limited situation is selected from the population to achieve this goal. The situation under consideration serves as a tool to reach general information in this type of research. This study aimed to obtain general findings of the learning environment based on mathematical modeling; therefore, the instrumental case study was adopted.

Participants

The study group consists of six seventh-grade students (13-year- old) who study at a school that can be easily accessible by the researchers. The participants of the study were selected through a purposeful sampling method. In the selection process, students' knowledge levels regarding the subject of area measurement were taken into consideration. The subject of area measurement is included in the mathematics curriculum from the third grade of primary school (MEB, 2018), and therefore, it is considered that the application group has preliminary information on the subject. Based on this assumption, in the first stage, a form titled "Area Knowledge Evaluation Form" was developed by the researchers and applied to determine the students' prior knowledge on the subject. The form was applied to 160 people and six students (three girls, three boys) who were randomly identified among the student groups that were determined to have incomplete knowledge due to the application, and the study group was formed. Students were coded under the following names: Serhat, Mehmet, Ali, Meral, Esma, and Pelin.

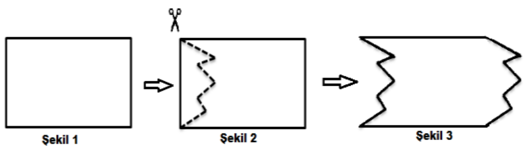
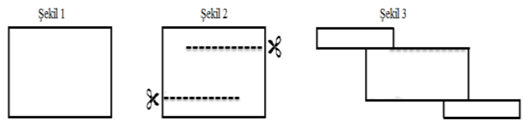
Data Collection Tools

Different data collection tools were used in this study. The main tools are mathematical modeling activities and interview forms made before and after the implementation.

Interview Forms

Semi-structured individual interviews were conducted with students before and after the implementation. To create the interview questions, a literature review has been conducted (Hart, 1981; Orhan, 2013), and some basic concepts and achievements regarding area measurement have been taken into account (MEB, 2018). The questions are arranged to reveal how students define the area, the ability to measure the area of polygons, knowledge of area conservation, unit square information, and area-perimeter-edge length relation. Two sample questions related to forms are presented in Table 1.

Table 1. Sample Questions from Pre-Interview and Last Interview Form

<table>
<tr><th>Pre- interview form</th><th>Last interview form</th></tr>
<tr><td>Q.3. Consider a rectangle. How does the rectangle’s area change when its length of all sides is doubled? Please explain.</td><td>Q.4. Think of a square. When two units increase a square’s side length and decrease the other side’s length, does it change the area?</td></tr>
<tr><td></td><td>(the table continues)</td></tr>
<tr><td>Q.5. Yasemin cut a rectangular paper in Figure 1, as shown in Figure 2. She then slid the cut piece to the right of the rectangle to form Figure 3. In your opinion, how does the area of the 3rd Shape change? Please explain.

</td><td>Q.3. A rectangular paper given in Figure 1 below is cut slightly on both sides, as shown in Figure 2, folded in the opposite direction to the side where it was cut, and Figure 3 is formed. In your opinion how does the area of the 3rd Shape change?

</td></tr>
</table>

After the interview forms were developed, two mathematics education experts were shown, and their ideas were taken, and revised accordingly. After the arrangements, the implementation was carried out with four students determined for the pilot study in the ‘‘Area Knowledge Evaluation Form’’ application group. As a result of the implementation, one of the questions was revised according to the expert opinion, and the interview forms were finalized.

Mathematical Modeling Activities

One of the eight activities, another data collection tool used in the application process, and seven mathematical modeling activities were created based on the literature review (Doruk, 2010). The following points were taken into account during the designing the activities: a) The problematic situation given in the activity is in a way that the context of real-life can make sense of the students with their past experiences, and the real-life situation coincides with the reality of the student (Lesh et al.,2000; Maaß, 2006), b) As aiming to teach mathematical concepts is a primary goal, the problem is more structured rather than completely open-ended in events (Bukova Güzel et al., 2016).

The developed activities are designed to support both conceptual and operational information on area measurement. The ‘‘Recycling Adventure Event,’’ ‘‘Patchwork Pillow,’’ and ‘‘Swimming Pool’’ problems are designed both to improve the unit square concept and to support operational information related to area measurement, to make the area feel like a covering. “Kamil's Sheep” and “Almond Claim” events emphasize the protection of the area and the relationship between the area-perimeter-edge length and support these achievements. “School Party,’’ “Halva with Cheese,’’ and “Inheritance Sharing” activities are designed to highlight the ability to measure the area. While determining the application order of the activities, a sequence was followed considering the conservation, unit square, expressing a region with different unit squares, the conversion of units, and measuring the area of polygons. Although the activities are designed to support different concepts related to the area, it is considered that they would function as a whole in gaining the area concept and area measurement skills and will support the development of other achievements in the area apart from the targeted activities. The activities were revised according to expert opinion and finalized as a result of the pilot implementation. One exemplary activity is presented in Figure1.

Recycling Adventure Problem

Mrs. Ayşe is planning to contribute to her household income by covering the old used materials leftover from household chores with fabric and selling them as ornaments. To increase the contribution, she wants to use the fabrics she will cover with the minimum number of materials. However, she has no idea how many pieces of fabric that should be used to cover the materials. She asks for help from you, as a mathematician, in this matter. Your task is to develop a measuring tool (unit) that will identify the piece of fabric covering the tin can that is given to you. Indicate in detail what aspects you considered when developing the measuring tool.

Figure 1. Mathematical Modeling Activity

Applications were recorded through a video camera and voice recorder. In the research, students’ activity solution papers and researchers’ notes consist of the other data collection tools.

Data Analysis

The data analysis of this research was performed in the following two stages: an embedded theory coding method (grounded coding) and a rubric evaluation method. In the first stage, all data were analyzed through the embedded theory coding method that requires creating categories and continuous comparison to analyze the data (Jones & Alony, 2011). In this approach, the following three main coding stages were employed to analyze the data through coding: open, axial, and selective coding. The data analysis process of the study was as follows: After all the data were collected, they were transcribed first, and then empowerment method was applied to the data (Ellis et al.,2016). All of the video and sound recordings of each application were watched again, taking into account the transcript text of that application, and were enriched with verbal expressions, gestures, attitudes, drawings, and images. Some transcripts were individually coded by the researchers. After the coding, the researchers compared and evaluated the codes together. For the compatibility between the codes, Miles and Huberman's (1994) intercoder reliability formula (Compatible codes / [Compatible codes + Incompatible codes] x100) was applied, and it was determined that they were 84%, 80%, and 82% for the first interview, the event, and the last interview, respectively. Incompatible codes were evaluated, associated with codes with the same meaning according to the situation, and new codes were created according to the situation. In axial coding, related codes are collected under the same title. As a result of selective coding, two important titles emerged, and data analysis was performed separately under these two titles.

The first topic is related to the students' area measurement knowledge and skills. ''Area Concept and Area Measurement Knowledge Evaluation Rubric'' has been developed with the codes obtained. In this way, the data collected in the preliminary interview and the final interview were evaluated according to the developed rubric, and it was aimed to examine the change in students' knowledge by supporting the rubric assessment with student explanations. The rubric consists of five main titles and 11 subtitles. Each subtitle is rated within itself (Appendix A). The students' explanations in the pre-interview and the last interview were graded according to rubrics by taking into account their development in the process. The second title emerging in the analysis process is related to the learning environment based on mathematical modeling activities. The codes and sample explanations are discussed in the results section of the study.

Results

Results Related to Students' Area Measurement Knowledge and Skills

In this research, the changes in students' area measurement knowledge and skills were presented through the findings obtained from the pre-interview and the final interview and the solution reports they presented during the modeling process. The students' scores from the evaluation rubric based on their pre-interview and final interviews' responses are presented in Table 2.

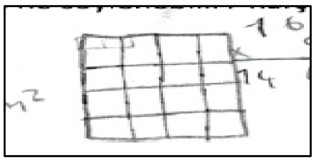
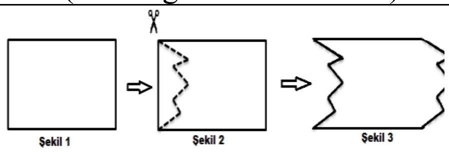
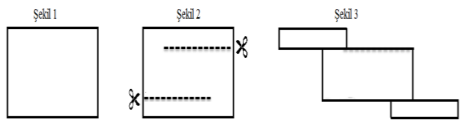
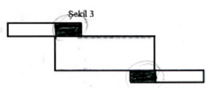
Table2. Students' Scores from the Evaluation Rubric in the Pre-Interview and Final Interview Form

Concept of area and area measurement skill	**HS***	**Serhat**		**Ali**		**Pelin**		**Meral**		**Mehmet**		**Esma**	
		P*	**L***	**P**	**L**	**P**	**L**	**P**	**L**	**P**	**L**	**P**	**L**
Perception of area concept	3	3	3	3	3	1	3	1	3	3	3	3	3
Area computing perception	4	1	4	1	4	2	3	0	3	1	3	0	3
Unit square	5	1	5	0	4	0	4	0	4	0	4	1	4
Area measurement units and conversion of units	5	1	5	2	5	2	4	1	4	1	4	0	4
Area conservation	1	1	1	1	1	0	1	0	1	0	1	1	1
Ability to calculate area of square and rectangle	2	1	2	1	2	1	2	1	2	1	2	1	2
Ability to calculate the area of a triangle	4	1	4	1	3	1	3	1	3	1	3	1	3
Ability to calculate the area of the parallelogram	3	0	2	0	2	0	2	0	2	0	1	0	2
Side length - area relation	2	0	2	0	2	0	2	0	2	0	2	0	2
Circumference- area relationship	2	1	2	1	2	0	1	0	1	0	1	0	1
Area- circumference relationship	2	1	1	1	1	0	1	0	1	0	1	0	1
TOTAL (0-6) unsatisfactory (7-13) fairly unsatisfactory (14-20) partially satisfactory (21-27) fairly satisfactory (28-33) satisfactory	33	11	31	11	29	7	26	4	26	7	26	7	26

* HS: Highest score possible , P: Preliminary interview, L: Last interview,

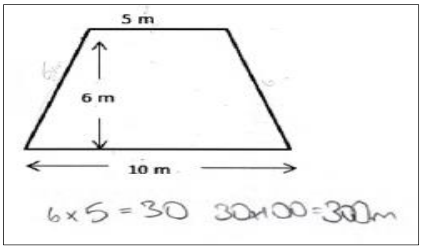
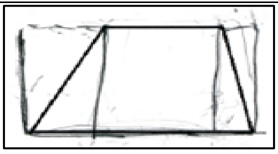
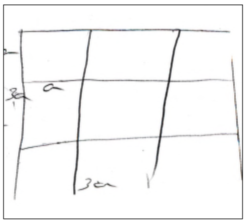
Table 2 shows that the students' knowledge about the subject has reached a sufficient category as a result of the application process. Although an individual difference has been observed in the students' development, it can be said that the learning environment based on mathematical modeling activities has a positive effect on all students' scores. To examine the development of the students more clearly, sample explanations are presented based on their answers to the questions in the preliminary and final meetings (Table 3).

Table 4 Sample Explanations of the Interviews

Category	Example explanation from the preliminary interview	Example explanation from the last interview
Perception of area concept	Researcher: What comes to your mind when you think of the area, Pelin? Pelin: The product of the width and length of something. Researcher: Can you show me the area here, where is the area here? (on the square) Pelin: This part, like that (she shows by drawing the width and length of the shape. Area is equal to the product of two sides.	Researcher: What comes to your mind when you think of the area, Pelin? Pelin: This is where something takes up, its interior. Researcher: Well, will there be areas of irregular shapes? Pelin: Yes, there is a place it occupies, but we cannot find it.
Unit square	Ali: As it is a square, 5 times 5 is 25 cm^2. Researcher: Well, can you show me this 25 cm^2 here? Ali: 25 cm^2 is inside the area. Researcher: Can you explain it a little more? Can you show what quantity is 25, that is 25 cm^2? Ali: No. Researcher: Why? Ali: (nodding ‘‘I don't know’’).	 Researcher: Can you draw me a square with an area of 16 br^2? Ali: Yes, I can draw. It would be 4 laterally and 4 vertically. So, that’s what you see here.
Area conservation	 Meral: I think it doesn’t change. Researcher: Why is that? Meral: Because it moves the amount it cut here. Researcher: What if I paste it above? Meral: When we paste it above, it may change. Because its height is expanding. We cannot calculate it because this is (cut length) a curve. I don’t know, perhaps it might change that way.	 Meral: It adds the same amount to  itself there. This part comes on top of the bottom. Researcher: So, does the area change? Meral: I think the area gets smaller. It overlaps, and the bottom overlaps as well. I think the area is decreasing. Researcher: How much does it decrease then? Meral: As much as the shape of this (filling the area).

(the table is continues)

Table 3. *Continuation of….*

Area measurement skill	 Esma: If here is 5 m and here is 10 m, then here is 6 m. Now (calculating), we multiply 6 by 5. We also multiply 30 by 10. Researcher: Why? Esma: The thing here is 5 m, these two are not equal. As it is not equal, we cannot multiply only one. We have to multiply all three.	Esma: To find the trapezoid area, we should complete the rectangle and then subtract these completed places. Researcher: What lengths should be known? Esma: For this place, the base of the shape must be known. We also need to know the height of the shape. Researcher: Can you show where you call the base? Esma: The base needs to be known, but these two parts need to be known. (triangle bases on the sides). And this middle piece. In total, there are three lengths for the base.
Area- side length relationship	Researcher: Does the area of a rectangle change, if its side lengths double? Serhat: When it is doubled, we use 4 cm for 2 cm and 8 cm for 4 cm. One of the areas is 8 and the other 32, enlarges 4 times. Researcher: So, why is it 4 times larger? Why is that? Serhat: Why could it be? Teacher, 4, hmm, I don't know. Researcher: Okay. Then what happens if the side lengths triple? Serhat: The area becomes 3 times larger.	Researcher: When the side length of a square is increased by 3 times, how many times does the area increase? Serhat: We can find it by using value. Researcher: I want you to do it without using a value. Serhat: If a becomes 3a. I t will be 3a. The other side will be 3a (drawing the shape). Serhat: We divide this place by 3. (divides for 7s). Then we can see that 9 of these can fit inside. Becomes 9 times bigger.

Although the pre-application levels of the students differed, the examples were presented over the same student to observe the development of the students more clearly. Considering all the examples, it would be safe to say that the concept of space was formed as a numerical value obtained by multiplying two lengths (width and length) in some students before the application (n = 2), and the concept of the unit square did not occur as one of the basic concepts of area measurement (n = 4). The findings of the analysis revealed that students have deficiencies in defining area measurement units, and conversion of units (n = 6), and some students think that the area changes depending on the shape without changing the quantity (n = 3). When calculating the area of the triangle (except the right-angled triangle) and the parallelogram, it can be said that students using wrong strategies and perform erroneous operations (n = 6) also did not notice the relationship between side length and area (n = 6). In the explanations after the application, it has been observed that the students correctly explain the concept of space and express the area as a covering one (n = 6). It has been observed that all students can correctly calculate the area of the polygons, and even explain the area relation of the square, rectangle, and triangle with the help of unit square (n = 6).Also, some students can explain the area relation of the parallelogram and trapezoid (n = 2). Table 4 shows that all students have conservation. The change in students' knowledge can be seen from the models and solution reports that emerged during the modeling process. The solution report of the students in the first activity is presented in Figure 2.

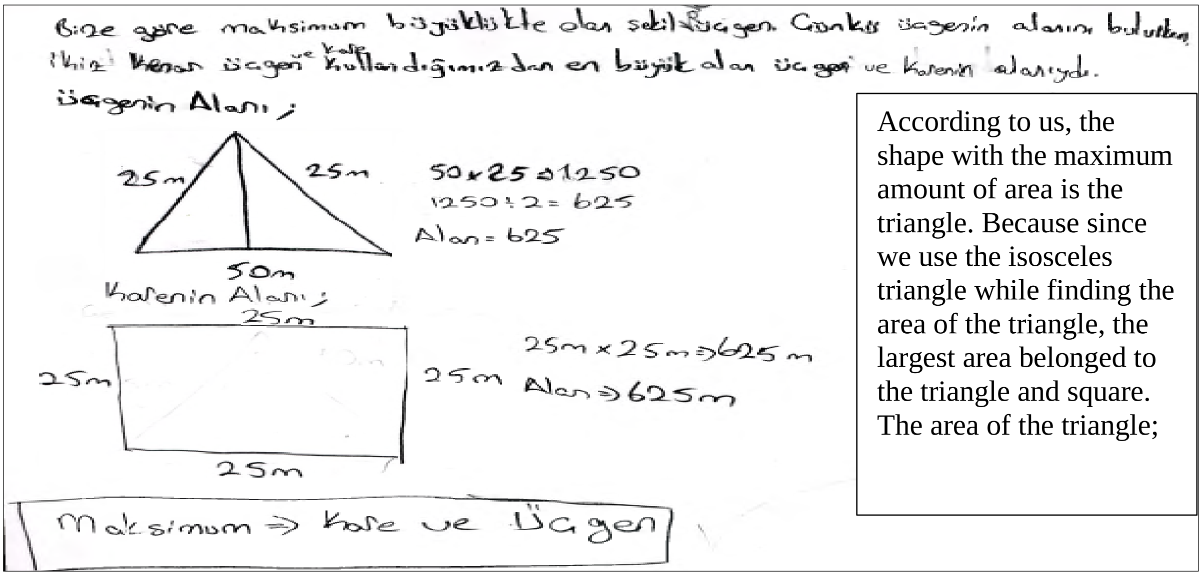


Figure 2. First Activity Solution Report

In the first activity, students were asked to find the maximum area they can create a 100-m fence. Students' solution report shows that there is an error in their knowledge. When calculating the triangle area, the students miscalculated the area taking into account one length of the sides instead of the height. At the same time, it is seen that the students expressed the measurement result with the wrong unit. This activity aimed for students to realize the relationship between the sides and circumference length. The next activity has the same purpose. The students reported that the circumference of the two rectangles with the same area at the stage they presented their solutions might be different. This is a mathematical development for students who think that the perimeter of the rectangles whose area is equal before the application will also be equal (n = 4), and this can be regarded as one of the first improvements during the modeling activities application process. In the next activity, students were asked to determine the amount of fabric that would cover a can. In the activity in which students used a spotted (polka dot) piece of fabric, they expressed the amount of fabric in unit squares. In this activity, an important progress by the students has been observed and it was seen that students expressed the area using the unit square. In this activity, students expressing the area with only unit squares started to express the same area with different units in the next activity. In this activity, students showed the area of the same area in both cm^2 and m^2, and they also showed the measurement result in m^2 correctly. Although it was not aimed to include in the activity outcomes, as a result of the question directed by the researcher while students discuss their models, they discovered the relationship between m^2 and cm^2 and wrote the result they found in m^2. Considering the incorrect student explanations regarding the relationship between the standard measurement units, this can be considered an important development. In the last activities aimed at the development of the students' area measurement skills, it is seen that the students started to calculate the area of the polygons correctly. The solution report regarding the seventh activity is presented as a sample calculation in Figure 3.

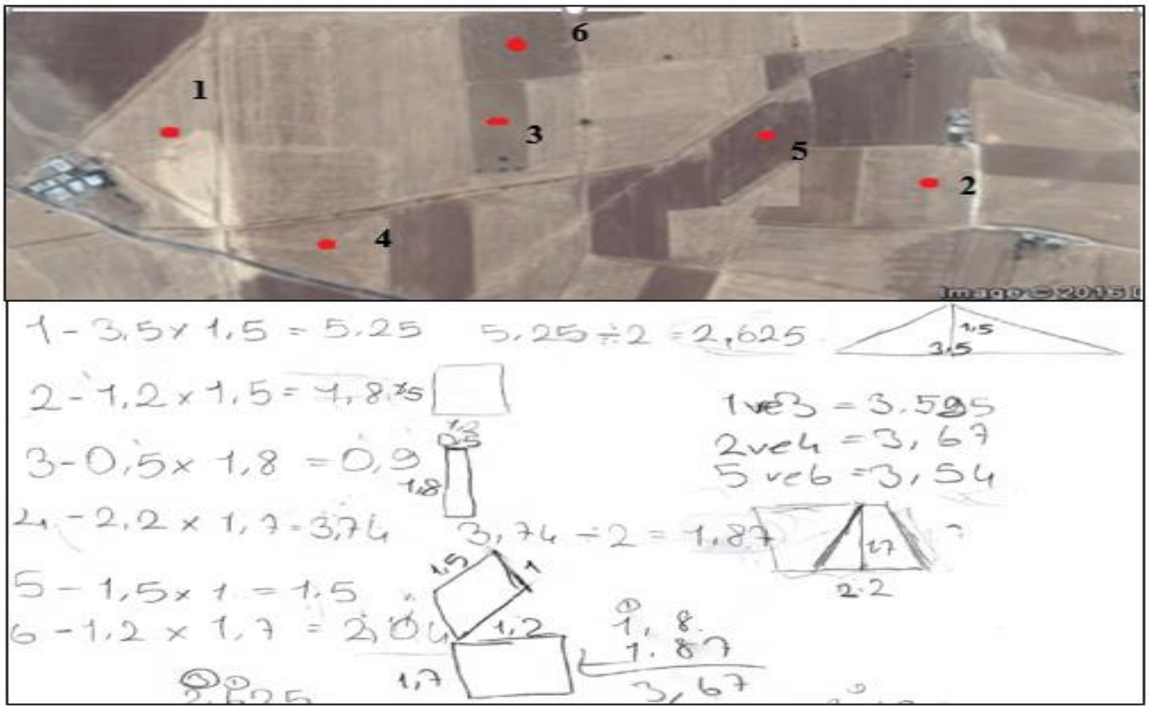


Figure 3. Solution Report Regarding the Seventh Activity

In the seventh activity, the students were asked to divide the six fields among the three siblings in the fairest way. As shown in Figure 3, the students correctly calculate the area of all polygons, including the trapezoid, parallelogram, and triangle. Students used the parallelogram to find the trapezoidal field area and measured the area by converting the trapezoid to a parallelogram. It is considered that it is an important progress that students correctly calculate the trapezoid area they have not encountered before. At the same time, students who can only calculate the area of the right triangle before the application (n = 6), who measure the area of the parallelogram incorrectly (n = 6), show that the area measurement skills of the students have improved because they made correct calculations during the application process.

Results Related to the Learning Environment Based on Mathematical Modeling Activities

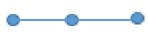
Results from the research show that mathematical modeling activities significantly affected students' learning. Student explanations regarding the learning of the unit square concept will be presented to show how the situation in question has been handled. The third mathematical modeling activity of the research applied for the unit square concept is "Recycling Adventure," as shown in Table 2. During the application process, students were given an activity and asked to evaluate individually for five minutes and then create a model with their groups. The dialogue between students at this stage is as follows (Figure 4).

Meral: What do we do now, any ideas?
Mehmet: Let's find out how much fabric we have. Look, there are gaps here. Let's say 1 cm for each gap.
Pelin: No, it will probably be more than 1 cm, it cannot be 1 cm. Let's think. Okay, you will take it as a unit.
Mehmet: OK, anyway, I'll make my calculation (counting the width and length of the fabric). You tell me, 1 m^2 equals to 1000 cm^2, right?
Pelin: Yeah. It was 1000 cm^2. But why do you multiply to find the amount of fabric?
Meral: No, I think it was 100 cm^2. 1 m^2 equals to 100 cm^2.
Mehmet: No. It was 1000 cm^2. Sides came out to be 22 cm and 19 cm. It makes 4180 when I multiply. It is 4 m^2.

Figure 4. Student Descriptions Regarding the Third Activity

The explanations that the students try to transform the problem into the language of mathematics also show that they try to remember their existing knowledge. The dialogues show that the students made both true and false statements. It is the correct approach that Pelin sees the distance between the two spots as a unit, and Mehmet multiplies the sides to determine the amount of fabric. Also, it is seen that students misunderstood the relationship between square meters and square centimeters. The most important point that attracts our attention here is that the students shared their information and presented it to the peer's evaluation. At this stage, it has been determined that the emergence of situations enabling students to evaluate their knowledge is very important in the realization of learning. The findings of the study show that students have the opportunity to learn by evaluating their knowledge a) individually, b) through peer guidance, and c) through teacher guidance. Some samples for these three situations will be presented below.

Peer guidance can be expressed as the development that the students have due to the explanations of his group friend. Dialogues between the students to find the amount of fabric they determined in the activity will be presented as an example of peer guidance. As mentioned above, Mehmet considered the distance between the two spots 1 cm, while Pelin stated that the distance between the two spots was more than 1 cm and accepted the range as 1 unit and showed a correct approach. This acceptance of Pelin played a supportive role in learning the concept of the unit square. A sample dialog for this situation is presented below.

Pelin: Yes, the unit square is a unit square because each gap is a unit.
Researcher: So, can you show me the unit square here?
Pelin: Look, teacher, this is a unit square (draws a side length).
Researcher: Can you show me how it is exactly?
Pelin: This is the unit (side length-). The product of these two is a unit square. (shows two unit lengths - ).
Meral: The product of these sides becomes a unit square (pointing the sides)
Pelin: Teacher, these two lengths and the product of these units will be a unit square.
Meral: I think just here (square) is a unit square.
Researcher: Well, Meral, can you show me the cm2?
Meral: Then it becomes a square with its sides being 1 cm.
Researcher: Pelin, what do you think?
Pelin: I think it makes more sense to consider it as a unit square, or rather it looks like that.

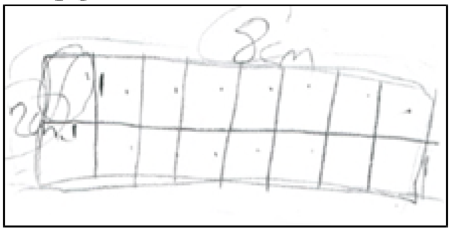
It appears that the knowledge of the unit square concept of Pelin, Mehmet, and Meral before the application is insufficient (Table 4). Pelin's explanations to determine the amount of fabric that will cover the tin can show that she maintains her incorrect perception. Expressing the distance between the two spots on the fabric as one unit and the unit square as the length of the two units, Pelin questioned her knowledge after Meral's explanation. It seems that Meral explained the concept of the unit square correctly. The fact that she defined a square centimeter correctly supports the idea that she learned the unit square correctly. The dialogue given above may not be sufficient to show that learning process has been completed, especially for Pelin, but in the continuation of the solution process, it has been determined that both students addressed the unit square correctly. Some examples will be presented below. Meral's influence on Pelin's concept of learning can be expressed as peer guidance. Likewise, Pelin's acceptance of the distance between two spots as a unit affected Meral's learning. Although the occurrence of Meral's development has not been fully reflected in the activation process, it is thought that it is effective to associate the unit length with the square region.

The situations in which the students made progress in the activity solution process without any external intervention can be considered as individual discovery (interaction with the activity). An example of an explanation for this situation is given below:

Researcher: What did you guys do?
Serhat: We calculated the area of the piece of fabric. These gaps can only be 1 cm anyway.
Esma: We took a centimeter as an estimate.
Ali: It would be 1,3 cm. More than 1 cm.
Researcher: Well, if you accept that it is not 1 cm, then how will you express it?
(They think for a while)
Ali: We would follow the unit calculation.
Serhat: Yes, it makes sense, we'll do it that way. Eleven units, this here is four units. Friends, the area is 44 unit squares.
Ali: Yes, this was a nice progress.
Researcher: How did you decide that it is a unit square?
Ali: Now, because we don't know the size of this square, we called it a unit, when we calculate it, it looks like a square shape anyway. When we multiply this side with that side, it becomes the square of a unit. For this reason, it is a unit square. Yeah, of course, that's very good indeed.

All in all, Ali uses correct expressions regarding the concept of the unit square. The explanations of Ali, who could not explain the concept of the unit square before the application, showed that he discovered the concept of the unit square upon accepting it as a unit between two spots. Ali's interaction with the activity allowed him to establish a mathematical relationship, and the situations that occurred in this way in the research were named individual discovery. In the modeling process of the students, the questions asked by the researchers were another factor supporting the development of the students, except for the conversations they had with their group friends and when they noticed individually. A sample dialogue that arises with the questions asked by the researchers to the students who determined the area of the fabric is presented below (Figure 5).

Researcher: Friends, you said that by multiplying 11 by 4, you found the area of this fabric as 44 unit squares. Can you show me here without multiplying to get 44?
Mehmet: For example, here (first row) there are 11 squares, in this order, there are 11, 44 in total.
Researcher: So, why are we multiplying the sides?
Pelin: Because, teacher, there are four 11s. For example, as there are four lines longitudinally and 11 lines transversely, we multiply 4 with 11, hence 44.



Researcher: Can you draw a rectangle with a long side of 8 cm and a short side of 2 cm to show its area in the unit square?
Meral: Isn't it like this? If we divide it by 2 transversely, we divide it into 8 parts longitudinally. It becomes 16 cm^2.
Ali: I think she's doing it correctly.
Researcher: Then what do those squares represent?
Pelin: It represents a square of 1 cm.

Figure 5. An Example of an Explanation for Teacher Guidance

The dialogue shows that the students explain the area relation of the rectangle by associating it with the unit square. The questions posed by the researcher played a supportive role in establishing this relationship. To fully reveal and reinforce the knowledge of the students, the correct answer to the second question asked by the researcher supports the idea that they have learned the unit square, which is one of the basic concepts of the area measurement. Conversion information between the students who learned the concept of the unit square was carried out in the next mathematical modeling activity. In the "Patchwork Pillow" modeling activity, the students were asked to determine the amount of each color fabric for the pillow cover. The students found the area of the different color fabrics used on the pillow cover in both unit square and square centimeters. The researcher then asked the students to express the results in m^2 to observe the change in their unit transformation knowledge. Mehmet, tried to explain the conversion of units algebraically (Figure 6).

Researcher: If I ask you to write this in m^2, how can you write it?
Esma: Ladder calculation.
Serhat: Then, we will convert cm to m. We were going up two steps when converting it to meters. If we add two zeros.
Meral: No, if we delete two zeros.
Mehmet: There is also something like 1 m^2, 1,000 cm^2.
Meral: Becomes 100. Because 1 m is 100 cm.
Mehmet: Okay, but it has a square. 1 m^2 is 1,000 cm^2. For example, do you think m and m^2 are the same?
Serhat: No, it wouldn't be the same.
Mehmet: Look, this is a m. This is m x m. See if this is 100, 100 times 100 makes 10,000. Ooooh, I was absurd.

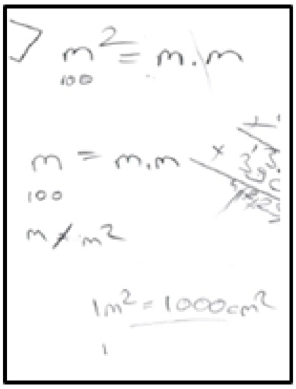
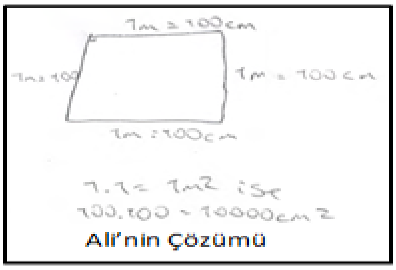


Figure 6. Student Descriptions Regarding the Unit Transformation

The ladder calculation, which teachers frequently apply in teaching the conversion of measurement units and coverts the relationship of the measurement units with their lower and upper counterparts into a visual form, was the first method students have applied. While the students explained and evaluated their knowledge, Mehmet questioned whether two units were different and tried to explain the difference between the two algebraically. Based on Mehmet's approach and the correct calculation he made, Serhat and Ali tried to find the conversion by doing some mathematical calculations (Figure 6).

Serhat: Let's draw a shape. When it continues from the calculation that Mehmet said, it turns out to be 10,000. Let's show it on the figure.
Ali: I did it. Can I say my opinion? Because I found 10,000.
Pelin: I think it's 10,000 as well
Ali: If 1 m equals 100 cm, I calculated it as its square. As it is a square of 1 m, it becomes 100 x 100, which equals to 10,000.



Esma: He found the correct result, and I think it is very reasonable.
Serhat: We thought so too. Here is 1 m, if we multiply 1 by 1, it becomes 1 m square. For example, if we convert 1 m to 100 cm, this contains 100 cm in 1 m. If we divide this part into 100 pieces like this (he draws a line parallel to the bottom of the square). One hundred pieces come on top of each other. This is 1 m in the same way, as a square (drawing another line parallel to the other side). So, there is a total of 10,000 of these squares here. (The little square indicated by the red circle)

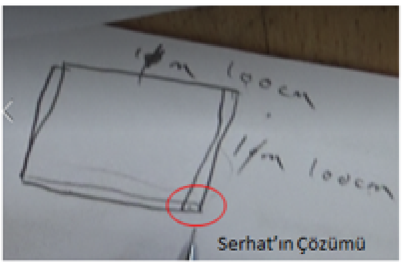


Figure 7. An Example of an Explanation for Teacher Guidance

The explanations showed that students explained the conversion of units in both algebraic and geometrical ways. Students did the unit conversion not by heart, but using the unit square and explaining the measurement units algebraically. This development, which was achieved by the students on the subject of area measurement, was supported by the question directed by the researcher and Mehmet's guiding explanation. Teacher and peer guidance, one of the learning opportunities that emerge in mathematical modeling activities, is observed in the dialogues given above.

Discussion, Conclusions and Suggestions

The results of the study show that mathematical modeling is effective in teaching the basic concepts of area measurement subjects such as unit square, area conservation, area measurement, and gaining skills. It would be appropriate to examine the results consistent with the literature (Dunne & Gabrailth, 2003; Park et al., 2013), both from the viewpoint of the applied method, that is mathematical modeling, and the subject taught. Considering the role of mathematical modeling in the said development, it can be said that activities offer important opportunities for students to question and evaluate their knowledge. The students' activation of their knowledge to form a model and its evaluation by interacting with the activity, peers, and teacher (researcher) involves a natural learning process. The first step in the exchange of information carried out through learning opportunities is remembering the information. In modeling activities, students engage in intensive cognitive activities and, thus, take an active role (Blum & Niss, 1991). For this reason, while trying to mathematicise the real-life situation and solve the model in the activities, the students run (remember) their existing knowledge and share it with their group friends. Information sharing within the group also includes a natural evaluation process. In this way, the students who reached the information of their group friends and presented their information to the approval of their peers had the opportunity to notice their incorrect information. Group support (Harel & Lesh, 2003), which is very important in guiding the student, was expressed as peer guidance in the research. Ng (2011) claimed that students are significantly influenced by group members in understanding modeling activity, interpreting context, using mathematical knowledge, and reasoning. In addition to Ng's (2011) findings, the results of this study also showed that students outside the group also have an impact and guide students. During the evaluation phase, students had the opportunity to evaluate and improve their knowledge, where they presented and discussed their models in the classroom. Hitt and González-Martín (2015) argued that other students undertook the duty of a locomotive in the modeling process and prepared the ground for learning. The study results showed that students both in and out of the group guide students to access new information.

Another learning opportunity that supports students' development in a mathematical modeling environment is determined as teacher guidance. In modeling activities, the teacher acts as a guide, rather than a source of knowledge (Ärlebäck et al.,2013; Dunne & Galbraith, 2003). The fact that the teacher reaches the student explanations with the right questions at the right time allows students to review their knowledge and realize their mistakes as well as an in-depth assessment. The researcher, who observed the students' situation in the research and mobilized the students' reasoning with critical questions when necessary, assumed the role of a similar teacher. Critical questions directed by the researcher helped reveal students' thoughts more deeply and determine the level of learning and played a triggering role in seeing the points and mathematical relationships that were not noticed in the activity. The explanation of the rectangle's area relation by linking the rectangle with the unit square is an example of this situation. Hitt and González-Martín (2015) explained this as the institutionalizing role of the teacher. The researchers claimed that the teacher's statements in the mathematical modeling activities to support the students' mathematical understanding emerging in the process and explaining the mathematical relations after the activity would increase the permanence of the learning. The results of the research are also in line with this idea.

One of the last learning opportunities is the changes that the student experiences due to interaction with the activity and is expressed as an individual discovery. Individual discovery is the mathematical insights that the students discover in the model building process only without any external intervention, such as peer or teacher guidance. In the process that students unconsciously review their conceptual structure (Lesh & Doerr, 2003), it is thought that they see the whole by combining the parts and, thus, construct mathematical understanding. It should be noted that the learning opportunities that arise during the research process are not independent of each other. It is thought that other learning opportunities have an impact on the realization of each. Learning is considered a long and complicated process, and the process has evolved through the synchronous operation of the three opportunities that emerged in the research.

When students' development is evaluated based on area measurement, it is possible to say that the third activity is a turning point. In the activity where some students got acquainted with the unit square concept and associated the unit square with the area relation of the rectangle, students mathematically comprehended why two lengths are multiplied in the area relation. The students' comprehension of the area relation by associating it with the unit square was also observed during the mathematical explanation of the area relation of the triangle in the same activity. As Harel and Lesh (2003) stated, student transferred the mathematical understanding that emerged in the model. These findings, which are also parallel with the explanations of Stephan and Clements (2003) and Zacharos (2006), showed that the concept of the unit square is very important for the area measurement subject, because covering the interior of a polygon with a unit square will naturally create the perception that the area is a region. At the same time, associating the number of unit squares covering the region with the area relation will enable the structuring of area measurement as reported by Stephan and Clements (2003).The results of the research showing that the perception of the students who perceive the area as ‘‘width x height’’ before the application has changed and turned into area conservation, also confirms the idea that the unit square is an effective tool in overcoming the learning difficulties in the width x height aspect (Kamii & Kysh, 2006). The mathematical structuring of the students’ area relation also contributed to the development of the area measurement skill naturally. It also made it easier for them to understand how to convert the standard area measurement units to cm^2 or m^2.

To summarize, the support of mathematical modeling activities is carried out through the opportunities it offers. Achieving all this development is possible with mathematical modeling activities by the concept and acquisition hierarchy of the subject planned to be taught. Besides, although there are opportunities to support learning in this research, it is not explained how learning occurs in the students’ minds during the mathematical modeling process. Also, research results are limited to the subject of area measurement. To show whether mathematical modeling is an effective tool for teaching mathematics, it is recommended to conduct further studies in different learning areas and conduct studies that detail the modeling process’ learning.

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Appendix A:

Concept of Area and Area Measurement Information Evaluation Rubric

		Levels	Description
Perceptions of the concept of area	Perception of area concept	Level 0 (0 points)	Not making a statement about the concept of the area or making a false statement.
		Level 1 (1 point)	Thinking the concept of area as a numerical value obtained by multiplying the width and height of the shape. (width x height perception)
		Level 2 (2 points)	Seeing the concept of area as the place occupied by shape and thinking it only a property of smooth shapes.
		Level 3 (3 points)	Thinking the concept of area as the place occupied by an object.
	Area computing perception	Level 0 (0 points)	Not making a statement about the area calculation or having a wrong perception.
		Level 1 (1 point)	Thinking the area of a shape as the product of two sides that intersect without looking for a 90-degree condition.
		Level 2 (2 points)	Thinking the area of a shape as the product of the shape's base and the height of the base.
		Level 3 (3 points)	A mathematical explanation of the area computing relations of the rectangle. (explaining relations by associating them with unit squares.)
		Level 4 (4 points)	A mathematical explanation of the area calculation relations of all polygons. (explaining relations by associating them with unit squares.)
Unit square	Unit square	Level 0 (0 points)	Not making a statement about the concept of unit square or making a false statement.
		Level 1 (1 point)	Measuring and expressing the area of polygons area intersect with 90 degrees on all sides, in square units.
		Level 2 (2 points)	Measuring and expressing the area of the rectangle with unit squares of different sizes.
		Level 3 (3 points)	Measuring and expressing the areas of all polygons in square units.
		Level 4 (4 points)	Measuring and expressing the area of a polygon with unit squares of different sizes.
		Level 5 (5 Points)	Measuring and expressing the area of a polygon in a nonstandard unit.

	Area measurement units and conversion of units	Level 0 (0 points)	Not making a statement about the area measurement units and using the area measurement unit incorrectly.
		Level 1 (1 point)	Using the area measurement unit correctly.
		Level 2 (2 points)	Defining area measurement units correctly and algebraically, but not geometrically.
		Level 3 (3 points)	Correctly defining the area measurement units geometrically.
		Level 4 (4 points)	Converting the area measurement units.
		Level 5 (5 Points)	Ability to explain the conversion of area measurement units mathematically.
Conservation	Area conservation (AC)	Level 0 (0 points)	Not having area conservation.
		Level 1 (1 point)	Having area conservation.
Area seasurement skill	Ability to calculate the area of square and rectangle	Level 0 (0 points)	Inability to calculate areas of square and rectangle or incorrect calculation.
		Level 1 (1 point)	Correct calculation of the areas of the square and rectangle.
		Level 2 (2 points)	Creating the area relation of the square and rectangle and explaining them mathematically.
	Ability to calculate the area of the triangle	Level 0 (0 points)	Inability to calculate the area of the triangle or incorrect calculation.
		Level 1 (1 point)	Correct calculation of the area of the right triangle.
		Level 2 (2 points)	Correct calculation of the area of all triangles.
		Level 3 (3 points)	Calculating the area of triangles by taking different sides as the base.
		Level 4 (4 points)	Creating the area relation of the triangle and explaining mathematically.
	Ability to calculate the area of the parallelogram	Level 0 (0 points)	Inability to calculate the area of the parallelogram or miscalculation.
		Level 1 (1 point)	Correct calculation of the parallelogram area.
		Level 2 (2 points)	Calculating the area by taking different sides of the parallelogram as the base.
		Level 3 (3 points)	Creating the area relation of the parallelogram and explaining mathematically.
Side length -circumference-area relation	Side length-area relation	Level 0 (0 points)	Failure or misrepresentation of the relationship between side length and area.
		Level 1 (1 point)	Explaining the relationship between side length and area in a limited way (by way of examples).
		Level 2 (2 points)	Generalizing the relationship between side length and area.

	Circumference-area relationship	Level 0 (0 points)	Not being able to create different polygons with the same circumference.
		Level 1 (1 point)	Ability to create different polygons with the same perimeter.
		Level 2 (2 points)	From polygons with the same circumference, seeing the area grow with the convergence of the side lengths.
	Area-circumference relationship	Level 0 (0 points)	Not being able to create different polygons with the same area.
		Level 1 (1 point)	Creating different polygons with the same area.
		Level 2 (2 points)	From the polygons with the same area, being able to see that the circumference increases with increasing distance of the sides from each other.

Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi (EFMED)
Cilt 15, Sayı 1, Haziran 2021, sayfa 95-117.ISSN: 1307-6086

Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Vol. 15, Issue 1, June 2021, pp.95-117.ISSN: 1307-6086

Araştırma Makalesi /Research Article

Öğretmen Adaylarının Öğrenme Stillerinin Şematik Not Hazırlamalarına Etkisi

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Gönderme Tarihi: 12.04.2021 Kabul Tarihi: 24.06.2021

Doi: 10.17522/balikesirnef.913929

Özet– Araştırmanın amacı öğretmen adaylarının öğrenme stillerinin fen konularında hazırladıkları şematik notlara etkisini belirlemek ve şematik notlarda kullandıkları görsel ve yazılı öğelerin kullanım amaçlarını tespit etmektir. Araştırma betimsel ilişkisel tarama modeli esas alınarak yürütülmüştür. Araştırmaya Alanya Alaaddin Keykubat Üniversitesinde ikinci ve üçüncü sınıfta öğrenim gören 44 fen bilgisi öğretmen adayı katılmıştır. Veriler Akgün ve ark. (2014) tarafından hazırlanan "Sözel veya Görsel Baskın Öğrenme Stilini Belirleme Ölçeği" ve katılımcıların ortaokul fen konularında hazırladıkları şematik notlarla toplanmıştır. Elde edilen sonuçlara göre katılımcıların çoğunluğunun baskın öğrenme stili görseldir. Görsel öğrenme stili baskın olanlar şematik notlarında sıklıkla çizim ve farklı yazı stilleri ile görselliği ön plana çıkarırken, sözel öğrenme stili baskın olanlar kelime ve cümleleri daha fazla tercih ederek detaylı açıklama yapmışlardır. Görsel öğrenme stili baskın olanların süreç oluşturma, gruplama ve listelemeye, sözel öğrenme stili baskın olanların açıklamaya daha fazla önem verdikleri tespit edilmiştir. Sonuçlar ışığında şematik notların öğretmenlere tanıtılması, öğrenme ve öğretme sürecinde kullanılması önerilmektedir.

Anahtar kelimeler: Öğrenme stili, görsel ve sözel öğrenme, fen öğretim materyalleri, şematik notlar, fen bilgisi öğretmen adayı.

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Geniş Özet

Giriş

Bilişsel öğrenme kuramı ile birlikte araştırmacılar bireyin öğrenme sürecindeki özellikleriyle ilgilenmeye başlamışlardır. Öğrenenlerin bilgiyi nasıl öğrenmeyi seçtiğini, bireye özgü özelliklerin bu seçimlerini nasıl etkilediğini sorgulamışlar (Morgan 1997), öğrenenlerin öğrenmeyi gerçekleştirmek için tercih ettikleri yolları belirlemeyi amaçlamışlardır. Bireylerin özelliklerini (Kolb, 1988), biyolojik (Dunn & Dunn, 1993) ve sosyal (Grasha, 1996) açılardan ele alarak öğrenme stillerini tespit etmişlerdir. Farklı öğrenme stilleri araştırmacıları bireysel öğrenme türlerini araştırmaya yöneltmiştir. Öğrenme türlerini görsel ve sözel başta olmak üzere farklı gruplarda incelemişlerdir. Görsel öğrenme, görsel olgularla etkileşim sonucu bilginin yapılandırılmasıdır (Seels, 1994). Resim, grafik, tablo veya çizimler görsel öğrenenlerin soyut kavramları somutlaştırmalarını ve kavramlar arasında ilişki kurmalarını kolaylaştıran görsel materyallerdir. Sözel öğrenme, bilginin sözel ve yazılı formlar aracılığıyla yapılandırılmasıdır. Konuşma, yazma veya okuma aktiviteleri sözel öğrenenler için önemlidir. Geleneksel sınıflarda dinleme, okuma, not alma etkinliklerinde sözel öğrenme baskındır (Armstrong, 2009). Görsel ve sözel öğrenme stiline sahip öğrencilere kullanabilecek öğretim materyallerinden birisi de şematik notlardır. Şematik notlar, bir metni okurken, bir konuşmayı dinlerken ya da bir işi organize ederken oluşturulan görsel hikâyelerdir. Yazı, çizim, şekil, sayı, işaretler gibi görsel ve yazılı öğeleri içerir (Rohde, 2013). Fen öğretiminde kullanımı yaygınlaşan şematik notlar, kavram öğretiminin yanı sıra bilimsel açıklamaların karmaşıklığını azaltmak ve problem çözme sürecinde kavramsal düşünmeyi tanıtmak için de kullanılmaktadır (Fernandez-Fontecha et al., 2018). Bilgilerin ilişkilendirilmesi, paylaşılması, hayal gücünün ve soyut düşünme becerilerin geliştirilmesi için kullanışlı araçlardır (Bratash, Riekhakaynen, & Petrova, 2020).

Araştırmanın amacı

Şematik notlar görsel ve yazılı öğeleri bir arada içerdiğinden, farklı öğrenme stiline sahip öğrencilerin ilgisini çekebilecek, not alma, planlama, özetleme, değerlendirme gibi farklı öğretimsel amaçlar için kullanabilecek öğretim materyalidir. Literatürde şematik notların hazırlanmasını (Rohde, 2013), kullanım amaçlarını (Altieri, 2017; Robinson 2018; Fernandez-Fontecha et al., 2018) ve fen öğretimindeki uygulamalarını (Enfield, Smith, & Grueber, 2008; Forbus, et al., 2011; Bratash, Riekhakaynen, & Petrova, 2020) tanıtan araştırmalar yer almaktadır. Şematik notların öğretimde kullanılmasına yönelik araştırmaların yaklaşık 10 yıldır yapıldığı ve bu konunun araştırmacıların son yıllarda daha fazla ilgisini çektiği görülmektedir. Ülkemizde şematik notların fen öğretiminde kullanıldığı ve öğrenmeye etkisinin analiz edildiği bir araştırmaya rastlanmamıştır. Bu araştırma eğitimcilere yeni bir bakış açısı sağlayabilir.

Ayrıca literatürde farklı öğrenme stillerine sahip öğrencilerin şematik notları nasıl kullandıklarına dair araştırma bulunmamaktadır. Bu araştırmanın amacı öğretmen adaylarının öğrenme stillerinin fen konularında hazırladıkları şematik notlara etkisini incelemektir. Bu amaçtan hareketle öğretmen adaylarının baskın öğrenme stilleri belirlenmiş, bunun şematik notlarındaki görsel ve yazılı öğelerin kullanımına etkisi araştırılmıştır. Ayrıca şematik notlarda yer alan görsel ve yazılı öğelerin kullanım amaçları incelenmiştir. Elde edilen sonuçlar farklı öğrenme stiline sahip öğrencilere yapılacak öğretimde şematik notların nasıl ve hangi amaçlarla kullanılabileceği konusunda eğitimcilere yol gösterebilir.

Yöntem

Bu araştırma öğretmen adaylarının baskın öğrenme stillerinin şematik not hazırlamalarına etkisini ortaya koyduğundan betimsel nitelikte ilişkisel tarama modelindedir.

Katılımcılar: Araştırmaya Alanya Alaaddin Keykubat Üniversitesinde ikinci ve üçüncü sınıfta öğrenim gören 44 fen bilgisi öğretmen adayı katılmıştır.

Veri toplama araçları: Katılımcıların görsel veya sözel baskın öğrenme stilini belirlemek üzere Childers, Houston ve Heckler (1985) tarafından geliştirilmiş ve Akgün, Küçük, Çukurbaşı ve Tonbuloğlu (2014) tarafından Türkçeye uyarlanmış olan "Sözel veya Görsel Baskın Öğrenme Stilini Belirleme Ölçeği" kullanılmıştır. Uyarlanan ölçek sözel ve görsel öğrenme stilleri olmak üzere iki alt boyuttan ve 16 maddeden oluşmaktadır. Araştırmanın diğer veri toplama aracı katılımcıların hazırladıkları şematik notlardır. Öğretmen adayları ortaokul düzeyinde istedikleri bir fen konusunu açıklamak için görsel ve yazılı öğeleri kullanarak şematik not oluşturmuşlardır.

Verilerin analizi: Katılımcıların baskın öğrenme stillerini belirlemek ve öğrenme stillerinin şematik notlarda kullandıkları görsel ve yazılı öğelere etkisini analiz edebilmek için betimsel ve karşılaştırma testleri kullanılmıştır. Şematik notların araştırmacılar tarafından hazırlanan kontrol listesi ile içerik analizi yapılmıştır.

Bulgular

Katılımcıların 34'ünün (%77.2) baskın öğrenme stili görsel, yedisinin (%16) sözeldir. Üç (%6.8) katılımcı ise ölçeğin alt boyutlarından eşit puan aldıkları için her iki öğrenme stili de baskındır. Tüm katılımcıların şematik notlarında çizim, madde işareti ve yazı stiline dikkat ettikleri tespit edilmiştir. Şematik notlarda en az kullanılan görseller tablolardır. Görsel öğrenme stili baskın katılımcılar şematik notlarında diğer katılımcılara oranla şekil, tablo, grafik ve diyagramları daha fazla kullanmışlardır. Dikkat çekici bir bulgu olarak, sözel öğrenme stili baskın olan katılımcılar şematik notlarında tablo ve grafiklere hiç yer vermemişlerdir. Tüm katılımcılar şematik notlarında başlık ve cümlelere (kısa açıklamalar) yer vermişlerdir. Sözel öğrenme stili baskın olan katılımcılar diğerlerine oranla konuyu alt başlıklar oluşturarak açıklamayı daha fazla tercih etmişlerdir. Bunun yanı sıra konuşma balonu ve bilgi kutularını diğerlerine oranla daha sık kullanmışlardır. Hem görsel hem de sözel öğrenme stili baskın olan katılımcıların tümü şematik notlarında yazılı semboller kullanmışlardır. Katılımcıların yazılı ve görsel öğeleri kullanım amaçları incelendiğinde, konuyu açıklamak ve önemli noktaları vurgulamak için tümünün bu öğeleri kullandıkları tespit edilmiştir. Ayrıca hepsi kavramları maddeler halinde açıklamak için listeleme yapmayı tercih etmişlerdir. Kelime, cümle ve çizimler açıklama, yazı stili ve renk vurgulama, madde işareti ve oklar listeleme için en sık kullanılan öğelerdir. Görsel-sözel öğrenme stili eşit olan katılımcıların tümü şematik notlarında organizasyona dikkat etmiş, bilgileri organize etmek için kullandıkları kâğıdı ya çizgilerle bölmüş ya da tablo, grafik ve diyagramlarla bilgileri açıklamışlardır. Ayrıca benzetim yapmak için çizim ve kelimeleri kullanmışlardır. Süreç oluşturarak konuyu açıklamayı en sık tercih edenler görsel öğrenme stili baskın olanlardır. Ayrıca bu gruptakiler diğerlerine oranla kavramları eşleştirmeyi, yazılı ve görsel öğeyi ilişkilendirip açıklamayı tercih etmişlerdir. Sözel öğrenme stili baskın olanlar ise konuyu açıklarken örnekler vermeyi diğerlerine oranla daha fazla tercih etmişlerdir. Katılımcıların öğrenme stillerine göre görsel öğeleri kullanımları incelendiğinde, görsel öğrenme stili baskın olanlar ile diğer gruplardakiler arasında görsel öğrenenlerin lehine anlamlı fark bulunmaktadır. Yazılı öğeleri kullanımları incelendiğinde, sözel öğrenme stili baskın olanlar ile diğer gruplardakiler arasında sözel öğrenme stili baskın olanlar lehine anlamlı fark bulunmaktadır.

Sonuç ve Tartışma

Katılımcıların çoğunluğunun görsel öğrenme stili baskındır. Bu durum derslerde görsel öğelerin sıklıkla kullanımını gerektirmektedir. Ancak Armstrong (2009) tarafından belirtildiği gibi derslerde konu öğretimi sıklıkla sözel olarak yapılmaktadır. Bu durum birçok öğrencinin derslerden verimli olarak yararlanmadığını göstermektedir. Etkili öğrenmek için bilgilerin hem görsel hem sözel hem de yazılı sunumuna yer verilmelidir (Felder, 1993). Bu durumda hem görsel hem de sözel öğrenme stili baskın öğrenciler daha anlamlı şekilde öğrenebilirler. Katılımcıların öğrenme stili şematik notlarda kullandıkları görsel ve yazılı öğeleri etkilemektedir. Fleming'e (2001) göre görsel öğrenenler konuları öğrenirken harita, grafik, tablo, şema, farklı yazı tipi ve renkleri, resimler gibi öğeleri kullanmayı tercih etmektedirler. Sözel öğrenenler ise yeni bilgilerini açıklamaktan, tartışmaktan, hikâye yazarak anlatmaktan hoşlanmaktadırlar. Okuyarak/yazarak öğrenenler ise listeleme, rapor yazma, not alma, Web sayfaları hazırlama gibi etkinliklerle öğrenmeyi tercih etmektedirler. Bu araştırmada da görsel öğrenme stili baskın olanlar şematik notlarında şekil, tablo, grafik, diyagram gibi görsel öğeleri sıklıkla kullanmışlardır. Bilgileri organize etmede ve sayfa düzenlemesinde renklendirme, yazı stilleri ve çizimlerin kullanımı dikkat çekmektedir. Sözel öğrenme stili baskın olanlar ise tanımlama ve açıklamaları bilgi notu, konuşma balonu, cümle ve kelimeleri kullanarak yapmışlardır. Pritchard (2009) görsel-sözel öğrenenlerin grafik, diyagram ve çizimlerin yanı sıra bilgiyi yazılı ifadelerle açıklamakta, her iki kaynağı da kullandıklarını belirtmektedir. Bu araştırmaya katılan ve görsel-sözel öğrenme stili eşit olanlarında görsel öğeleri sözel öğrenme stili baskın olanlardan, yazılı öğeleri de görsel öğrenme stili baskın olanlardan daha fazla kullanmaları avantajlı bir durumdur. Araştırmanın diğer önemli sonucu da, şematik notlardaki görsel ve yazılı öğelerin kullanım amacı ile ilgilidir. Görsel öğrenme stili baskın olanlar kavramları ilişkilendirme, sözel öğrenme stili baskın olanlar örnekleme, görsel-sözel öğrenme stili eşit olanlar ise benzetimlerle açıklamaya ağırlık vermişlerdir. Bu çalışmada farklı öğrenme stiline sahip bireylerin şematik notlarında bilgiyi zihinlerinde nasıl organize ettikleri, kavramları nasıl ilişkilendirip açıkladıkları ortaya konmaktadır.

The Effects of Learning Styles of Pre-service Teachers on Their Sketchnotes Designs

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Received :12.04.2021 Accepted : 24.06.2021

Doi: 10.17522/balikesirnef.913929

Abstract –The study aims to investigate the effect of the pre-service teachers' dominant learning styles on their sketchnotes designs prepared for science topics as well as determining their reasons for the visual and written elements used in these sketchnotes. The study was designed following descriptive correlational survey model. The participants consisted of 44 teacher pre-service of science teaching at grades two and three studying at Alanya Alaaddin Keykubat University. The quantitative data for the study was obtained through "Verbal and Visual Dominant Learning Style Scale" developed by Akgün et al. (2014) while the qualitative data was gathered from the participants' sketchnotes prepared for various science topics in the secondary school science curriculum. The findings indicate that the majority of the participants had visual dominant learning style. As the participants with visual dominant learning style gave prominence to visuals by using drawings and various writing styles frequently in their sketchnotes, the ones with verbal dominant learning styles used more words and sentences along with frequent textual detailed explanations. It was also found that the participants with visual dominant learning style placed more importance to process building, grouping, and listing and the ones with verbal dominant learning styles placed more emphasize on explanations. The findings of the study are meant to introduce sketchnotes to teachers and to promote the use of them in their teaching practices.

Key words: Learning style, visual and verbal learning, science teaching materials, sketchnotes, pre-service science teacher.

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Introduction

The introduction of Cognitive Learning Theory led researchers to place specific attention to learner characteristics during learning processes. They have investigated how learners choose the way to learn, how learner characteristics influence these choices (Morgan, 1997), and tried to explain the processes that learners go through during learning. Researchers have also attempted to identify learning styles by categorizing learners' characteristics as cognitive and emotional (Kolb, 1981), biological (Dunn & Dunn, 1993), and social (Grasha, 1996). For Kolb (1981), learning styles are the methods individually chosen to perceive and process information. A similar definition by Dunn (1984) states that each individual determines the way to understand and saves information, which is usually conducted in a unique way. According to Fleming (2001), learning style is also an individual's characteristics and preferred ways of gathering, organizing, and thinking about information. Grasha (1996) explains the concept based on social learning theory and claims that learning styles are predispositions that affect learners' receiving information, their interactions with teachers and peers, and their participation skills to learning experiences.

Acknowledging the significance of learning styles, researchers have explored individual learning types and preferences. Gardner (2011), for instance, has classified types of individual learning and intelligence in his "Multiple Intelligences Theory". He has demonstrated nine types of intelligence including verbal/linguistic, visual/spatial, and bodily/kinesthetic as well as logical/mathematical, musical, interpersonal, intrapersonal, naturalistic and existential intelligences (Gardner, 2011). Unfortunately, the evidence reported in educational research indicates that the present programs of schools is mostly based on verbal/linguistic intelligence, leaving out the other types. Providing learners with information utilizing both visual and audio modes, as suggested by the "sensory-channels" model of presenting information, is usually assumed to be achieved by just using the board to present linguistic input. However, as the physicist John Howarth describes, using imagery and picture language (visual/spatial intelligence) assists learners through problem-solving processes and enhances achievement:

> *I make abstract pictures. I just realized that the process of abstraction in the pictures in my head is similar to the abstraction you engage in dealing with physical problems analytically. You reduce the number of variables, simplify and consider what you hope is the essential part of the situation you are dealing with; then you apply your analytical techniques. In making a visual picture it is possible to choose one which contains representations of only the essential elements—a simplified picture, abstracted from a number of other pictures and containing their common elements.(John-Steiner, 1987, cited in Armstrong, 2009).*

Visual learning is defined as the construction and acquisition of information through interactions with visual elements (Seels, 1994). Visual materials are crucial in visual learning. As teaching materials, pictures, graphs, tables, or drawings can facilitate learning as they enable learners to visualize abstract concepts and internalize them more easily. Visuals also help learners to understand relationships between concepts while increasing their attention and enriching the learning process. Visualization, colour cues, picture metaphors, idea sketching, and graphic symbols are among the teaching strategies and materials that could be used in visual learning. Verbal learning is, to an extent, the construction of information via verbal and written forms. Speaking, reading or writing activities are important for verbal learning, which are dominant learning procedures commonly practiced in traditional classroom activities such as listening to teachers' lectures, reading from text books, or writing down the information on the board. Yet, activities like storytelling, discussion, brainstorming, word games, journal writing, or publishing could also be used to support verbal learning (Armstrong, 2009).

Materials used in visual and verbal learning processes help comprehension, increase retention, and enrich learners' learning experiences. The interaction between learners and learning materials occurs though the language of visual designs in the materials. Both words (e.g., in sentences, paragraphs or headings) and the images (e.g., such as pictures, designs and photos included to add simple or abstract meanings) form the information communicated in visual materials. Whatever elements are used in these materials, all compose the learning elements in harmony (Alpan, 2008) and help learners, particularly the ones with visual/verbal learning styles. Sketchnotes are among the materials that could be used for learners with visual/verbal dominant learning styles.

Sketchnotes

A sketch is defined as 'a quick rough drawing or outline by hand in simple strokes (Kurz, 2008 cited in Fernandez-Fontecha et al., 2018). Sketches can increase learners' abilities of thinking, transferring, and of their formation of knowledge. The relationship between the individual and the sketch is in fact the interaction of the mind, the eye, the hands, and the image and involves the acts of questioning and resolving. These acts are based on the stages of analysis, synthesis, and evaluation (Yakın, 2015). Sketching enables learners to depict and communicate abstract ideas; to illustrate processes of structures of complex systems; and to clarify and to externalize complex chunks of information. Sketchnotes also reflect learners' cognition as learners need to use visual, spatial, and conceptual knowledge and skills when preparing and communicating with sketches; and therefore, they provide opportunities for understanding human cognition more generally (Forbus, et al., 2011).

Sketchnotes, or visual note-taking, are visual stories created while reading a text, organizing an event, or listening to a talk. While they could be easily created by using just pen and paper, sketchnotes, engage learners in a productive information accumulation process that can lead to further knowledge production (Li et al., 2002). They can consist of a mixture of text and visuals such as handwriting, drawings, hand-drawn typography, shapes, pictures, arrows, boxes & lines, objects, frames, letters, or numbers (Rohde, 2013). An example of sketchnote is presented in Figure 1.

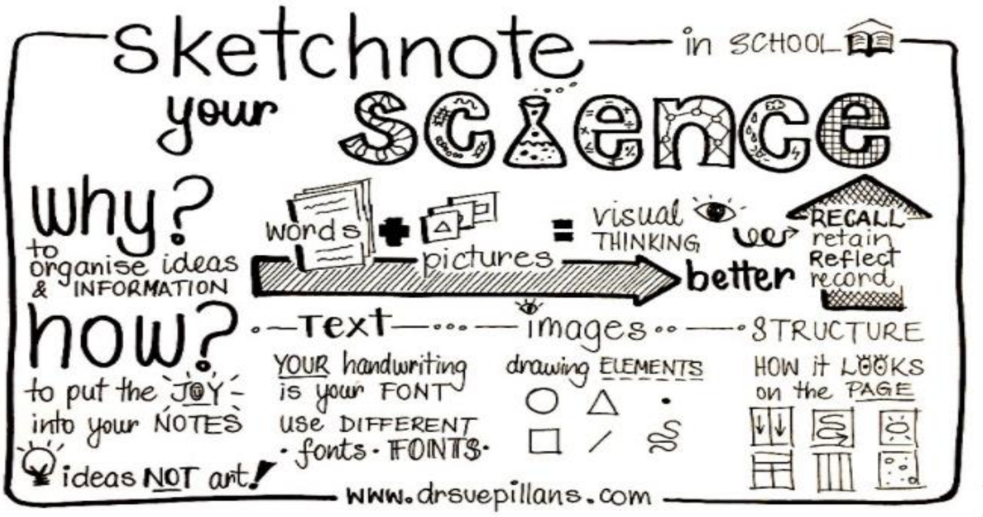

Figure 1. Example of a sketchnote (Panao, 2021)

Recently, sketchnoting has been gaining popularity at scientific and technical events such as conferences and workshops, where the content of an event is captured visually, later edited and shared via social networks and blogs. They are also increasingly being used in science teaching as they are effective tools to simplify complex scientific explanations and to introduce conceptual thinking in problem solving processes (Fernandez-Fontecha et al., 2018). Bratash, Riekhakaynen, and Petrova (2020) imply that the sketchnoting technique is useful for developing such cognitive skills as abstract reasoning, imagination, artistic vision of the world. Furthermore, sketchnotes have quite high informative value and help to memorize and recall the information. The sketches are used by students to share their ideas with one another. Thus, making sketches involves students in epistemic practices of science including representing observations and ideas, as well as comparing and communicating ideas (Enfield, Smith, & Grueber, 2008).

By using sketchnotes, chunks of information could be listed, grouped, or associated in written or visual formats. They can be used to take notes of the learning materials, summarize, brainstorm, interact or to prepare a plan for any learning task. They can also enable learners to supplement their handwritten text by reinforcing major concepts with images and help them to organize their thoughts without requiring learners to be talented in drawing or painting. Sketchnotes can help learners to improve their creativity as they can be used freely and creatively for any subject. They help to visualize the learning material and thus, to make learning easier and more retentive. By making lessons more enjoyable, sketchnotes can also increase learner participation and concentration as well as encouraging creative thinking (Enfield, Smith, & Grueber, 2008; Robinson, 2018; Fernandez-Fontecha et al., 2018).

Aims of the study

As sketchnotes include both visual and verbal elements, they can attract the attention of learners with different learning styles and could be used as educational tools for different teaching purposes such as to take notes, plan, summarize or to evaluate. Thus, determining how sketchnotes are affected by learners' verbal or visual learning styles could enable better planning for lesson materials, assignment tasks, or other instructional activities. The related literature includes studies that focus on preparing sketchnotes (Rohde, 2013), reasons of their use (Altieri, 2017; Robinson 2018; Fernandez-Fontecha et al., 2018) and their application in science education (Enfield, Smith, & Grueber, 2008; Forbus, et al., 2011; Bratash, Riekhakaynen, & Petrova, 2020). It could also be observed that there have been studies conducted on the use of sketchnotes in the last 10 years and this line of research has been gaining popularity among researchers in recent years. However, no research conducted to investigate the use and the impacts of sketchnotes or how they are prepared by learners with different learning styles could be found in Turkish context. Therefore, the present study could provide an alternative approach to educators. In this respect, the study aims to investigate the effect of the participant pre-service teachers' dominant visual and verbal learning styles on their designs of sketchnotes prepared for science topics while determining the reasons for including visual and written elements in these sketchnotes. In this respect, the participant pre-service teachers' dominant learning styles were determined and the effects of these learning styles on the elements used in their sketchnotes were analysed. The visual and written elements in the sketchnotes were also analysed in terms of their intended purpose. With these aims in mind, the following research questions are sought:

1) What are the dominant learning styles of the participant pre-service teachers?

2) Which visual and written elements do the participants use?
3) What are the participants' reasons for including visual and written elements in their sketchnotes?
4) Are there statistically significant differences between the pre-service teachers' dominant learning styles and their use of visual elements in their sketchnotes?
5) Are there statistically significant differences between the pre-service teachers' dominant learning styles and their use of written elements in their sketchnotes?

Method

The study was designed following descriptive correlational survey model as it aims to explore the effect of pre-service teachers' dominant learning styles on their sketchnotes designs on science topics. While descriptive research refers to investigation of an event or a phenomenon in its existent state, correlational studies are used in order to explore relationships between two or more phenomena (Karasar, 2002).

Participants

The sample of the study was formed following convenience sampling method. The participants consisted of the pre-service teachers who were registered in one of the courses of the researcher and who volunteered to participate in the study. In total, 44 higher education learners studying at Faculty of Education at Alanya Alaaddin Keykubat University. They were at the second grade (n=24) and at the third grade (n=20) of science teaching department. While the majority of the participants were female (n=30), the males constituted a smaller group (n=14). They had previously taken courses on science learning and teaching approaches and teaching materials as well as physics, chemistry, and biology.

Data tools

The data was collected using a Likert-type questionnaire and sketchnotes. In order to identify the participants' visual or verbal dominant learning styles, "Style of Processing Scale" developed by Childers, Houston and Heckler (1985) was used. The scale consists of 22 total items under two dimensions, visual learning style and verbal learning style, with 11 items each. Designed as a Likert Scale, the items are anchored in 4 (Always True For Me), 3 (Usually True For Me), 2 (Usually Not True For Me), and 1 (Never True For Me). Scoring low on the scale would indicate that the participant has verbal dominant learning style while high scores would imply having visual dominant learning style. The internal consistency of the subscales were calculated using Cronbach Alpha, and it was found that the sub-scales have high internal consistency values (α= .81 for verbal learning style dimension and α= .86 for visual learning style dimension). The scale has been adapted to Turkish by Akgün, Küçük, Çukurbaşı and Tonbuloğlu (2014) and published as "Sözel veya Görsel Baskın Öğrenme Stilini Belirleme Ölçeği [Verbal and Visual Dominant Learning Style Scale]". The adapted version of the scale has two dimensions (verbal learning style and visual learning style) with eight items for each and 16 items in total. Cronbach Alpha value of the adapted Turkish Scale is calculated as α= .69 for verbal learning style dimension and α= .71 for visual learning style dimension.

The participants were also requested to prepare a sketchnote for a topic they would choose among secondary school science topics by using visual and written elements. The participants were asked to prepare sketchnotes for different grades (from 5^{th} to 8^{th}) on one of the science topics (e.g., Cells and Divisions, DNA and Genetic Codes, Matter and Heat, Matter and Industry, Basic Machinery, Electric Charges, Photosynthesis, etc.). They were informed about preparing sketchnotes and possible materials they could use along with some sample sketchnotes. Then, they were allocated a week to prepare their sketchnotes. Previous to these implementations, an ethical approval was obtained from Science and Engineering Scientific Research and Publications Ethics Committee of Alanya Alaaddin Keykubat University (12.03.2021/9705).

Data analysis

The responses of the participants to the questionnaire were analysed statistically using SPSS 22.0 program. The participants who scored high in visual dimension were grouped in visual dominant learning style, the ones who scored high in verbal dimension were grouped in verbal dominant learning style, and finally the participants who scored equally in both dimensions were included in visual-verbal learning style group. Since the data was not normally distributed, non-parametric analyses were conducted.

For the sketchnotes, content analyses were conducted by the researchers. First, the visual and written elements in their sketchnotes were analysed by each researcher separately and the relevant codes and the themes were formed. The agreement level between the two researchers' results was calculated using Miles and Hubermann's (1994) formula and was found to be 82%. Then, the researchers discussed the codes and the themes determined separately and prepared a checklist based on the agreed codes and themes. Then, two experts, a science teacher and an academician in science teaching, were asked to analyse the checklist and give feedback. Each was given five different sketchnotes to analyse using the checklist. Based on their feedback, the checklist was modified by the researchers and finalized before it was used in the analyses of the present (Table 1). The scores obtained from the checklist for the sketchnotes and the scores from the learning styles questionnaire were analyzed statistically.

Table 1. The checklist used to analyse sketchnotes

Visual Elements	Examples	Written Elements	Examples	Reasons for Use	Visual-Written Elements
Drawings	Objects, symbols, models, etc.	Words		Organizing	Tables, diagrams, charts, shapes, sub-headings
Shapes	Square, triangle, rectangle, star, line, etc.	Sentences		Establishing Relations	Arrows, shapes
Arrows	→,↑,↓,↔, etc.	Heading		Creating Process	Arrows, shapes, bullets
Punctuation Marks	Quotation mark, exclamation mark, question mark, parentheses, brackets, etc.	Sub-heading		Emphasizing	Drawing, shapes, font styles, arrows, punctuation marks
Mathematical Symbols	+, -, x, =, >,< ,∞, etc.	Written Symbol	Symbols, formulas, equation	Grouping	Arrows, shapes, bullets
Bullets	√, >, ∗, •, letters, numbers, etc.			Listing	Bullets, math symbols, arrows
Font Style	Bold-thin, italic, upper-lower case, underlined, font shadow, coloured, etc.	Frames	Speech balloons, information boxes	Modeling	Drawing, words, sentences
Tables	Single variable, bivariate, etc.			Explaining	Words, sentences, heading, sub-heading, written symbol, drawing, frames, math symbols
Charts	Bar, line, pie, etc.			Exemplifying	Drawing, frame, words, written symbol
Diagrams	Venn diagram, flow, organization chart, etc.				

The visual and written elements in the sketchnotes and their purpose of use were analysed using the checklist prepared for the research. Visual elements include the visuals such as drawings, arrows, shapes, marks, font styles, tables, charts, or diagrams used to explain the topic. Written elements, on the other hand, comprises words, sentences, headings, sub-headings, frames, or written symbols included for explanation. The reasons for using of these elements may vary. For example, arrows could be used to signal a process or to show relationships. Similarly, in order to emphasize a concept, an exclamation mark could be added or the word could be underlined or coloured. Figure 2 illustrates a sketchnote prepared by one of the participant pre-service teachers. The analysis of the sketchnotes could be explained through the following example.

Figure 2. A sketchnote prepared by a participant learner

The sketchnote shown in Figure 2 was prepared to explain the concepts of temperature and heat. The main concepts (Heat and Temperature) are written in capital coloured letters and framed at the top of the sketchnote that includes various visual and written elements. The concepts are also explained under two headings using written elements such as single words or sentences along with visual elements of symbols (for energy) and objects (e.g., calorimeter pot, thermometer). Written and visual elements are associated by arrows while warning information is displayed within a frame (information box) and coloured. In order to show accurate and wrong daily use of the concepts, bullets are used (x, √) for the headings and the two groups are divided by a line while each example is presented by another bullet point (•), short sentences, or written symbols (°C) to add extra explanation. In the sketchnote, modeling [model (snow flake, sun), object (house) and symbol] is done by using different coloured font styles (e.g., underlined, capital cases, or colours).

Findings

The dominant learning styles of the participants are displayed in Table 2. Considering the dominant learning styles of the participants, the results indicate that 34 of them (77.2%) had visual, 7 (16%) had verbal, and 3 (6.8%) of them, scoring equally in the sub-dimensions of the scale, had visual/verbal dominant styles.

Table 2.Dominant learning style of the participants

Learning style	N	%
Visual learners	34	77.2
Verbal learners	7	16
Visual-Verbal learners	3	6.8
Total	44	100

The visual elements used in the sketchnotes of the participant learners based on their dominant learning styles are displayed in Table 3.

Table 3.The distribution of visual elements in sketchnotes based on dominant learning style

Visual elements	Visual learners		Verbal learners		Visual-verbal learners		Total	
	n	%	N	%	n	%	N	%
Drawings	34	100	7	100	3	100	44	100
Shapes	29	85,2	5	71,4	2	66,6	36	81,8
Arrows	29	85,2	3	42,8	2	66,6	34	77,2
Punctuation Marks	24	70,5	4	57,1	2	66,6	30	68,1
Mathematical Symbols	30	88,2	4	57,1	2	66,6	28	63,6
Bullets	34	100	7	100	3	100	44	100
Font Styles	34	100	7	100	3	100	44	100
Tables	25	73,5	-	-	2	66,6	27	61,3
Charts	27	79,4	-	-	2	66,6	29	65,9
Diagrams	27	79,4	4	57,1	2	66,6	33	75

It can be seen that all the participants paid attention to using drawings, bullets, and font styles in their sketchnotes. Tables, on the other hand, were the least frequently used visual elements. The participants with dominant visual learning style were found to include more shapes, arrows, tables, charts, and diagrams in their sketchnotes compared to the participants with verbal dominant and verbal/visual dominant learning styles. Another significant finding is that the participants with verbal dominant learning style did not use tables or charts. The distribution of the written elements in the participants' sketchnotes based on their dominant learning styles are presented in Table 4.

Table 4.The distribution of written elements in sketchnotes based on dominant learning style

Written elements	Visual learners		Verbal learners		Visual-verbal learners		Total	
	n	%	N	%	N	%	N	%
Words	23	67,6	7	100	1	33,3	31	70,4
Sentences	34	100	7	100	3	100	44	100
Headings	34	100	7	100	3	100	44	100
Sub-headings	21	61,7	6	85,7	1	33,3	28	63,6
Frames	20	58,8	6	85,7	2	66,6	28	63,6
Written Symbols	20	58,8	6	85,7	3	100	29	65,9

The results show that all of the participant learners included headings and sentences (short explanations) in their sketchnotes. However, verbal learners added further explanations by using sub-headings while employing single concept (word) use (e.g. Golgi-packet, mitochondria-energy, etc.) for emphasizing or modeling. Similarly, these learners were found to use speech balloons and information boxes more frequently. The visual/verbal learners, on the other hand, all used written symbols in their sketchnotes. Table 5 displays the reasons for using written and visual elements in the sketchnotes.

Table 5.The reasons for using written and visual elements in the sketchnotes

Reasons for Using Elements	Visual learners		Verbal learners		Visual-verbal learners		Total	
	n	%	n	%	n	%	N	%
Organizing	30	88,2	4	14,2	3	100	37	84,1
Establishing Relations	27	79,4	3	42,8	1	33,3	31	70,4
Creating Flows	15	44,1	1	14,2	-	-	16	36,3
Emphasizing	34	100	7	100	3	100	44	100
Grouping	22	64,7	4	14,2	1	33,3	27	61,3

Listing	34	100	5	71,4	3	100	42	95,4
Modelling	20	58,8	2	28,5	2	66,6	24	54,5
Explaining	34	100	7	100	3	100	44	100
Exemplifying	22	64,7	5	71,4	1	33,3	28	63,6

When analysing the participants' reasons for using written and verbal elements, it is found that all of the learners used both elements to explain and to highlight the important points. Also, all of the participants preferred listing in order to explain the content itemized in bullets. The findings also show that words, sentences, and drawings were used most frequently for explanations; font styles and colours for emphasis; while bullets and arrows were mostly preferred for listing. The analyses of the sketchnotes prepared by the visual-verbal learners indicate that all of these learners paid particular attention to organization by either using tables, charts, and diagrams to explain the content or by drawing lines to divide the page into multiple sections. This group was also found to use modeling most frequently by utilizing words and drawings (e.g. for DNA, atom, circuit model, etc.). Creating flows of processes were used most frequently by the visual learners. They explained topics such as substance cycle, seasons, or food chain using circular processes. This group also preferred to explain information by using arrows to match concepts or to relate written and visual elements more frequently than the other two groups while choosing to use words and drawings for exemplification. The differences between the participants' dominant learning styles and the frequency of their using visual elements in their sketchnotes are displayed in Table 6.

Table 6.The differences in the scores received from the visual elements in the sketchnotes based on dominant learning styles

Learning Style	N	Mean Rank	df	x^2	p
Visual learners	34	26,35	2	14,376	,00
Verbal learners	7	8,14			
Visual-Verbal learners	3	12,33			

The visual elements used in the participants' sketchnotes were analysed based on their dominant learning styles. According to the results from Kruskal Wallis H-test independent samples test, there is a significant difference in the use of visual elements based on the participants learning styles ($x^2(2)=14,376$, $p<.05$). The reason for the difference was analysed using Mann Whitney U-Test for independent samples. The results show that there is a significant difference in terms of visual element use between the participants with visual learning style and the ones with verbal style (U=23,00, p<.05). The visual learners are found to use visual elements significantly more frequently than the visual-verbal learners (U=16,00 p<.05). However, there is no significant difference in the use of visual elements between the participants with visual-verbal learning style and verbal learners (U=6,00 p>.05). The differences in the scores of the participants' received from the written elements in the sketchnotes based on their dominant learning styles are presented in Table 7.

Table 7.The differences in the scores received from the written elements in the sketchnotes based on dominant learning styles

Learning Style	n	Mean Rank	df	x^2	p
Visual learners	34	20,50	2	7,482	,02
Verbal learners	7	34,07			
Visual-Verbal learners	3	18,17			

The written elements in the participants' sketchnotes were analysed using Kruskal Wallis H-Test independent samples test. There is a significant difference in the use of written elements based on learning styles ($x^2(2)=20,50$, p<.05). The reason for the difference between the groups were investigated using Mann Whitney U-Test for independent samples. Accordingly, a significant difference was found in terms of written element use between the participants with verbal learning style and the ones with visual style (U=47,00, p<.05). It is revealed that verbal learners use written elements significantly more frequently than visual-verbal learners (U=1,50, p<.05). On the other hand, the visual learners are found to be using written elements at similar levels as the visual-verbal learners (U=47,00, p>.05).

Results and Discussion

Learners use their learning styles actively while accessing, understanding and processing information. While some learners respond better to diagrams, charts and pictures; others learn better with verbal or written explanations. The majority of the participant learners in the study were determined to have visual dominant learning style (77.2 %). A similar result was found in the results of the study conducted by Günes, Bati and Katrancı (2017). When the participant learners' distribution based on their learning styles were analysed, it was found that 65 % of them were, 8 % were verbal, and 27 % of them had balanced distribution. However, considering the common fact that the majority of the classroom instruction is carried out verbally, it can be argued that many learners cannot benefit from the lessons instructed verbally. Those who learn effectively are the ones that can process information both visually and verbally (Felder, 1993). In learning situations where knowledge is transferred both verbally and visually, all learners learn more effectively. Furthermore, Iuera, Neacşu, Safta, and Suditu (2011) claim that there is a significant relationship between learning styles and teaching styles. Accordingly, when teachers use instructional approaches and tools based on their learning styles could lead to difficulties for both learners and teachers with different learning styles. As it is important to have a concordance between the teacher's and the learners' learning styles, teachers need to exhibit instructional practices considering those with different styles while learners are advised to accommodate to activities and tasks based on different styles. In fact, Hayes and Allison (1997) point out that when learners are involved in learning activities that do not match their preferred learning style, they are likely to develop learning competences necessary to cope with a wide range of learning requirements. At this point, sketchnotes could assist learners to develop such skills. Using visual and verbal elements in their sketchnotes, learners can acquire various learning styles and skills through utilizing sketchnotes for learning processes such as providing explanations, planning, or making learning decisions.

Another significant finding of the study is that the learners' dominant learning style is influential in their use of visual and written elements in the sketchnotes. The learners with visual learning styles used more visual elements in the sketchnotes they prepared while verbal learners used written elements more. Explaining learning based on sensory-model, Fleming states that visual learners prefer maps, charts, graphs, diagrams, brochures, flowcharts, highlighters, different fonts and colours, pictures, word pictures, and different spatial arrangements. On the other hand, verbal learners like to explain new ideas to others, discuss topics with other students and their teachers, use a tape recorder, attend lectures and discussion groups, and use stories and jokes. Read/Write learners prefer lists, essays, reports, textbooks, definitions, printed handouts, readings, manuals, Web pages, written explanations, and taking notes (Fleming, 2001). The visual learners in the study were found to use visual elements such as shapes, charts, tables, diagrams frequently while integrating drawings, different font styles and colours were dominant in organizing and designing their pages. Conversely, verbal learners mostly used speech balloons, information boxes, sentences, and words for the definitions and explanations in their sketchnotes. It was also evident that verbal learners used headings and sub-headings to organize their sketchnotes. On the other hand, the participant pre-service teachers with both learning styles used visual and written elements together. The learners in this group used drawings, charts, tables, diagrams in addition to written elements to explain their topic

(Pritchard, 2009). It should also be noted that visual-verbal learners are advantageous in that they can utilize visual elements more frequently than verbal learners do while integrating more written elements than visual learners do. As Enfield, Smith and Grueber (2008) indicate, sketches are visuals used as communication tools like sentences. Sketches prepared using various elements can be used to provide extensive explanations or to represent ideas. The use of multiple elements can also help to communicate the explanations or comparisons of various scientific ideas.

Another significant finding of the study is the reasons for using visual and written elements in the sketchnotes. Analysing the elements in the sketchnotes based on the participants' dominant learning styles, it was found that they used these elements to explain, list, or to highlight concepts. In addition, visual learners mostly explained concepts by forming associations whereas verbal learners preferred exemplifying. Modeling was most frequently used by visual-verbal learners. Similarly, Altieri (2017) maintains that learners use colours, words, symbols, or drawings in their sketchnotes to show meaning and relationships between ideas, and that sketchnotes are effective in sharing and discussing ideas. Bratash et al. (2020) highlight that unusual letters and portraits are important pieces of information that are found interesting and useful by learners as they enable them to summarize, memorize, and/or retain information. Robinson (2018) also highlights that sketchnotes assist learners in organizing ideas and in improving their creativity.

Implications

The present study sheds light on how learners organize information in their minds and how they are able to associate and explain their ideas or concepts. Based on the findings of the study, the following suggestions could be proposed:

1) In the study, visual and written elements in the pre-service teachers' sketchnotes prepared for a science topic were analysed based on their dominant learning styles. Further studies can focus on the sketchnotes prepared for teaching or for evaluation of the taught concepts. Sketchnotes could be used to explore learners' conceptual change or to identify their misconceptions.

2) Sketchnotes can be used to explore cognitive and meta-cognitive strategies used by learners to plan, monitor, and to evaluate their learning processes. Sketchnotes could also be used to improve learners' use of meta-cognitive strategies.

3) In addition to preparing sketchnotes by using papers and pencils, there are software programs that allow learners to create sketchnotes in computer environment. Using such educational software programs, learners can prepare sketchnotes in a short time by integrating numerous visual and written elements and share them online.

4) Introducing sketchnotes to in-service and pre-service teachers could help disseminating and broader use in teaching and learning processes. They enable teachers easily plan and enrich their teaching.

5) Use of sketchnotes in other courses could assist learners. They help learners by providing more entertaining and more fruitful learning experiences suitable to their learning styles.

Notes

Ethical approval for this study was obtained from Science and Engineering Scientific Research and Publications Ethics Committee of Alanya Alaaddin Keykubat University (12.03.2021 / 9705).

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Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi (EFMED)
Cilt 15, Sayı 1, Haziran 2021, sayfa 118-143.ISSN: 1307-6086

Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Vol. 15, Issue 1, June 2021, pp.118-143.ISSN: 1307-6086

Araştırma Makalesi /Research Article

Ortaokul Matematik Öğretmen Adaylarının İspat Kavramlarının Fenomenografik Bir İncelemesi

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Gönderme Tarihi: 18.05.2021 Kabul Tarihi: 11.06.2021

Doi: 10.17522/balikesirnef.939068

Özet – Öğretmen adaylarının matematiksel akıl yürütmeyi öğretme yetenekleri sahip oldukları ispat kavramlarının kalitesine bağlıdır. Bu nitel çalışma, ortaokul matematik öğretmen adaylarının ispat kavramlarına odaklanmaktadır. Bu amaçla, bu çalışma öğretmen adaylarının ispat deneyimlerindeki farklılıkları belirlemek için fenomenografik bir yaklaşım kullanmıştır. Yarı yapılandırılmış görüşmelerin analizi, niteliksel olarak farklı beş kategori ortaya çıkarmıştır. Buna göre, ispat (a) bir problem çözme yoludur, (b) anlamanın bir aracıdır, (c) düşünmeyi ikna edici bir şekilde açıklamaktır, d) mantıksal argümanlar kullanarak varsayımları doğrulamaktır ve (e) matematiğin keşfi için bir araçtır. Bu çalışma, ispat kavramlarıyla ilgili pedagojik bilgiye katkıda bulunmaktadır. Sonuçlar, matematik öğretmeni hazırlık programlarının kalitesini artırmak için kullanılabilir.

Anahtar kelimeler: fenomenografi, ispat kavramı, öğretmen adayı

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Geniş Özet

Giriş

Matematiğin daha iyi öğretilebilmesi için tüm sınıf seviyelerinde ispata dayalı düşünmeye önem verilmesi gerekmektedir (Herbst & Balacheff, 2009; Stylianides & Stylianides, 2009). Öğrenciler, bulundukları sınıf seviyelerine uygun öğretim etkinlikleriyle matematiksel ifadelerin doğruluğunu veya yanlışlığını gösterme potansiyeline sahiptir (Stylianides, 2007). Önceki çalışmalar, hem ilkokul hem de ortaokul öğrencilerinin ispata yönelik etkinliklerde bulunabileceklerini ve matematiksel bir iddianın doğruluğunu nasıl tartışacaklarını anlayabileceklerini göstermektedir (Almeida, 2001; Miyazaki vd., 2017). Bununla birlikte, öğretimlerinde ispat etkinliklerine yer vermeleri ve öğrencileri bu etkinlikler için motive edebilmeleri için, matematik öğretmenlerinin etkili bir ispat anlayışına sahip olmaları gerekir (Knuth, 2002a; Stylianou vd., 2015). Ancak yapılan çalışmalar matematik öğretmenlerinin ve öğretmen adaylarının ispatın doğasını anlamamış olabileceklerini göstermektedir (Bansilal vd., 2017; Tanışlı, 2016). Ayrıca, öğretmen yetiştirme programlarının, öğretmenlerin kapsamlı bir ispat anlayışına sahip olmalarına rehberlik etmesini destekleyecek şekilde düzenlenmesine katkıda bulunabilecek olmasına rağmen, az sayıda araştırma matematik öğretmen adaylarının ispat kavramlarına odaklanmıştır (Lesseig vd., 2019; Sears, 2019). Bu nedenle, matematik öğretmen adaylarının ispat kavramlarının daha iyi anlaşılmasını sağlayabilecek çalışmalara ihtiyaç duyulmaktadır.

İspat kavramlarıyla ilgili çalışmalar, matematiksel bilgiye, yani deneysel, tümevarımlı veya tümdengelimli süreçlere (Makowski, 2020; Martin & Harel, 1989; Morris, 2002; Sears, 2019; Zeybek, 2017) veya içerik bilgisine yani ispatın anlamına odaklanmaktadır (Knuth, 2002a; Lesseig vd., 2019; Varghese, 2009). Bu çalışmada da, ispatla ilgili içerik bilgisi araştırılmıştır.

Bu çalışmada, matematik öğretmen adaylarının ispat kavramlarını belirlemek için nitel bir yaklaşım türü olan, fenomenografi kullanılmıştır. Bu bağlamda, çalışmanın araştırma problemi şu şekilde ifade edilmiştir: Ortaokul matematik öğretmen adaylarının ispat kavramlarının doğası ve kapsamı nedir?

Bu çalışma, öğretmen eğitimcilerinin öğretmen adaylarının ispatla ilgili içerik bilgilerini daha iyi anlamalarını sağlayabilir. Elde edilecek sonuçlar, öğretmen adaylarının matematik öğretim pratiklerini olumlu etkileyebilecek bir ispat anlayışına sahip olarak mezun olmalarına katkıda bulunabilir. Ayrıca, son yıllarda yapılan bir çalışma öğretmen adaylarının ispat kavramlarının kültürel olarak farklılaşabileceğini göstermiştir (Lesseig vd., 2019). Farklı ülkelerde çalışmalar yapılması öğretmen adaylarının ispat kavramlarının doğasının daha iyi anlaşılmasını sağlayabilir. Bu nedenle, bu çalışmanın sonuçları öğretmen eğitiminde kültürel farklılıkların anlaşılmasına da katkıda bulunabilir.

Yöntem

Eğitim araştırmalarında fenomenografi, öğrencilerin belirli bir fenomeni (bu çalışmada ispat kavramı) deneyimledikleri, anladıkları, algıladıkları veya kavramsallaştırdıkları niteliksel olarak farklı yolları ve bu fenomeni anlama yollarındaki çeşitliliği tanımlamayı amaçlamaktadır (Marton, 1981). Bu niteliksel olarak farklı anlama yollarının "referans" (veya atfedilen) ve "yapısal" olmak üzere iki bileşeni vardır (Marton & Pong, 2005; Pang, 2003). Referans ve yapısal bileşenlerin bir araya getirilmesi "sonuç alanı" olarak adlandırılır. Sonuç alanı, bir fenomenin çalışılan grup tarafından nasıl anlaşıldığının farklı yollarını ve bu yollar arasındaki ilişkileri temsil eden bir çerçevedir. Bu çerçeve birbiri ile nasıl ilişkili olduğu açıklanan kategorilerden oluşur (Akerlind, 2005).

Bu çalışmadaki katılımcılar bir devlet üniversitesinin matematik eğitimi anabilim dalında öğrenim gören dördüncü sınıf öğretmen adaylarıdır. Öğretmen adaylarının ispatı öğrendikleri ve kullandıkları matematik derslerinin çeşitliliği, ispat ile ilgili daha fazla ve farklı deneyimler yaşamalarını sağlayabilir. Bu farklı deneyimler öğretmen adaylarının ispat anlayışlarındaki çeşitliliğin daha iyi anlaşılması için önemlidir. Bu nedenle, ispatla karşılaşabilecekleri tüm matematik derslerini almış ve genel not ortalamalarına göre farklı başarı seviyelerinde olan öğretmen adaylarının ispat kavramları incelenmiştir. Veriler yarı yapılandırılmış bireysel görüşme yoluyla toplanmış ve analiz edilmiştir.

Bulgular

Veri analizinde araştırmacılar kendi ispat kavramlarının ya da literatürde önceden belirlenmiş ispat kategorilerinin veride olup olmadığına değil, tamamen öğretmen adaylarının yaklaşımlarına ve verdikleri yanıtlardaki çeşitliliğe odaklanmaya çalışmıştır. Fenomenografik analiz, ortaokul matematik öğretmen adaylarının ispat kavramlarının niteliksel olarak beş farklı kategoriyle ifade edilebileceğini göstermiştir. Ayrıca, bu kategorilerdeki farklılıklar "bilişsel süreçler", "kapsam", "ana odak" ve "duygular" olmak üzere dört boyutta tanımlanabilmiştir. Bu boyutlar ve kategoriler öğretmen adaylarının perspektifinden ortaya çıkmış ancak literatürde yer alan ispatla ilgili bazı anlamları da içermektedir. Buna göre, kategoriler ve ifade ettikleri anlamlar arasındaki ilişkiler basitten karmaşığa şu şekildedir: İspat bir problem çözme yoludur (Kategori A), ispat anlamak için bir araçtır (Kategori B), ispat düşüncenin ikna edici bir şekilde açıklanmasıdır (Kategori C), ispat mantıksal argümanlarla varsayımların doğrulanmasıdır (Kategori D) ve ispat matematiğin keşfi için bir araçtır (Kategori E).

İspat problem çözerken gerekli olan bilişsel süreçlerden biridir. Ancak ispatın sadece bir problem çözme yolu olarak görülmesi (Kategori A) farklı bağlamlardaki ispat farkındalıklarını sınırlandırabilir. İspatın bir çözüm yolu olarak görüldüğü bu kategori bu nedenle, ispat anlamak için bir araçtır kategorisinden (Kategori B) daha az anlam içermektedir. Kategori B' de sadece çözüm yolu değil bu çözüm yolunun kavramsal olarak bir konunun anlaşılmasındaki rolü de önemlidir. Bir düşüncenin veya matematikte kavramsal olarak anlaşılanın başkalarına da yazılı veya sözel olarak ikna edici bir şekilde açıklanmasının (Kategori C) bir ispat olduğunu düşünmek de Kategori A ve Kategori B' den daha fazla anlam içermektedir. Benzer şekilde, varsayımların mantıksal argümanlarla doğrulanmasını (Kategori D) bir ispat olarak görmek, önceki kategorilerden daha fazla anlam içerir çünkü bu kategoride öğretmen adayları ispatın matematiksel yapısının farkındadırlar. İspatı matematiğin keşfi için bir araç olarak görmek (Kategori E) ise önceki tüm kategorileri kapsamaktadır. Çünkü bu kategoride ispat sadece var olan matematiksel bilgiyle (problem çözüm yolu, matematiğin anlaşılması, açıklanması veya varsayımların doğrulanması) sınırlı değildir. Var olan bu bilgilere ek olarak yeni matematiksel bilgilerin keşfedilmesi olarak da görülmektedir. Bu nedenle Kategori E öğretmen adaylarındaki en karmaşık anlamı taşıyan kategori olarak nitelendirilmiştir.

Kategorilerin yapısal bileşeninin matematiksel bilgi ve ispat literatürüne paralel olarak tanımlanabileceği görülmüştür. Örneğin, Sfard (2000) matematiksel bilgiyi bir söylem olarak tanımlamakta ve bireysel olarak sonuçları bulma veya bu sonuçların diğerlerine iletilmesi olarak sınıflandırmaktadır. Buna göre, bu çalışmada elde edilen Kategori A ve B ispatın bireysel olarak sonuçların bulunması ve anlaşılması, Kategori C, D ve E ise sonuçların diğerlerine iletilmesi olarak sınıflandırılabilir. Ayrıca, Zaslavsky ve diğerleri (2012) bir açıklamanın matematiksel yapıdan bağımsız kişisel olarak ispat olarak kabul edilebileceğini belirtmektedir. Benzer şekilde, Kategori A, B ve C ispatın kişisel, Kategori D ve E ise ispatın matematiksel kabulü olarak sınıflandırılabilir.

Tartışma ve Sonuç

Bu çalışmada elde edilen kategoriler toplanan veriden ortaya çıkmıştır, ancak literatürde daha önce görülen bazı ispat anlamlandırmalarını da içermektedir. Önceki çalışmalardan farklı olarak kategoriler arasında görülen hiyerarşik ilişki ortaokul matematik öğretmen adaylarının ispat kavramsallaştırmalarındaki artan farkındalıklarla ilgili bir çerçeve sunmaktadır. Bu çerçevenin karşılaştırılabileceği başka bir çalışma bulunmamaktadır. Ancak, elde edilen kategorilerin içerdiği her bir anlam, önceki çalışmalarda belirtilen ispat anlamlandırmalarıyla karşılaştırılabilir. Örneğin, ispatın problem çözme yolu olduğu Uygan ve diğerlerinin (2014) çalışmasının, ispatın matematiği anlamadaki rolü ise Baştürk (2010) tarafından yapılan çalışmanın sonuçları ile benzerlik göstermektedir. Kategoriler kültürel açıdan da karşılaştırılabilir. Örneğin, bu çalışmadaki ispatın anlamak için bir araç olması ve ispatın matematiksel argümanlar kullanarak varsayımların doğruluğunun gösterilmesiyle ilgili anlamlar Lesseig ve diğerlerinin (2019) çalışmasındaki Koreli ve Amerikalı öğretmen adaylarının ispat tanımlarında da görülmüştür. İspatın matematiğin keşfi için bir araç olmasına ise sadece Koreli öğretmen adaylarının yanıtlarında rastlanmıştır.

Sonuç olarak, bu çalışmada bulunan kategoriler, öğretmen eğitimcileri tarafından öğretmen adaylarının ispat anlayışlarını anlamak ve değerlendirmek için bir model olarak kullanılabilir. Ayrıca, bu çerçeve öğretmen adaylarının matematik öğrenimlerinde ve öğretimlerinde ispatın önemli yönlerini göz önünde bulundurmalarına yardımcı olabilir. Ancak, daha detaylı ve genelleştirilebilir bir çerçeve elde etmek için başka çalışmalara da ihtiyaç vardır.

A Phenomenographic Investigation of Middle School Pre-service Mathematics Teachers' Conceptions of Proof

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Received :18.05.2021 Accepted : 11.06.2021

Doi: 10.17522/balikesirnef.939068

Abstract – The capability of pre-service teachers to teach mathematical reasoning depends on the quality of their proof conceptions. This qualitative study focuses on proof conceptions of middle school pre-service mathematics teachers. To this end, this study employed a phenomenographic approach to identify the variation in pre-service teachers' experience of proof. Analysis of semi-structured interviews revealed five qualitatively different categories: proof is (a) a way of problem-solving, (b) a means for understanding, (c) explaining thinking in a convincing way, d) validating conjectures using logical arguments, and (e) a means for discovery of mathematics. This study contributes to the pedagogical knowledge about a framework of proof conceptions. Results may be used to promote the quality of the mathematics teacher preparation programs.

Key words: phenomenography, pre-service teachers, proof conception

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Introduction

Mathematics educators argue that proving activities should become a part of mathematics teaching practices at all grade levels (Hanna, 2000; Herbst & Balacheff, 2009; Stylianides & Stylianides, 2009). The reason for this argument is that the logic of proof is necessary to develop students' mathematical reasoning. Students of all grades have the potential to understand the truth or falsehood of mathematical statements through some grade-level appropriate teaching activities (Stylianides, 2007). For example, previous research shows that students at elementary grades can engage in proof-oriented activities and understand how to argue for the truth of a mathematical claim (Almeida, 2001; Shifter, 2009). Similarly, previous studies report that middle-grade students can construct justifications for their solutions and convince their peers by explaining their reasoning (Aylar & Şahiner, 2014;

Miyazaki et al., 2017; Mueller, 2009). These findings support the view that students should encounter the activities involving reasoning and proving in early grades.

The manifestation of proof in school mathematics largely depends on the nature of teachers' views and understandings about proof (Knuth, 2002a; Stylianou et al., 2015). However, providing opportunities for their students to engage in proof-oriented activities can be challenging for mathematics teachers (Stylianides et al., 2013). Previous research shows that mathematics teachers may not have a proper understanding of proof (Tanışlı, 2016). Similarly, research demonstrates that pre-service teachers have difficulties in understanding and constructing proofs (Bansilal et al., 2017; Baştürk, 2010; Zeybek, 2015). These results suggest that teacher preparation programs should pay a careful attention to the proof understandings of pre-service mathematics teachers. The research on proof conceptions may lead to refining teacher preparation programs in a way to better support the development of teachers' understanding of proof. However, the studies focusing on pre-service mathematics teachers' conceptions of proof are not so abundant (Lesseig et al., 2019; Sears, 2019). Therefore, there is still much work to do to further clarify pre-service mathematics teachers' proof conceptions.

Studies regarding proof conceptions usually focus on mathematical knowledge, i.e., empirical, inductive, or deductive processes (e.g., Makowski, 2020; Martin & Harel, 1989; Morris, 2002; Sears, 2019; Zeybek, 2017), or subject matter content knowledge, i.e., the meaning of proof (e.g., Knuth, 2002a; Lesseig et al., 2019; Varghese, 2009). This present study focuses on the subject matter content knowledge.

Literature Review

Understanding Mathematical Proof

Proof plays a central role in mathematical thinking and it can be defined primarily as an argumentation (i.e., logical process) that justifies the truth of mathematical claims. Besides, researchers indicate that proof is not only whether the mathematical claims are true, but also is about why these claims are true (Hanna, 1995; Hersh, 1993). Rav (1999) states that proofs involve the know-how of mathematics and they are the bearers of mathematical knowledge. According to him, proof should be seen as new methods, strategies, concepts to solve problems, the foundation of interconnections between theories, and the systematization of the mathematical results. Similar to Rav (1999), de Villiers (1999) also emphasizes proof as a systematization (i.e., integrating various mathematical results to establish a deductive system of axioms, definitions, and theorems.). Besides, de Villiers (1999) argues that proof serves as a means of the creation of new mathematical results through a deductive process. He states that proof should also be regarded as a communication tool among members in a community, for example, between mathematicians or between teachers and students. He also states that proof should be understood as an intellectual challenge. Mathematicians may view proving as a challenging activity such as solving puzzles or other creative attempts. In addition, researchers emphasize that proof serves as a means of understanding mathematics (Hersh, 1993; Knuth 2002a; Weber, 2010).

Prior Research on Meanings of Proof

According to de Villiers (1990), teachers should understand that the above discussed aspects of proof are crucial at all grade levels. Otherwise, teachers may think that it is not reasonable to introduce proof in early grade mathematics. Knuth (2002a) finds similar meanings in teachers' explanations regarding the nature and the role of proof. According to him, teachers view proof as logical thinking, displaying thinking, communicating mathematics, explaining mathematical reasons, and creating mathematics knowledge. Similarly, in another research, Knuth (2002b) reveals that mathematics teachers view proof as a means of verification, explanation, communication, knowledge creation, and systematization of results. However, studies show that pre-service teachers may not be aware of some of these meanings of proof. For example, in the work of Mingus and Grassl (1999), the majority of pre-service mathematics teachers state that proof is an explanation for mathematical concepts used in arguments. Varghese (2009) finds that a minority of the pre-service teachers consider the explanatory and discovery meanings of proof. She also finds that secondary school pre-service teachers mostly define proof as verification of a mathematical statement. Pre-service teachers' awareness of proof as a verification tool is the most reported finding in the studies (e.g., Baştürk, 2010; Likando & Ngoepe, 2014; Uygan et al., 2014). In another study, Dickerson and Doerr (2014) state that how high school mathematics teachers think about the role of proof varies widely. In their study, teachers view proof as a tool to build mathematical understanding, develop logical thinking and metacognitive skills, and reify mathematical knowledge.

In addition, Lesseig et al. (2019) demonstrate that a minority of secondary school pre-service teachers are aware of the discovery and communication meanings of proof. Their study also shows that proof conceptions vary across countries. For example, in their research, Korean pre-service teachers mostly mention the verification and understanding functions of proof but do not mention the systematization and communication functions of proof. Unlike the Korean pre-service teachers, American and Australian pre-service teachers consider the systematization function of proof. Also, only American pre-service teachers mention the communication role of proof.

The present study

Given that the pre-service teachers' capability to teach reasoning depends on the quality of their proof conceptions, in this study, we aim to understand the subject matter proof conceptions of middle school pre-service mathematics teachers. Pre-service mathematics teachers' understanding of proof concept mostly depends on their proof experiences in the high school or university mathematics courses. The variety of these experiences can reveal different conceptualizations of proof. A particular focus on these conceptualizations may lead to allow a deeper understanding of the proof conceptions of pre-service teachers. This focus may provide a framework for teacher educators to facilitate the pre-service teachers' education by changing less desirable proof conceptions to the more desirable ones. As pre-service teachers' proof conceptions may vary from culture to culture (Wilder, 1981) addressing proof conceptions of pre-service teachers in different countries might provide some additional information to reveal a more definite picture of proof conceptions. Therefore, the results of this study may also contribute to the understanding of cultural differences in teacher education. As will be described later in the paper, in this study, the approach we chose to determine the proof concepts of pre-service mathematics teachers is phenomenography. In this context, the present study investigates the following research question: What are the nature and range of pre-service mathematics teachers' conceptions of proof?

Methods

Research Design

In educational research, phenomenography aims to describe the qualitatively different ways that students experience, understand, perceive or conceptualize a particular phenomenon (conception of proof in this study) and the variation in the way of understanding this phenomenon (Marton, 1981). Conceptions, ways of experiencing or ways of understanding are the examples of the terms used to describe the knowledge that phenomenography investigates (Marton & Pong, 2005). Phenomenography assumes that the way of understanding or conceptualizing something is an internal relationship between the experiencer and the experienced phenomenon. The experiencers cannot be aware of all the characteristics of a phenomenon at the same time. Also, individuals may experience different characteristics of a phenomenon. Even if they experience some similar characteristics, they may perceive them in different ways (Marton & Pang, 2008; Pang, 2003; Yates et al., 2012). Therefore, there are qualitatively different ways of understanding a phenomenon. On the other hand, these different ways are not endless but are limited in number (Marton & Booth, 1997; Pang, 2003; Cibangu & Hepworth, 2016). These qualitatively different ways of understanding can be described regarding two aspects: the referential aspect (or attributed component) and the structural aspect (Marton & Pong, 2005; Pang, 2003).

In line with the research question of this study, the referential aspect deals with what proof understandings the pre-service mathematics teachers have. The referential aspect aims to produce description categories to represent such conceptions. Thus, using phenomenography in this research, we aimed to reveal a set of description categories describing the pre-service mathematics teachers' ways of understanding proof.

The structural aspect, on the other hand, deals with the relationship among the description categories. Despite some distinctions among the categories, they are oriented on the same phenomenon. Therefore, it is reasonable to expect the categories to be logically related to each other (Limberg, 2008; Marton, 1981). This relationship can be described hierarchically from least to most complex or from general to specific (Marton, 2000). The nature of this relationship (i.e., how these qualitatively different categories are related to each other and how they together form a whole) is referred to as the structural aspect. The structural aspect can also be considered as the researcher's interpretation of the variation among the description categories (Marton & Pong, 2005; Pang, 2003).

The combination of the referential and the structural aspects forms the outcome space. The outcome space can also be regarded as a framework that represents the different ways of how a phenomenon is understood by the studied group, and the relationships among these ways (Akerlind, 2005).

Finally, it is important to state that this present study does not intend to reveal if pre-service mathematics teachers possess some specific or pre-determined proof conceptions.

Instead, the study intends to provide an outcome space that illustrates the range of proof conceptions present within the group of pre-service mathematics teachers.

Participants

The participants of this study were 16 undergraduate students (11 females and 5 males) majoring in mathematics education (middle school mathematics, grades 5-8) at a state university. The participants were selected using the purposive sampling method to maximize the variation in their proof understandings. The criteria used to this end were the following: First, the participants should be among the fourth-grade level students who took all the mathematics courses in their curriculum (e.g., Abstract Mathematics, Analysis I-II, Algebra, Linear Algebra I-II). The variety of mathematics lessons pre-service teachers took may allow them opportunities to experience different aspects of the concept of proof. Second, the study group should be composed of students from a wide range of achievement levels. Since students' achievement levels may be related to their proof schemes, cumulative grade point average (CGPA) scores were taken into account to obtain the required variation in the sample. CGPA scores of the students sampled in this concern varied from 1.94 to 3.51 (out of 4). Third, the sample should include students of different gender because gender may also be related with the conceptualization of proof.

Overall, with these criteria, we aimed to assure that the participants possessed a wide range of experiences a phenomenographic study requires (Marton & Booth, 1997). The pre-service teachers voluntarily participated in the study. We informed the participants about what we aim, and what we expect for the output in the study. We also informed the participants that their names and interview records would be kept confidential.

Data Collection

The suggestions of Akerlind (2005) on preparing interview questions and conducting interviews guided our data collection process. We used the semi-structured interview procedure that is usually referred as a useful data collection technique in a phenomenographic study. We tried to prepare interview questions that would reveal the variation in proof understandings of participants. To this end, we conducted pilot interviews with a different group of pre-service teachers to test the interview questions we prepared. The final set of interview questions after the revision process, could be specified as follows: a) what proof and proving mean to pre-service teachers, b) how pre-service teachers define proof, c) what features they think an argument should include to be a proof, and d) how they evaluate their own or others' proofs. Also, during the interview process, participants were sometimes asked to further explain "what they mean" and "why they think that way" to elicit their intentional attitude towards the proof concept. Each interview lasted around 30 minutes. Interviews were recorded and then transcribed verbatim for data analysis.

Data Analysis

Although some steps have been suggested to follow, there is no agreed method for conducting phenomenographic data analysis (Han & Ellis, 2019). In this study, we followed similar data analysis steps as in the work of Akerlind's (2005) and Gonzales's (2010). First, we independently read all interviews several times to understand the details and gain a sense of the data. We highlighted the sections related to the question being investigated based on their commonalities and differences. In this process, to minimize subjectivity, we attempted to discern meanings found in the participants' responses and did not attempt to measure predetermined categories in the literature. Also, we refrained imposing what we believe to be the concept of proof.

Second, after the investigations of all meanings between and within the transcripts' sections, we came together to compare and discuss the initial list of meaning statements we had specified. In this step, first, we agreed on the meaning statements. Then we tried to reduce these initial sets of meaning statements by looking for dimensions of variation as experienced by the participants. We grouped the meaning statements which we thought representing a similar understanding of proof. As a result, we obtained initial "categories of description" that represented the variation in pre-service teachers' understanding of proof.

Third, we re-read the transcripts to better distinguish each category from the others and decided on the final version of the description categories. We independently re-examined the accuracy of the categories several times by focusing on critical aspects of the proof understandings of the pre-service teachers. This process enabled us to define the variation among the categories of the proof itself as experienced by the pre-service teachers. After reaching a consensus on the categories of description, we grouped the transcripts by the category they best represent.

Next, we re-examined the dimensions of variation in the categories together with the participants' responses to interpret the structural aspect. We investigated empirical and logical inclusive relationships to reveal the hierarchical relationships between the categories. Concerning the empirical inclusiveness, we saw that pre-service teachers' responses in one category include some meanings that exist in preceding categories. For example, the meanings such as "correctness" and "explaining" in Category C (i.e., proof is explaining thinking in a convincing way) exist in the responses related to Category D (i.e., proof is validating conjectures using logical arguments). Therefore, Category D includes Category C. We explained how we defined the logical inclusiveness among the categories in the Findings section below.

Findings

In this section, we primarily present the categories of description that emerged in the data analysis process. Then, we explain the outcome space that describes the relationships (structural and inclusive) between the categories with their referential aspect.

This study identified five categories of description of proof: a) proof is a way of problem solving, b) proof is a means for understanding, c) proof is explaining thinking in a convincing way, d) proof is validating conjectures using logical arguments, and e) proof is a means for discovery of mathematics. The dimensions of variation and the categories of description of proof are seen in Table 1.

Table 1 Dimensions of Variation and Categories of Description of Conceptions of Proof

	Category A	**Category B**	**Category C**	**Category D**	**Category E**
Key aspects	proof is a way of problem solving	proof is a means for understanding	proof is explaining thinking in a convincing way	proof is validating conjectures using logical arguments	proof is a means for discovery of mathematics
Cognitive process	problem solving, using strategies	deep thinking, not learning by heart, reasoning	transferring, communicating, demonstrating, explaining, accepting	articulating reasons, validating, arguing step by step	improving, discovery, expanding
Main Focus	finding a result	conceptual understanding	explaining thinking, arguments or solutions	extended how to validate arguments mathematically	further extended to construct new mathematical results
Scope	correctness of a solution	grasping the meaning	certainty, reality, convincing arguments	existing conjectures, already known knowledge	new conjectures, discovering new knowledge
Feelings	not clearly seen	positive disposition	feeling of no-doubt, making sure	not clearly seen	appreciation, admire mathematicians work

The dimensions of variation are the main focus, scope, cognitive process, and feelings. After explaining each category of description with quotes from transcripts, we demonstrated the outcome space (referential and structural relationships) and inclusive relationships among the categories of description in Table 2.

Description of Categories

To indicate that the selected quotes are from different transcripts a number and gender of participants were provided at the end of the quotes (e.g., PST1, gender).

Category A: Proof is a way of problem solving

In this category, the proof is seen as being synonymous with a way of problem solving. The responses in this category do not go further than considering proof as a way of solution. In this category, pre-service teachers emphasize the solution or right answer to a problem. The following quote illustrates this understanding.

> I think it [proof] is to be the solution to a problem, and, well, if the term "unfalsifiable" is correct, proof can be a way of unfalsifiable solution. The definition of proof is the best of the ways that are used to solve a problem we encountered. [PST12, female]

Some pre-service teachers in this category expressed the way of problem-solving. In the following quote, one pre-service teacher talks about modeling the problem-solving process and describes the similarity between proving and solving a problem. However, her expressions are limited to follow some steps.

> …when being encountered a problem, first, [we're looking at] what is given in the problem,...it [proof] is also, similar to the steps of problem-solving. For the next, what do I know, what is the thing related to what I know? Following [step], what was in the second step of problem-solving? We can use a model, for example. Similarly, we also need modeling while making proof. [PST3, female]

Certainly proving is one of the important cognitive processes for problem solving, but seeing proof as the best way to solve a problem limits the awareness of proof in other contexts. This understanding may cause future teachers to give importance only to problem-solving practices and therefore not to include other proving practices in their teaching. This category is different from Category B because there is no evidence that proof is associated with reasoning in other contexts in mathematics. Therefore, this category is the least complex category we found in the analysis of data.

Category B: Proof is a means for understanding

In category B, pre-service teachers viewed proof as a means for grasping the meaning or going deep into a subject. Pre-service teachers presenting this understanding think that proof is important for conceptual understanding. According to them, subjects cannot be learned without proof but learned by heart. For example:

> What do I mean by proof? If we interpret [proof] in the context of mathematics, I understand something such as grasping, making sense of a subject, going deeper...For example, while teaching the order of fractions, it is written generally directly as "this is greater than that"... [In class] I used a model to explain why one is bigger and why another is smaller. Well, the proof came into play here. We used models to see which one is closer to 1. How closer to 1? How many pieces do I have to add to both of them to reach 1? [I asked]. Is the piece we add to this bigger or is the piece we add to the other bigger? [I asked]. In this way, [students are] making sense of them. Well, here I put the proof into play. [PST8, male]

> If we want to go deeper into a subject [in mathematics], [in other words], if we want to understand it conceptually, for me, proof is necessary … We should understand its logic; there should not be learning by heart. [PST11, male]

In addition, some pre-service teachers possessing the view in this category have a positive disposition towards the proving process due to its role to better understand and teach mathematics. The following quote is an example of these feelings.

> [With the help of proof] When I will explain a subject [in mathematical content] to the students I can easily make them assimilate it, because I have assimilated it. I can get them to love mathematics more easily. Thus, it will attract more attention from the student. [PST14, male]

Category B is different from Category A. In Category A, the main focus is on finding a solution to a problem, whereas in Category B the main focus is on conceptual understanding. Category B reflects a more complex perception of what proof is in mathematics. Therefore, Category B includes Category A. According to pre-service teachers, proof is a valuable means for learning and teaching mathematics. However, although they mention the role of proof in understanding, the answer of how this understanding is possible is seen more clearly in Category C. In addition, there is no evidence about the details of the cognitive processes in proving as seen in Category D.

Category C: Proof is explaining thinking in a convincing way

The conception in this category represents a shift from understanding an idea to explaining thinking. In Category C, the scope of the pre-service teachers' proof understandings is explaining thinking written or verbally. As seen in the following quotes, according to pre-service teachers, it is important to be convinced or to convince others that a thinking or an idea is correct, and proof is a means that enables a thinking to be understood by others.

> For example, we say that prime numbers are infinite. .. I should think about how this happened. If it's proof in my mind so that I can both explain and convince the others. [PST10, female]

> In my opinion, proof means...to be able to explain thinking to someone clearly and to show them its correctness. [PST14, male]

> For example, when a friend of mine does a proof in class, sometimes, I am getting stuck on something in their explanation. When I get stuck with something like this, this proof is not accepted for me. I do not know if their way of proof is right, but it is not accepted for me when I get stuck at a point when I do not understand. It is important to be descriptive and explanatory... As I said, it is also very important that you can convey and write what you say. This is necessary to have it admitted to being true, in other words, to show that it cannot be falsified and that whoever does will get the same thing. [PST12, female]

In this category, it is also seen that there are feelings that encourage pre- service teachers to prove such as, not doubting and being sure.

> I make sure that something [an idea] is correct, so I feel comfortable. I do a proof to be sure. The proof is done to show how it [the idea] exists. [PST7, female]

Category C differs from Category B in that it focuses not only on grasping the mean of an idea but also on convincingly explaining its reality or rationality. Similarly, Category C different from Category A. In category A, the scope is only a solution of a problem, whereas, in Category C, the scope is an understandable explanation of a solution. Therefore, Category C reflects a more complex understanding of what proof is.

Category D: Proof is validating conjectures using logical arguments

In Category D, proof is described as a means for validation of given conjectures in mathematics. As seen in the following quotes, pre-service teachers are more aware of the processes of mathematical proof.

> When you say proof, the first thing that comes to my mind is to prove something, to show its correctness. Well, it means to show that a conjecture is true by using particular things mathematically, [for example], by using particular axioms. [PST7, female]

> When we go from the least to the most complex feature, we are explaining lots of features and finally, after combining and justifying all of these features, we are getting that complex structure [proof]. [PST5, female]

In the following quotes, pre-service teachers explain logical arguments in the justification process by using the expressions such as “sequence,” “path,” “cause-effect,” “pre-end relationship,” or “steps.”

> When I look at the proofs, they all have a sequence. I realized that one part of "proof" comes before

another according to a logical sequence... If one comes after, it will not support the other. So, one must come before the other. [PST15, female]

The proof is a conclusion that being reached after following a particular path by establishing a pre-end relationship or a cause-effect relationship. [PST1, male]

[In the proof] I must have given a justification for each step. [PST14, male]

I examine the steps. I examine the meanings of statements...one statement must be the reason for the following statement. I look at these steps. The proof is used to see how these (statements) are connected and related to each other. [PST7, female]

In this category, arguing step by step, justifying, and articulating reasons are the new cognitive processes we found in pre-service teachers' responses. These processes describe how pre-service teachers use proof to validate conjectures. In both Category C and Category D, pre-service teachers focus on demonstrating the truth of an argument. However, in Category D, pre-service teachers ascribed a more specific meaning to proof. The content of this category is more aligned with the formal definition of "proof" in mathematics compared to previous categories. Therefore, Category D is qualitatively different from the other categories.

Category E: Proof is a means for discovery of mathematics

What makes this last category qualitatively different from the prior categories is the understanding of proof as a means for the discovery or invention of new results or knowledge in mathematics. In this category, rather than proof being a means for validating existing conjectures, the new conjectures themselves are discovered or invented by proof. The following quotes illustrate this understanding.

For example, the proof was required to reveal number theorems…Proof was required to find the existence of natural numbers, the existence of integers, the existence of all of them… So nothing had certainty. I think all emerge from particular proofs and finding out the truth of particular theorems. [PST4, female]

Because through the use of proof, some concepts in nature also were discovered like Fibonacci. [PST5, female]

As seen in the following quote, some pre-service teachers see the discovery function of proof as expanding the boundaries of mathematics.

There is different mathematics used by someone [a mathematician] in terms of further development of mathematics we use, and the proof is required to expand the boundaries of this mathematics. [PST1, male]

In addition, admiration or appreciation is the feeling that we found in the responses of pre-service mathematics teachers who present this view.

> The proof is the stages of the emergence of something geometric or anything mathematically... I admire people who can prove, because... I could never think of that. [PST2, female]

Category E is the most complex category we found as the proof concept of pre-service mathematics teachers.

In Table 2, the outcome space that describes the relationships between the categories with their referential aspect is presented. As seen in Table 2, we organized the categories from least to the most complex way of understanding proof according to the depth of meaning we explained above. The outcome space we presented is hierarchically inclusive. In Table 2, we presented this outcome space with referential and structural aspects of each category together.

Table 2 Referential and Structural Aspects of Categories of Description, and Hierarchical Relationships

	Structural (discourse)		**Structural** (acceptance)	
Referential	Oneself	Others	Personal	Mathematical
Proof is a way of problem solving	A		A	
As in (A) and a means for understanding	B		B	
As in (B) and explaining thinking in a convincing way		C	C	
As in (C) and validating conjectures using logical arguments		D		D
As in (D) and a means for discovery of mathematics		E		E

As stated above, Category E reflects the more inclusive and complex understanding of proof in mathematics. It includes the elements of previous categories. In this category, "proof" is not only seen as a solution for problems, a means for understanding or verification of thinking and already known knowledge but it also is considered as a means of discovery of new knowledge in mathematics. Similarly, Category D includes not only some elements of previous categories such as finding solutions, understanding mathematics, and explaining thinking, but it also includes an awareness of how to validate conjectures mathematically. On the other hand, Category A represents the least complex understanding of proof, as it shows no awareness of conceptual understanding and explaining thinking or validating conjectures at all. Proof awareness in Category A is only limited to the solution of a problem.

According to Sfard (2000), mathematical knowledge is a discourse practice with oneself (trying to find or understand results) and with others (trying to communicate results to someone else). Similarly, we considered Categories A and B as the "oneself" component because pre-service mathematics teachers' conceptualizations are mostly related to their own proving and understanding. We considered Categories C, D, and E as the "others" component because the conceptualizations in these categories include meanings of communicating a proof with others. Besides, Zaslavsky et al. (2012) stated that the decisions given in accepting something as proof may not always be mathematical but may also be personal. In Categories A, B, and C, there is no evidence that the proof understandings of pre-service teachers should be mathematical. Therefore, in the acceptance aspect, Categories A, B and C are identified as the "personal" component. In category A, pre-service teachers may think that their solution to a problem is proof although it is not proof. In Category B, the reasoning that helps them to understand mathematics better may not be a mathematical proof. Similarly, in Category C, it seems that the proof understanding is personal because there is no strong evidence that the responses related to "explaining thinking in a convincing way" are consist of the cognitive processes of mathematical proof. On the other hand, in Categories D and E, the cognitive processes better reflect the nature of mathematicians' work. Therefore, we considered Categories D and E as the mathematical component.

Discussion and Conclusion

The phenomenographic analysis of the pre-service teachers' responses regarding the proof conception revealed five qualitatively different categories. These categories emerged from the data but also reflected some of the meanings presented in the introduction. The hierarchical relationship between these categories from least to most complex is; proof is a way of problem solving, proof is a means for understanding, proof is explaining thinking in a convincing way, proof is validating conjectures using logical arguments, and proof is a means for discovery of mathematics. Four dimensions of variation were emerged (cognitive processes, scope, main focus, and feelings) in understanding these proof conceptions. Unlike previous studies, this study reveals expanding awareness of the proof conception that provides a deeper understanding of the proof conceptions of pre-service middle school mathematics teachers. The framework we obtained may be helpful to understand how teachers need to know proof they teach (Ball et al., 2008). Below, we discussed the categories found in this study with a selection of the available literature.

Previous research indicates that pre-service teachers may view proof as a problem-solving process (Uygan et al., 2014). Similarly, in this study, we found a category (Category A) in which pre-service teachers equate proof with a way of problem solving. In recent research, Son and Lee (2021) show that pre-service teachers' problem-solving views do not go further than a means to a solution. In this respect, combined with the literature, pre-service teachers who focus on answer or solution in this proof conception may tend to view problem-solving as finding a solution. However, with this lower-level perspective on problem-solving, the mathematical reasoning feature of proof may not go beyond finding a solution to a problem in school mathematics. Therefore, the relationship between pre-service teachers' proof conceptions and problem-solving conceptions needs to be detailed in further studies.

Also, previous studies indicate that proof should be used to promote the understanding of mathematical concepts (Knuth, 2002a; Weber, 2010). In this study, Category B (proof is a means for understanding) is in line with this view. Similarly, Dickerson and Doerr (2014) report that one of the concepts in the answers of mathematics teachers is "proof provides understanding." Baştürk (2010) finds a similar conception in which proof is seen as deep thinking by pre-service teachers. In his research, first-year secondary school pre-service mathematics teachers who presented this view focused on learning mathematical ideas and criticized learning by heart. This result parallels the cognitive processes we found in Category B.

In this study, Category C denotes that proof is explaining thinking in a convincing way. This finding is in line with the literature that indicates that the notion of convincing argument can be seen in the proof conceptions of undergraduates (Davies, Alcock, & Jones 2021, Knuth, 2002a).

Results of this study might be considered from a cultural perspective as well. For example, in the work of Lesseig et al. (2019), both American and Korean pre-service teachers indicate that proof serves to deepen understanding of mathematical concepts. Similarly, teachers in this study also emphasized the "understanding role" of proof. The work of Lesseig et al. (2019) also states that Korean pre-service teachers focus on the verification meaning of proof. Korean pre-service teachers do not consider the systematization role of proof while American and Australian pre-service teachers consider it. Korean and Turkish pre-service teachers' proof understandings may be very similar. Like Korean pre-service teachers, Turkish pre-service teachers hold conception (Category D, i.e., proof is validating conjectures using logical arguments) related to the verification/validation meaning of proof. Likewise, in this study, an understanding linked to the systematization role of proof is absent in Turkish pre-service teachers' responses.

This similarity also exists concerning the discovery meaning of proof. In the work of Lesseig et al. (2019), few but only Korean pre-service teachers mention the discovery of mathematical theorems. In another study, Varghese (2009) states that only one pre-service teacher is aware of the discovery role of proof in his study group. The most complex level category of description revealed in this study is "proof is a means for discovery of mathematics." This more advanced understanding of proof might be a reason of why only the minority of pre-service teachers mention this conception.

Before concluding, it is crucial to address some limitations in the study. The study revealed proof conceptions of 16 participants coming from one Turkish university. Further research from different universities with more participants may reveal different proof understandings of middle school pre-service mathematics teachers. Another limitation of the study may be that the participants' lack of appropriate vocabulary in explaining their thinking about proof. This study is the first phenomenographic attempt to examine the pre-service mathematics teachers' conceptions of proof. Despite its limitations, the categories of description found in this study offer a framework for expanding awareness of proof conceptions. The framework in this study may be used by teacher educators as a model to understand and evaluate pre-service teachers' conceptions of proof. Also, this framework may be helpful for pre-service teachers to consider crucial aspects of proof in their mathematics learning and teaching. However, further studies are needed to obtain a more detailed and generalizable framework. In this respect, research associating conceptions of teaching proof in middle school and conceptions of proof may provide more insight into relevant literature.

Notes

Ethical approval for this study was obtained from Ethics Committee for Human Studies in Social Sciences of Bolu Abant İzzet Baysal University (01.02.2021 / 21).

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Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi (EFMED)
Cilt 15, Sayı 1, Haziran 2021, sayfa 144-185. ISSN: 1307-6086

Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Vol. 15, Issue 1, June 2021, pp. 144-185. ISSN: 1307-6086

Araştırma Makalesi / Research Article

Üstbiliş Destekli Tartışma Tabanlı Öğrenme Yaklaşımının Fizik Eğitiminde Kavramsal Değişim ve Üstbiliş Üzerine Etkisi

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Gönderme Tarihi: 23.03.2021 Kabul Tarihi: 30.04.2021

Doi: 10.17522/balikesirnef.902038

Özet –Kavramsal değişim süreci, öğrencinin ön kavramının bir problemi çözmede yetersiz kalması ile başlar. Öğrencinin bilimsel kavramı kabul ederek ön kavramını terk etmesi ile son bulur. Alanyazında kavramsal değişim kuramı ve değişkenleri detaylı bir şekilde tanımlanmış olmasına rağmen, kuramın sınıfta nasıl uygulanacağı ile ilgili bir boşluk vardır. Bu nedenle bu araştırmada, kavramsal değişim kuramına uygun üstbiliş stratejileri ile desteklenmiş tartışma tabanlı bir öğretim yaklaşımı tasarlanmış ve uygulanmıştır. Araştırma deseni olarak nicel baskın statülü karma model kullanılmıştır. Araştırmaya bir ortaöğretim kurumunun 10. sınıfında öğrenim gören 51 öğrenci katılmıştır. Araştırma verileri Özel Görelilik Kuramı Tanı Testi, Üstbiliş Özyeterlilik Ölçeği ve yarı yapılandırılmış görüşmeler ile toplanmıştır. Verilerin analizi sonucunda, uygulanan öğretimin öğrencilerin kavramsal değişimine olumlu katkısı olduğu sonucuna ulaşılmıştır. Uygulanan öğretimin öğrencilerin üstbilişine özellikle izleme, değerlendirme ve planlama boyutunda katkı sağladığı tespit edilmiştir.

Anahtar kelimeler: fizik öğretimi, özel görelilik kuramı, ön kavramlar, kavramsal değişim, üstbiliş.

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Bu araştırmanın bulguları sorumlu yazarın doktora tezinin bir bölümünü içermektedir.

Geniş Özet

Giriş

Kavramsal değişim süreci, derste öğrencinin ön kavramının bir problemi çözmede yetersiz kalması ile başlar. Öğrencinin, öğretmen tarafından sunulan bilimsel kavramı akla yatkın işe yarar ve anlaşılır bulmasına bağlı olarak kabul etmesi, artık memnuniyetsizlik duyduğu ön kavramını terk etmesi ile son bulur (Posner vd. 1982). Pintrich vd. (1993), Posner vd. (1982)'nin bu kuramını öğrencilerin motivasyonunu ve kişisel özelliklerini dikkate almadığı gerekçesi ile eleştirmiştir. Bu eleştiri kavramsal değişimde motivasyonu ve bireysel özellikleri dikkate alan çalışmaların önünü açmıştır (Dole ve Sinatra,1998; Gregoire, 2003; Tyson vd.1997; Alsop ve Watts, 1997). Alanyazında kavramsal değişim kuramı ile ilgili bu kuramsal araştırmalara ek olarak öğretim içeren araştırmalar da yapılmıştır (Yıldız, 2008; Kapartzianis, 2012; Kural, 2015; Planinic vd. 2005; Ültay vd. 2015). Kavramsal değişim ile ilgili tüm bu araştırmalar incelendiğinde, öğrencilerin kavramsal değişim sırasında bilimsel kavramın nasıl farkına varacağı ve bu kavramın öğrencilere nasıl sunulması gerektiği üzerinde durulması gereken sorulardır. Zhou (2010) bu durumu göz önünde bulundurarak Bilim Öğretiminde Tartışma Yaklaşımını geliştirmiştir. Bu araştırmada ise Zhou (2010)'nun yaklaşımına öğrencilerin kendi düşüncelerini derinlemesine inceleyebilmelerini için üstbiliş eklenmiştir. Çünkü düşünmeyi düşünmek anlamına gelen üstbiliş kavramsal değişimin bir değişkeni olduğu gibi kavramsal değişimi doğrudan etkileyen motivasyonun da bir değişkenidir.

Bu araştırmada üstbiliş stratejilerinin eklenmesi ile birlikte Üstbiliş Destekli Tartışma Tabanlı Öğrenme Yaklaşımı adı verilen bu öğrenme yaklaşımının ortaöğretim öğrencilerinin özel görelilik kuramı ile ilgili kavramsal değişimine ve üstbilişine etkisi araştırılmıştır.

Yöntem

Araştırmada desen olarak nicel baskın statülü karma model kullanılmıştır. Araştırmanın veri toplama araçları öğretimden önce ve sonra eş zamanlı olarak uygulanmıştır.

Araştırmada kullanılan öğrenme yaklaşımı problemin sunulması, ön kavramların açığa çıkarılması, bilişsel çatışma yaratma, bilimsel bilginin inşası, bilimsel bilginin savunulması ve değerlendirme basamaklarından oluşmaktadır. Yaklaşıma üstbiliş stratejileri ise gruplara ayrılmış öğrencilere verilen izleme, planlama ve değerlendirme uzmanlıkları ile sağlanmıştır. Öğrenciler her hafta dönüşümlü olarak izleme, planlama ve değerlendirme kılavuzlarını kullanarak bu görevleri üstlenmiştir. Öğretim yaklaşımının basamakları her hafta özel görelilik kuramının bir konusuna uygulanmıştır. Öğretim altı hafta sürmüştür.

Araştırmanın örneklemi kolay ulaşılabilir örnekleme yöntemi ile belirlenmiştir. Araştırmaya Manisa ilindeki bir lisenin 10. sınıfında öğrenim gören yaşları 16 ile 17 arasında değişen 51 öğrenci katılmıştır.

Araştırmanın nitel verileri araştırmacılar tarafından geliştirilen üç aşamalı bir test olan "Özel Görelilik Kuramı Tanı Testi" ve "Yarı Yapılandırılmış Görüşme Formu" ile toplanmıştır. Araştırmanın nicel verileri ise Thomas, Anderson ve Nashon (2008) tarafından geliştirilen "Üstbiliş, Özyeterlilik ve Öğrenme Süreçleri Ölçeği" ile toplanmıştır.

Tanı testi verileri öğrencilerin üç aşamalı teste verdikleri yanıt kombinasyonlarına göre kategori ve alt kategorilere ayrılmıştır. Öğrencilerin öğretim öncesinde ve öğretim sonrasında bu kategorilere ve alt kategorilere dağılım frekansları oluşturulmuştur. Görüşme verileri ise benzer şekilde alt kategorilere ayrılmıştır. Öğrencilerin öğretim öncesindeki ve öğretim sonrasındaki alt kategori geçişleri bir diyagram ile sunulmuştur. Ölçek verileri ise betimleyici istatistik ve fark testleri kullanılarak analiz edilmiştir.

Bulgular

Özel Görelilik Kuramı Tanı Testi Bulguları

Tanı testi verilerinin analizi sonucunda altı kategori ve 20 alt kategori oluşturulmuştur. Öğretimin etkisi ile kategorilerdeki değişim genel olarak incelendiğinde öğretimin öğrencilerin kavram yanılgılarını, şanslı tahmin/düşük güven içeren yanıtlarını ve eksik kavramlarını azalttığı sonucuna ulaşılmıştır. Buna rağmen yapılan öğretimin öğrencilerin bilimsel kavramlarını ve yanlış pozitif kavramlarını artırdığı sonucuna ulaşılmaktadır. Bu sonuçlar yapılan öğretimin kavram yanılgıları ve eksik kavramları bilimsel kavramlara dönüştürmede etkili olduğunu göstermektedir. Buna ek olarak yanlış negatif yanıtların az olması ise elde edilen sonuçların güvenilir olduğunu göstermektedir.

Kavramlardaki değişimler tek tek incelendiğinde yapılan öğretimin en fazla ışık hızı ile ilgili doğru kavramın oluşmasına katkı sağladığı sonucuna ulaşılmıştır. Öğretim eşanlılık ile ilgili kavramsal değişime de olumlu yönde katkı sağlamıştır. Fakat öğretim yaklaşımının öğrencilerin enerji-kütle kavramları ile ilgili doğru kavramlarını kavram yanılgılarına dönüştürdüğü tespit edilmiştir.

Tanı testi ile elde edilen alt kategoriler ve değişimi ışık hızı, eşanlılık ve enerji-kütle başlıkları altında aşağıda açıklanmıştır.

Işık Hızı ile ilgili kavramsal değişim: Işık hızı kavramı ile ilgili üç alt kategori belirlenmiştir. Alt kategori 1 doğru bir açıklama, alt kategori 2 ise yanlış bir açıklama içermektedir. Öğretimin etkisi ile alt kategori 1'in artması ve alt kategori 2'nin azalması, öğrencilerin öğretimin etkisi ile ışık hızının gözlemcinin ve kaynağın hızından bağımsız olduğu bilgisini öğrendiklerini göstermektedir. Ayrıca alt kategori 3 yanlış bir açıklama içermektedir. Bu kategori öğretim sonrasında artmıştır. Bu durum öğretimin bazı öğrencilerde ışık hızı ile ilgili yanlış genellemelere sebep olduğu şeklinde yorumlanmıştır. Bu öğrenciler ışık hızının boşlukta sabit bir hızla ilerlemesi durumunu ışığın tüm ortamlarda aynı hızda ilerlemesi şeklinde genellemiştir.

Eşanlılık ile ilgili kavramsal değişim: Eşanlılık ile ilgili iki alt kategori belirlenmiştir. Alt kategori 6 doğru bir açıklama, alt kategori 7 ise yanlış bir açıklama içermektedir. Öğretimin etkisi ile alt kategori 6'nın artması, öğrencilerin bir gözlemciye göre aynı anda olan bir olayın başka bir gözlemciye göre aynı anda olmayabileceği bilgisini öğrendiklerini göstermektedir. Alt kategori 7 ile ilgili yanıtların artması ise öğretimin bazı öğrencilerde ışık hızı kaynağın hızından etkilenir fakat ihmal edilir düşüncesini oluşturduğu şeklinde yorumlanmıştır.

Enerji ve Kütle ile ilgili kavramsal değişim: Enerji ve kütle ile ilgili altı alt kategori belirlenmiştir. Alt kategori 16 doğru bir açıklama içermektedir. Alt kategori16'daki artış öğretimin etkisi ile öğrencilerin kütlesi olan cisimlerin ışık hızına ulaşamayacağı bilgisini öğrendiklerini göstermektedir. Alt kategori 15 doğru bir açıklama, alt kategori 18 ise yanlış bir açıklama içermektedir. Öğretimin etkisi ile alt kategori 15'in azalması ve alt kategori 18'nin artması, öğretimin bazı öğrencilerin sahip olduğu 'kütle değişmeyen madde miktarıdır' bilgisini 'ışık hızına yakın hız değerlerinde kinetik enerji kütleye dönüşür' düşüncesine dönüştürdüğünü göstermektedir. Tüm bunlara ek olarak öğretim sonrasında kategori 20'de artış tespit edilmiştir. Bu artış öğretimin öğrencilerde kuvvet uygulanarak hızlandırılan parçacıkların ulaşacakları hızın bir limiti olduğu bilgisini öğrendiklerini göstermektedir.

Yarı Yapılandırılmış Görüşme Verileri

Yarı yapılandırılmış görüşmelerden elde edilen alt kategoriler ve değişimi ışık hızı, eşanlılık ve enerji-kütle başlıkları altında aşağıda açıklanmıştır.

Işık Hızı ile ilgili kavramsal değişim: Altı öğrenci öğretimin etkisi ile Alt kategori 2'den, Alt kategori 1'e geçmiştir. Bu durum, öğretim öncesinde ışık hızının kaynağın ve gözlemcinin hızına bağlı olduğunu düşünen öğrencilerin öğretimin etkisi ile ışık hızının gözlemcinin ve kaynağın hızından bağımsız olduğunu düşündüklerini göstermektedir. Bir öğrenci öğretim öncesinde ve öğretim sonrasında Alt kategori 2'deki görüşü korumaya devam etmiştir. Bu öğrenci öğretim öncesinde de öğretim sonrasında da ışık hızının kaynağın ve gözlemcinin hızına bağlı olduğunu düşünmektedir.

Eşanlılık ile ilgili kavramsal değişim: Dört öğrenci öğretim öncesinde ve öğretim sonrasında alt kategori 6'ya uygun yanıt vermiştir. Bu öğrenciler öğretim öncesinde ve öğretim sonrasında bir gözlemciye göre aynı anda olan iki olayın bir başka gözlemciye göre aynı anda olmayabileceği bilgisine sahiptir. Üç öğrenci öğretimin etkisi ile Alt kategori 7'den Alt kategori 1'e geçmiştir. Bu durum öğretim öncesinde, ışık hızı kaynağın hızından etkilenir fakat ihmal edilir düşüncesine sahip olan öğrencilerin öğretimin etkisi ile ışık hızı gözlemcinin ve kaynağın hızından bağımsızdır düşüncesine sahip olduklarını göstermektedir.

Enerji-kütle ile ilgili kavramsal değişim: Üç öğrenci öğretim öncesinde ve öğretim sonrasında Alt kategori 15'e uygun yanıtını vermiştir. Bu kategoride yer alan öğrenciler öğretim öncesinde ve öğretim sonrasında kütle değişmeyen madde miktarıdır şeklindeki doğru yanıtlarını korumuştur. İki öğrenci öğretimin etkisi ile Alt kategori 15'den, Alt kategori 17'ye geçmiştir. Bu durum öğretim öncesinde, kütle değişmeyen madde miktarıdır düşüncesine sahip olan öğrencilerin öğretimin etkisi ile ışık hızına yakın hızlarda ilerleyen cisimlerin kütlelerini doğru ölçmek mümkün değildir düşüncesine dönüştüğünü göstermektedir.

Üstbiliş Özyeterlilik Ölçeği Bulguları

Üstbiliş Özyeterlilik Ölçeği bulguları incelendiğinde öğrencilerin öğretim sonrasındaki ortalama puanlarının öğretim öncesindeki ortalama puanlarından daha yüksek olduğu sonucuna ulaşılmaktadır. Fakat bu fark istatistiksel olarak anlamlı değildir. Ölçek faktörlerindeki değişim incelendiğinde ise öğrencilerin yapılandırmacı bağlantılama, izleme, değerlendirme ve planlama, konsantrasyon kontrolü faktörlerinde öğretim sonrasındaki ortalama puanlarının öğretim öncesindeki ortalama puanlarından yüksek olduğu sonucuna anlaşılmaktadır. Buna rağmen, öğrencilerin öğretim sonrasında fizik öğrenmede özyeterlilik ve öğrenme riskleri farkındalığı faktörlerinde ortalama puanlarında artışa rastlanmamıştır.

Sonuç ve Tartışma

Geliştirilen öğretim yaklaşımının öğrencilerin kavramsal değişimine olumlu katkısı olduğu sonucuna ulaşılmıştır. Bununla birlikte öğrencilerin, bir kavramı öğrenirken bilimsel olmayan ön kavramını koruyabildiği, bilimsel kavrama geçiş yapabildiği, iki kavramı bir arada kullanabildiği veya yeni bir bilimsel olmayan kavram oluşturabildiği tespit edilmiştir.

Araştırma sonuçları göz önünde bulundurularak modern fizik öğretiminde ilk olarak öğrencilerin sezgisel ve bilimsel olmayan düşüncelerinin klasik fizik kavramlarına dönüştürülmesi kavramsal değişimde bilişsel çatışmanın güçlü olması için ise sanal laboratuvar, simülasyon ve animasyon gibi öğretim materyallerinin geliştirilmesi önerilmektedir.

Araştırmanın öğretim yaklaşımının öğrencilerin üstbilişine olumlu katkısı olduğu sonucuna ulaşılmıştır. Fakat bu artış düşük düzeydedir. Ölçeğin alt boyutları incelendiğinde ise öğretim ile üstbiliş ölçeğinde sağlanan artışın büyük ölçüde ölçeğin izleme, değerlendirme ve planlama boyutundan kaynaklandığı anlaşılmıştır. Öğrencilerin üstbiliş düzeyini artırmak güç olduğu için araştırmacılara ve öğretmenlere öğretimde üstbiliş stratejilerini uzun süreli uygulamaları önerilmektedir.

The Effect of Metacognitive Supported Argument-Based Learning Approach on Conceptual Change and Metacognition in Physics Education

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Received : 23.03.2021 Accepted : 30.04.2021

Doi: 10.17522/balikesirnef.902038

Abstract – The process of conceptual change begins when a preconception of a student fails to solve a problem. It ends when the student abandons this preconception and accepts a scientific concept. Although the conceptual theory of change and its variables are described in detail in the literature, there is a gap in how the theory can be applied in the classroom. For this reason, a course incorporating an argumentation approach supported with metacognitive strategies in accordance with the theory of conceptual change was designed and implemented for the subject of special relativity theory. A qualitatively dominant status mixed-method approach was used as the research design. The participants of the study were 51, 10th-grade students studying at a secondary school. Data were collected with qualitative and quantitative measurement tools. It was concluded that the applied course contributed positively to the students' conceptual changes and regulation of cognition (planning, monitoring, evaluating).

Key words: teaching physics, theory of special relativity, preconceptions, conceptual change, metacognition.

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The data of this research includes a part of the corresponding author's doctoral thesis.

Introduction

The theory of conceptual change has been firstly proposed by Posner, Strike, Hewson and Gertzog, (1982). The inspiration for this theory comes from the theory of scientific revolution (Kuhn, 1970). Kuhn (1970) created the theory of scientific revolution to explain the process of scientific development. According to this theory, scientists enter a period of crisis due to the inability of the paradigms they create to explain the scientific facts. This crisis period motivates scientists to create a new paradigm. With the creation of a new paradigm, the period of crisis is overcome, and the scientific revolution is achieved. Posner et al. (1982) created the theory of conceptual change in a way that was similar to the theory of Kuhn (1970). Posner et al. (1982) have stated that students experience dissatisfaction with their preconceptions due to the inability of their non-scientific preconceptions to solve problems. According to this theory, it is emphasized that students who tend to maintain their preconceptions experience a conflict between the preconception and a scientific concept when the scientific concept is introduced. Posner et al. (1982) have described the conceptual change as a process of accommodation, which begins suddenly with cognitive conflict and progresses gradually. Posner et al. (1982) have also explained all the characteristics affecting conceptual change with the concept of conceptual ecology. Conceptual ecology is defined as everything that pre-exists in the cognitive structure of a person (Duit and Treagust 1998; Posner et al. 1982). Pintrich, Marx and Boyle (1993) have criticized the theory of conceptual change of Posner et al. (1982), claiming that it ignores students' motivation and personal characteristics. Pintrich et al. (1993) have emphasized in this critique that scientists' interests and objectives cannot represent students' interests and objectives, and the school environment cannot represent the scientific community too. It has been stated that the role of students in the school during learning is not the same as the role of scientists in the scientific community.

Motivation, on the other hand, is defined as activities that maintain learning behaviour (Palmer 2005). Motivation determines the direction of students' learning efforts in learning activities and tasks in the classroom environment, as well as affecting the adaptation of students to different learning tasks. The concept of motivation was first defined as a concept that depends on external factors (reward and good note-taking) with the effect of behavioural learning theory. However, it has been noticed that external factors such as rewards and getting good marks lose their effect in case of continuity. Therefore, motivation has been redefined depending on internal factors. According to this definition, it was emphasized that following cognitive processes, setting goals, determining metacognitive strategy increase motivation (Ryan and Deci, 1998; Eggen and Kauchak, 2001).

Pintrich et al. (1993) have defined the theory of conceptual change of Posner et al. (1982) as a cold conceptual change model to emphasize the mechanic's feature of this theory, which did not take into account motivation. The theory of conceptual change, which includes motivation, is expressed as a warm conceptual change because it considers students' personal characteristics (Pintrich, 2003). These critiques of Pintrich et al. (1993) about the conceptual change theory of Posner et al. (1982) have paved the way for studies that take into account personal characteristics such as the effect of fears and self-esteem etc. in conceptual change. This kind of researches was explained as follows.

In their Cognitive Reconstruction of Knowledge Model (CRKM), Dole and Sinatra (1998) have stressed that the strength, richness, coherence, as well as high commitment level of preconceptions, increase resistance to conceptual change. In Gregoire's (2003) Cognitive-Affective Model of Conceptual Change (CAMCC), it has been stated that concerns and fears can result in a strong rejection of new knowledge. Tyson, Venville, Harrison & Treagust (1997) have highlighted the importance of epistemology and ontology in conceptual change. Alsop and Watts (1997) have proposed a model with four components that emphasizes the importance of cognitive, affective, conative and self-esteem characteristics for conceptual change. The conative component in this model is explained in relation to the concept of metacognition. In addition to these theoretical studies on the theory of conceptual change in the literature, researches involving educational practice has also been conducted. When researches involving educational practice on the theory of conceptual change in science education is examined, it is understood that such research studies in which different instructional methods and techniques are implemented rather than research incorporating instructional models structured according to the theory of conceptual change. In these research studies, the effect of lessons involving the 5E teaching model (Yıldız 2008), instructional steps of conceptual change (Kapartzianis 2012; Kural 2015), cognitive conflict, changing concepts, analogy and Socratic dialogue techniques (Planinic et al. 2005), and texts for conceptual change (Ültay, Durukan and Ültay, 2015) on students' conceptual change have been investigated. In these studies, it was stated that the teaching made had a positive contribution to the conceptual change (Yıldız, 2008; Kapartzianis, 2012; Kural, 2015; Planinic et al. 2005; Ültay et al. 2015). Besides, it was stated that students tend to preserve their pre-concepts (Yıldız 2008; Kapartzianis, 2012; Planinic et al. 2005).

When the theoretical research on conceptual change is examined, it is understood that the components affecting conceptual change have been defined. In addition, various instructional methods and techniques that influence conceptual change positively have been determined in instructional educational research on conceptual change. However, these studies do not explain how students will adapt a scientific concept during conceptual change and how this concept should be presented to the students by considering their affective characteristics. Zhou (2010) has developed the argumentation approach in science education with this deficiency in mind. The most important feature of this approach is that it defines argumentation, which is known for its importance in science education, as an important variable of conceptual change (Osborne, Erduran and Simon, 2004). Zhou (2010) has explained the importance of argumentation in conceptual change by referring to Kuhn's (1970) theory of scientific revolution, as other conceptual change theorists (Posner et al. 1982; Pintrich et al. 1993) have explained. Zhou (2010) has stated that a scientific revolution would be based on the discussion of different views of scientists. Therefore, Zhou (2010) argues that with the effective use of argumentation in the instructional environment, students' affective characteristics will be activated and their motivation will be improved. This thought inspired the authors of this study to add metacognition as a component in a conceptual change study. Therefore, in addition to Zhou's (2010) approach, it was considered that scientists make scientific debates by understanding each other's views, comparing these views with their own opinions and reflecting on their thoughts. This means that students should also aware of their views, examine their own and others' views in a classroom environment. All these efforts indicate the importance of metacognition which should be incorporated into instruction during the teaching of scientific concepts.

Metacognition, defined as thinking about thinking, has two components: knowledge of cognition and regulation of cognition (Flavell 1979). Knowledge of cognition is defined as knowledge of one's own cognitive capabilities and limitations. Regulation of cognition involves one's contemplating his cognition, planning his activities, being aware of his learning performance, and evaluating his performance (Schraw, Gripped and Hartley, 2006). Metacognition is considered a component of conceptual change (Sinatra and Pintrich, 2003) as well as a component of motivation that directly affects conceptual change (Pintrich, et al. 1993). Conceptual change in which metacognition is taken into account has been defined by Sinatra and Pintrich (2003) as intentional conceptual change. The effects of lessons involving metacognitive strategies have been investigated in instructional educational research on metacognition in science and mathematics education (Kramarski and Mevarech 2003; Yıldız 2008; Seraphin, Philippoff, Kaupp & Vallin, 2012; Jayapraba 2013). In these studies, it has been shown that metacognition is effective in acquiring many skills. Metacognition gives students the ability to assess their cognitive strengths and weaknesses and teach them to use knowledge strategically (Seraphin et al. 2012). Moreover, metacognition is reported to be effective in allowing students to transfer information to graphic interpretation (Kramarski and Mevarech 2003) and in improving students' academic success (Jayapraba 2013). Students' use of their metacognitive abilities during teaching is another factor that improves the quality of teaching. However, it has been reported not to be easy for students to learn how to use their metacognitive abilities (Yıldız 2008).

This study is therefore aimed at developing and applying a teaching approach by the conceptual change theory by taking account of the contribution of many researchers from the past to the present. Moreover, it has not been adequately described in the literature how to apply teaching by the warm conceptual change theory in the classroom environment. Hence, Zhou's (2010) argumentation approach in science education was used as a basis for instructional design. By adding the use of metacognitive strategies to this design, because of the stated importance of metacognition in the conceptual change process, an instructional design called "metacognitive supported argument-based learning" was developed. Special relativity theory was taught to grade 10 students using this teaching approach. The subject of special relativity theory was selected because the theory of special relativity is a preliminary example (prototype) of a scientific revolution (Posner et al., 1982).

For the purpose of this research, the following research problems have been defined:

Are argumentation-based metacognitive strategies supported learning approach effective in transforming students' preconceptions into scientific concepts?

Are argumentation-based metacognitive strategies supported learning approach effective in increasing students' metacognition levels?

In the following section, the reviews of literature regarding the teaching of the special relativity theory and the contributions made by studies in the literature to the teaching of the special relativity theory are included.

Related Research about Special Relativity

For conceptual change to begin, students must not be able to solve problems with their preconceptions. Preconceptions of the students are important in creating the teaching content of the research. Hence, a systematic literature review was conducted to investigate students' preconceptions about the special relativity theory. Determined preconceptions related to the special relativity theory in the literature are given below.

Özcan (2017) has identified students' misconceptions about the concepts of reference systems, relative time and length in a study, in which 14 physics education students participated. Based on the results, it was stated that the students interpreted time dilation in the theory of special relativity not as a scientific reality, but as an optical illusion. Furthermore, it was emphasized that the students expressed that the mass of objects moving at speeds close to the speed of light increased and that the laws of physics were different in different reference systems. Panse, Ramadas and Kumar (1994) investigated the conceptual comprehension levels of students on the concepts of reference system and the simultaneity in their study, which included 111 graduate physics education students. In this study, it was emphasized that the students thought there was a limit to reference systems. Scherr, Shaffer & Vokos (2001) have also carried out a study on 800 social science and physics education students and examined their thoughts on the concepts of the theory of special relativity, simultaneity, and reference systems. In their study, it was concluded that most students learned the concept of simultaneity as the simultaneity of events measured by a single observer in a problem about the measurement of light signals. It was also stated that the students had difficulty understanding this concept because they attempted to explain this concept with the concept of absolute time that they had learned in classical physics. Additionally, it was determined that the students had difficulty understanding the concept of reference system. For this reason, it was stressed that the students could not comprehend that the results of an event were the same in different reference systems.

Selçuk (2011) has investigated the conceptual understanding levels of undergraduate students about the concepts of time, length, mass and density in the special relativity theory unit in her study, which included 185 physics and elementary education students. In this study, it was understood that the students thought that the duration of an event was equal for an observer placed in the stationary reference system and for another observer in the reference system moving at close to the speed of light. In addition to that, it was emphasized that the students thought that the change in the length of objects moving at speeds close to the speed of light happened in every direction. In the study, it was indicated that some of the students thought that the change in object lengths at speeds close to the speed of light was not actually happening, but that this change occurred perceptually. Furthermore, the students pointed out that the mass of an object moving at speeds close to the speed of light was greater than the stationary mass of the object. This idea led the students to misinterpret the change in densities of objects moving at speeds close to the speed of light. Selçuk and Çalışkan (2010) investigated the conceptual understanding levels of 46 physics education students about the theory of special relativity. In this study, the students interpreted the relativity of time as the slower operation of a mechanical clock at speeds close to the speed of light. In addition, it was expressed that the students were unable to internalize the change in lengths of objects at speeds close to the speed of light and attempted to solve problems related to this subject with the relative speed equations they had used in classical physics courses. Moreover, it was highlighted that the students had difficulty understanding the concept of reference system. In their study on 30 physics education students, Turgut, Gurbuz, Salar & Toman (2013) investigated the effect of modern physics course on students' conceptual understanding of the theory of special relativity. It was expressed that the lessons given during the study contributed to the understanding of the concept of relative time. It was revealed that the students had difficulty solving problems related to the relativity of length before and after teaching. The students expressed that the change in lengths of objects at speeds close to the speed of light was perceptual. Moreover, it was pointed out that the students thought that the mass of objects increased at speeds close to the speed of light after teaching. Özdemir, Kural and Kocakülah (2014) investigated the effect of constructivist teaching techniques on the conceptual change of the concepts of the theory of special relativity. The study had 50 tenth-grade students as participants. Based on the results of this study, it was concluded that the constructivist teaching techniques contributed to the conceptual understanding of the students. However, it was reported that the students solved problems related to the speed of light by adding the speed of the light source to or subtracting it from the speed of light. It was also stressed in the study that the students had difficulty learning the concepts of the reference system and simultaneity. Alvarado, Mora, and Reyes (2019) investigated the effect of peer instruction on students' beliefs and attitudes about special relativity theory. In the study in which 25 high school students participated, it was stated that peer education had a positive effect on students' beliefs and attitudes. In addition, it was determined in the study that the students had various alternative thoughts about the special theory of relativity. Some of the alternative concepts determined in the research are as follows; the speed of light is relative. Time does not depend on the speed of the observer. Students may have confusion applying the concept of relativistic mass in classical equations.

When the results of these studies are evaluated together, it is understood that the students' preconceptions related to the special relativity theory are shaped by the students' classical physics concepts and their incomplete classical physics knowledge. On account of this, problems that were used to teaching special relativity theory in this study are formed that students could not explain with classical physics knowledge and incomplete classical physics knowledge. Creating cognitive conflict was expected to be achieved on these problems.

While teaching content in this study has been arranged, factors that make teaching the theory difficult and recommendations for teaching the theory have been taken into account. The literature concerning these factors and recommendations are summarized below.

Kızılcık and Yavaş (2017) have carried out a study on 691 science-education and secondary-school students. They have examined the factors that make teaching the theory of special relativity difficult. Based on this study, those factors are expressed as the teaching of the theory is limited to mathematical problems and students' efforts to explain the theory of special relativity with classical knowledge of physics. Özcan (2011) has also carried out a study on 34 physics education students and examined their problem-solving approaches on the theory of special relativity. In that study, it was concluded that the students' problem-solving approaches were not scientific and strategically planned. It was emphasized in this study that the conceptual deficiencies of the students regarding the theory of special relativity caused them to be confused about reference systems. It was stated that this situation made it difficult for the students to solve problems related to the theory. Villani and Arruda (1998) have emphasized the importance of the history of science to teach effectively the theory of special relativity. In that study, it is stated that when students are taught the theory, they need to understand the differences between classical physics and modern physics, and the conceptual disconnections. To do that, it is stated that the original writings of scientists should be used in the instructional environment and class discussions about these writings should be carried out. Furthermore, the importance of talking about experiments and technological applications related to the theory of special relativity during lessons, as well as the use of visual materials, has been emphasized. This research includes various activities providing not only calculating mathematical equations but also, argumentation and classroom discourse. Besides, teaching content includes knowledge about science history and real situations about the theory. Alvarado (2017) conducted a study with 30 high school students. He compared the effect of peer instruction and traditional lecture on the teaching of special relativity theory. In the study, it was emphasized that the students had difficulty in correctly determining the variables of the theory-related formulas. It has been concluded that peer teaching is more effective than traditional teaching in teaching the theory. Also, the importance of persuasion discussions among students to overcome monotony in the teaching of the theory is emphasized. Croxton, V. & Kortemeyer, G. (2018) investigated the effect of the play A Slower Speed of Light, which was organized according to the Flipped method, on students' awareness, attitudes, and behaviours towards the special theory of relativity. In the study, it was stated that the game has positive effects on awareness, attitude, and motivation, although it has various limitations.

The related literature has been reflected in this study with a holistic approach by including the contradiction of classical-modern physics in the teaching content, considering the factors that make the teaching of the theory difficult and the suggestions that facilitate its teaching. In this way, rich content was formed for physics teachers that they can use in the teaching of special relativity theory. It is thought that this aspect of the research will contribute to the teaching of the theory.

Method

The mixed-method has used in this research. The mixed-method means that combining different quantitative and qualitative data collection tools in the same experimental research (Johnson, Onwuegbuzie and Collins, 2007). A convergent design which is one of the mixed-method research design was utilized in this study. According to this design, qualitative and quantitative data are collected and analysed concurrently and independently, and research data are interpreted and discussed with a convergent approach (Pardede, 2018).

The quantitative aspect of the research is more dominant than the qualitative aspect of research. Both qualitative and quantitative collection tools applied same time before and after the teaching application. For this reason, this research is the same time in terms of time and quantitative in terms of dominance (Venkatesh, Brown and Sullivan, 2016).

Table 1 Research implementation design

Before implementation	Implementation of teaching model	After implementation
The theory of special relativity–diagnostic test Semi-structured interview	Metacognitive Supported Argument-Based Learning Approach	The theory of special relativity–diagnostic test Semi-structured interview
Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S) Scale		Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S) Scale

To address the aim of the study, 10th-grade students participated in the course which took eight weeks. Data collection instruments were administered to the students before and after the course.

One of the reasons for using the mixed method in the study is overcoming the threat of validity problem which emerge when the researcher used only qualitative or only quantitative data. The other reason for using the mixed method in the study is to achieve a more widely reliable picture of students' conceptual change process and to investigate deeply this process (Johnson et al, 2007).

Research Sample

When the time this research was performed, content about special relativity theory was included in 10th-grade secondary school physics curriculum in Turkey (Turkey Ministry of National Education, 2008). Therefore, this research was conducted with students who studied special relativity unit in the 10th grade. The research sample was determined through the convenience sampling method (Onwuegbuzie and Collins, 2007). In the convenience sampling method, attention is paid to ensure that the sample is easily accessible. The researchers who use this method should consider its weakness in terms of the power of representing the research universe. Therefore, a school that represents average Turkish students' profile was selected from among the schools where the research was carried out. The features of the research school are as follows: A low achiever student in the sample scored 391 base points from the high school entrance exam and was settled in this school. A high achiever student can obtain a maximum of 500 points in this exam. It can be said that the students in the sample have got an average academic success in Turkey.

The school that the research was performed is located in the district where 41.135 people live in. The main livelihood of the people in this district is agriculture and animal husbandry. The people living in the city also represent an average socioeconomic level of Turkey.

The research sample consisted of 10th-grade students studying at a secondary school in a district of Manisa province in Turkey. The study included 51 students studying in Cohorts A and B of the school. A total of 27 students, including 12 females and 15 males, were studying in Cohort A, and a total of 24 students, including 14 females and 10 males, in Cohort B. The participants were between 16 and 17 years old.

Instructional Approach and Instructional Implementation

In this section, the instructional approach of the study, the implementation schedule of the course, and the instructional steps are presented.

Incorporation of metacognitive strategies in instructional approach: Zhou's (2010) Argumentation Approach in Science Education consists of six steps that are eliciting preconceptions, creating cognitive conflict, constructing scientific notion, defending scientific notion and evaluation. These steps of the instructional approach are described in detail in the following sections. The metacognitive strategies were incorporated into some of the steps of the designed instruction as described in Table 2.

Table 2 Incorporation of the Metacognitive Strategies in the Instructional Approach

Regulation of cognition	Group roles	Activities of Specialization	Instructional Material	Implementation Step
Monitoring	Monitoring Specialist	Follows the thoughts of group members and himself. Follows changes in the views of himself and his friends during their teamwork. Attempts to perform the tasks specified in the monitoring manual.	Monitoring Manuals	Eliciting preconceptions
Planning	Planning Specialist	Determines a strategy for problem solving. Defines a certain amount of time and the resources needed for the solution. Attempts to perform the tasks specified in the planning manual.	Planning Manuals	Defending scientific notion
Evaluation	Evaluation Specialist	Evaluates his and his group mates' thoughts during the course. Highlights the points that make learning difficult and those that make it easier for them. Attempts to perform the tasks specified in the evaluation manual.	Evaluation Manuals	Evaluation

Metacognitive strategies were integrated into the instructional approach together with group roles. In the teaching approach of the research, group roles were used as in cooperative learning (Yeşilyurt, 2019). With these roles and guides, how students can activate their metacognitions during their education has been made concrete. These roles constitute an important part of the research in terms of enabling students to use metacognitive strategies during teaching. With these group roles, it was intended to have the students monitor, plan and evaluate their cognitive experiences. The students in groups alternately assumed these roles every week. In this way, each student in the group has undertaken one of these roles at least once. The students who assumed these roles were called monitoring, planning and evaluation specialists. Monitoring, planning and evaluation manuals were designed to make the task easier for the students to perform the activities specified in the group roles. The guidelines presented in these manuals are given in Table 3.

Table 3 Guidelines in the Manuals

Monitoring Manual	Planning Manual	Evaluation Manual
Compare your own thoughts about the outcome of the problem with the opinions of your group mates. Ask your group mates questions to find out what they think about the problem. Let them explain the reasons behind their thoughts. During the group activity, stop the debate at certain intervals you consider appropriate and try to observe the changes in your friends' ideas regarding the outcome of the problem. Ask questions. As a result of the group discussion, try to understand whether there are any changes in your ideas and your group mates' ideas about the outcome of the problem. Think about the reasons for any changes you and your group mates may make in your opinions regarding the outcome of the problem at the end of the group debate.	Try to understand the problem with your group mates. Let your group mates make a prediction about solving the problem. Reach a consensus in a common prediction as a group. Set a deadline for solving the problem. Check out the information you've learned throughout the course to solve the problem with your group mates. If you need any further information necessary to solve the problem, identify it. As a group, solve the problem. Review your solution. If you have not been able to make adequate progress in solving the problem, modify your plan. Is your prediction correct?	Identify points where your group members are successful and unsuccessful during the study. Describe the learning difficulties you have experienced during your work as a group. Try to evaluate your group performance and the individual performances of the group members. Describe what the approach, hypothesis, and so forth you have set as a group contributes to solving problems. Describe how much you have learned as a group and as an individual during this course. Evaluate performance of yourself and your group mates in participating in the activities during this course. Think about what you need to do to improve your performance in the activities. Express the thoughts of your group mates and yourself at the beginning of the course. Think, by also considering the reasons, why your group mates and you have changed your thoughts during the course. Express the thoughts of your group mates and yourself at the end of the course.

These guidelines include activities to organize the cognitive knowledge of students during the course. These manuals were prepared as checklists. The student on duty of that week marked the activities (completed/not completed) using the guidelines presented in the manuals.

Preparation and implementation of the instructional approach: Preparations made before implementation of the course and the weeks of implementation, the class schedules, durations and the steps of implementation are shown in Table 4.

Table 4 Preparation and Implementation Schedule of the Course

	Course Hour	Subjects	Duration	Implementation
		A. Pilot Study		
1	2	Speed of Light	90	Instructional steps were implemented for each subject.
2	2	Simultaneity	90	
3	2	Relativity of Time	90	
4	2	Relativity of Length	90	
5	2	Theory of Relativity, Mass and Energy	90	
		B. Preparation Studies Before the Actual Implementation		
1	2	Lesson on Conceptual Change Accommodation Conditions	90	Lesson on the terms of clarity, plausibility, dissatisfaction and usefulness
2	2	Establishment of the Instructional Order	90	Formation of instructional groups, determination of the seating arrangement of groups, announcement of the instructional approach and group roles
3	2	Practice Lesson: Serial and Parallel Connection of Batteries and Electromotive Force	90	Instructional steps
		C. Actual Implementation		
1	2	Speed of Light	90	Instructional steps were implemented for each subject.
2	2	Simultaneity	90	
3	2	Relativity of Time	90	
4	2	Relativity of Length	90	
5	2	Theory of Relativity, Mass and Energy	90	

Pilot study: A pilot study was carried out one year before the actual implementation. The pilot study was implemented in a secondary school in Balıkesir province, Turkey. The sample of the pilot study was selected by the convenient sampling method as in the actual implementation. The experience was gained in the pilot study was utilized in the actual implementation. Thanks to the pilot study, the timeline of the instructional steps were regulated, group roles were reviewed and strategies were developed to increase students' participation in the argumentations. Also, the actual implementation and instructional materials were reviewed.

Preparation studies before the actual implementation: Before the actual implementation, a lesson was carried out on conceptual change accommodation conditions, an instructional order was established, and a practice lesson was performed. The lesson on accommodation conditions included the terms of dissatisfaction, intelligibility, plausibility, and fruitfulness expressed by Posner et al. (1982) to explain the process of conceptual change. It was conducted in accordance with the instructional steps established by Hennessey (1993) and in a similar way to the lesson implemented by Yıldız (2008).

Establishment of the instructional order: Help was obtained from the teacher of the course when forming the instructional groups. The students were divided into three groups as low, moderate and high achieving according to their scores and academic achievements in the most recent school exam. Each group was assigned one student from the high-level group, one student from the low-level group, and two students from the moderate-level group. The students were asked to name their groups. During the instructional period, the student groups were seated together at fixed tables in the physics laboratory. The course was conducted with six groups. During the course, a projection device and a whiteboard were used. Before starting the course, the specifics of the course to be implemented for six weeks were explained to the students. Group roles and guidelines in the manuals were explained and every group member learned that they will work as monitoring, planning and evaluation specialists in their group by turns.

Practice lesson: In order for students to get used to the instructional model, a practice lesson was taught before the actual implementation. The grade 10 physics curriculum includes the topics of electromotive force and the serial and parallel connection of batteries in the electric unit before the theory of special relativity subject. These topics were taught by using the instructional approach adopted in this study.

Instructional steps

The teaching of each subject was completed in a total of two-course hours (90 minutes) each week following the instructional steps. These steps are briefly explained below. The course was taught by the first researcher.

Presenting problem context (10 minutes): This step of the course was initiated with a problem situation. Famous thought experiments and paradoxes related to the theory of special relativity, which were thought to be of interest to the students, were selected as problem contexts. The Michelson-Morley experiment, train paradox, twin paradox, ladder paradox and lighthouse paradox were used as problem contexts during the course. The problem contexts related to these subjects were projected on a screen. All students were asked to examine the problem contexts individually. The researcher initiated a class discussion to help students get a good understanding of the problem contexts by asking them a variety of questions. For example, a problem context involving the Michelson-Morley experiment was presented in a subject related to the speed of light. In this problem, the Michelson-Morley experiment was questioned in terms of its being carried out in the direction of the Earth’s rotation and a perpendicular direction to the Earth’s rotational direction.

Eliciting preconceptions (15 minutes): The students were asked to develop a solution for the problem context introduced in the previous step. All students then shared their suggestions for a solution with the group members. Then, the students were asked to develop a single solution proposal on behalf of the group as a result of this discussion. At this step, each group's monitoring specialist observed the views of himself and his group mates according to the steps expressed in the monitoring manual. The researcher wandered among the groups and asked questions aimed at eliciting the students' preconceptions for the solution of the problem. After the group discussion was over, the monitoring specialist of each group was given the floor. The monitoring specialists explained their solutions or solution proposals agreed by their groups to their classmates. Moreover, each monitoring specialist expressed his group's view, explaining what his group mates' thoughts were, and who changed or did not change their minds after the discussion. The views of the investigative group were summarized on the whiteboard.

Creating cognitive conflict (20 minutes): The correct answer to the problem situation presented to the students during the Presenting Problem Context step was expressed. At this step, simulations and animations on the internet about the problem context were used. Furthermore, it was ensured that the students noticed the discrepancy between the group opinion about the problem written on the whiteboard in the previous step and the outcome of the problem. At this point, a class discussion was held. During the discussion, the researcher posed several questions to determine whether the students experienced cognitive conflict. For instance, when talking about the speed of light, it is stated that the rays reaching the detector at the same time in any case and a simulation of the Michelson-Morley experiment (Virginia University Fowler's Physics Applets) was projected on the screen to perform it in a virtual environment.

Constructing scientific notions (20 minutes): The worksheets that the researcher prepared about the course subject were distributed to the students where each group received one pack. The students studied these worksheets as a group. The researcher wandered among the groups and answered the students' questions about the subject in the worksheets. Next, the scientific notions in the worksheets were briefly summarized by the researcher. Finally, the problem context mentioned at the beginning of the course was solved with the help of the scientific notions in the worksheets.

Defending scientific notion (15 minutes): Different problem about the concept that could be solved using scientific knowledge was projected on the screen. The students solved the problem according to the information given in the worksheets. At this step, the planning specialists of the groups established a solution plan for solving the problem with their group mates according to the steps expressed in the planning manual. The student groups worked to solve the problem. For instance, at this step, a problem was solved with regard to the speed of light in different environments from moving and stationary observers' perspectives.

Evaluation—compare, apply, metaknowledge (10 minutes): At this step, the students were asked to evaluate the conceptual change they experienced at the end of the one and half an hour instructional period. At this stage, the monitoring specialists explained the change in the views of the group members and their views about the concept they were taught according to the steps in the monitoring manual.

Data Collection Instruments of the Study

In this research, Theory of Special Relativity–Diagnostic Test which is a quantitative data collecting tool and Theory of Special Relativity–Semi-Structured Interview Form which is a qualitative data collection tool was used to determine students' conceptual change process. Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S) which is also a quantitative data collecting tool was used to determine the change in students' metacognitive levels. These measurement tools are explained in detail below.

The theory of special relativity–diagnostic test: The reason for students' responses in multiple-choice tests cannot be understood. Knowing the reasons for students' answers to the questions is important for the detection of the conceptual change process. Moreover, whether students are confident in their answers or not is also important for the conceptual change process. Hence, three-tier tests are more useful than multiple-choice tests to detect students' conceptual change. Because students can express their responses and confidence levels in this test (Sari and Abdurrahman, 2019). In this research, a three-tier test was used for the investigation of students' conceptual change process in detail. The development process and features of the Theory of Special Relativity – Diagnostic Test are explained below.

During the development of the diagnostic test, three-tier test development stages were taken into account (Çetinkaya and Taş, 2016). Firstly, a concept map was developed to detect of test's content and scope to ensure content validity. In this process, the 10th-grade physics course curriculum (Turkey Ministry of National Education, 2008) and Physics for Scientists and Engineers with Modern Physics (Serway, 1996) which is one of the university physics textbooks was utilized for the design of the concept map. The basic concepts were determined with the map and one case was formed for each concept. There was a case for each question related to the concepts of the speed of light, classical time, simultaneity, relative time, relative length and mass/energy in the Theory of Special Relativity–Diagnostic Test.

The first stage of the questions was a multiple-choice concept question, and the second stage was a question of justification for this concept question. In the third stage of the questions, the students were asked to state their confidence in the accuracy of their answers to the first two questions. The test included a total of 14 questions, three questions about each of the concepts of the speed of light, relative length and mass/energy, two questions about each of the concepts of simultaneity and relative time, and one question about the classical concept of time. The KR-20 reliability coefficient of this test, developed by the researchers, was calculated as 0.88. The average difficulty index of the test was 0.52. The discrimination indices for the concept questions of the test ranged from 0.30 to 0.49 and those for the justification questions ranged from 0.30 and 0.44.

The theory of special relativity – semi-structured interview form: Although the theory of special relativity–diagnostic test is convenient for measurement of conceptual changes process, students' views are limited by the options of the questions. For this reason, interviews that students would be able to explain their views without limitation were conducted. Obtaining data with interviews would also increase reliability of the data obtained with the diagnostic test. In addition, students' views were analysed in detail thanks to interviews data. Development process and features of semi-structured interview form are explained below.

A case was given for each of the concepts of speed of light, classical time, simultaneity, relative time, relative length and mass/energy in the interview form as in the diagnostic test. Both of the data collection tools are parallel to the each other in terms of their content.

Firstly, semi-structured interview pre-form which include these concepts about special relativity was formed. This pre-form was evaluated in terms of comprehensibility and suitability to student level by a physics teacher who had been worked for a secondary school for ten years. The pre-form revised in line with the teacher's suggestions. Secondly, the pre-form was used for interviews of the pilot study. Pre-form was rearranged thanks to experiences which were gained in these interviews and finally, the theory of special relativity–semi-structured interview form was formed.

Two students from the high-level and low-level groups and four students from the moderate-level group were interviewed before and after the actual implementation. These students were selected from their groups (high, low and moderate level groups) randomly.

General achievements in physics were taken into account in dividing the students into groups. The physics teacher of the students helped in this regard. At this stage of the research, the purpose of determining the students in this way is to increase the power of qualitative research findings to represent the class. Each interview lasted 15–20 minutes.

Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S): Metacognition is generally measured with Likert-type scales such as motivation, attitude, and self-efficacy. In this study, the Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S) scale developed by Thomas, Anderson and Nashon (2008) was used. The scale consists of 30 five-point Likert type items. The items were gathered under 5 factors. These factors on the scale include constructivist connectivity, monitoring, evaluation and planning, science learning self-efficacy, learning risks awareness, and control of concentration. Linguistic equivalence, validity and reliability studies of the scale were carried out. Based on the verification of the data through confirmatory factor analysis, it was seen that the five-factor structure of the original scale also applied to the Turkish version of the scale. Factor loading values of the items ranged from 0.50 to 0.73, while item-total score correlations ranged from 0.39 to 0.65. The Cronbach-alpha coefficient calculated for the entire scale was 0.93 (Author, 2016).

Data Analysis

Data analysis approach that was used for mixed method (PCMH Research Methods Series, 2013) in this study was outlined below.

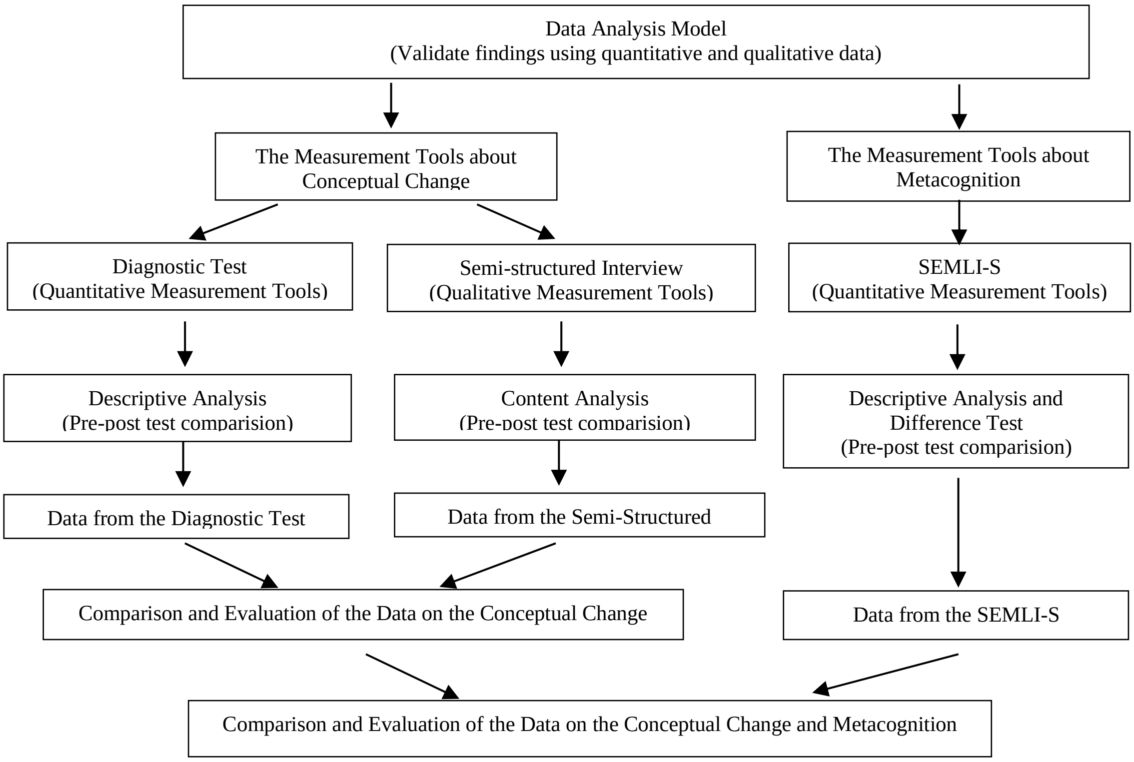

Figure 1 Data analysis approach for this study

Research data which are obtained by qualitative and quantitative data collection tools simultaneously were analysed independently each other. The research results were discussed and evaluated comparatively with a convergent approach.

Analysis of the theory of special relativity – diagnostic test data: Descriptive analysis was utilized for analysis of the theory of special relativity–diagnostic test. The data from the Theory of Special Relativity–Diagnostic Test were first divided into categories and subcategories. During the analysis of the Theory of Special Relativity–Diagnostic Test, the categories discussed by Hestenes and Halloun (1995) and used by Arslan, Çiğdemoğlu and Moseley (2012) were used, as shown in the table below.

Table 5 Categories for the Theory of Special Relativity – Diagnostic Test

Concept Question	Justification Question	Confidence in Accuracy	Categories
Correct	Correct	Confident	Scientific Concept
Correct	Incorrect	Confident	Misconception (False Positive)
Incorrect	Correct	Confident	Misconception (False Negative)
Incorrect	Incorrect	Confident	Misconception
Correct	Correct	Not confident	Lucky Guess, Low Confidence
Correct	Incorrect	Not confident	Incomplete concept
Incorrect	Correct	Not confident	Incomplete concept
Incorrect	Incorrect	Not confident	Incomplete concept

If the students accurately responded to the concept and justification questions and they were confident in their answers, they were considered within the category of scientific concept. The responses of the students collected under the false positive/false negative theme were considered as evidence for the internal validity of the scale (Hestenes and Halloun, 1995). If the students chose incorrect responses in the concept and justification questions and they were confident in their answers, they were considered within the category of misconception. If the students accurately answered the concept and justification questions but they were not confident in the accuracy of their answers, they were considered within the lucky guess or low confidence category (Arslan et al, 2012). The fact that the students' answer to one of the concept or justification questions was correct, or that they responded both the concept and justification questions incorrectly and they were not sure of their answer, they were considered within the category of incomplete concept. An incomplete concept represents a conceptual situation between a scientific concept and a misconception.

These categories contain different thoughts about the concepts of special relativity theory. Therefore, they were divided into subcategories as shown in the table below. In this study, only the data on the concepts of speed of light, simultaneity and energy/mass, which were inquired in the diagnostic test, were analysed. For this reason, the table below describes only the categories related to these concepts.

Table 6. Subcategories of Responses to the Theory of Special Relativity–Diagnostic Test*

Concept	Category	No	Subcategory	Concept	Category	No	Subcategory
Speed of Light	Scientific Concept/Lucky Guess Low Confidence	1	The speed of light is not affected by the speed of the observer and the source.	Energy/Mass	Scientific Concept/Lucky Guess Low Confidence	15	Mass is the amount of matter that does not change.
	Misconception / Incomplete Concept	2	The speed of light is affected by the speed of the source or the observer.		Scientific Concept/Lucky Guess Low Confidence	16	Objects with mass cannot reach the speed of light
	Misconception (False Positive) /Incomplete Concept	3	Light has the same velocity in all environments.		Misconception /Incomplete Concept	17	It is not possible to accurately measure the masses of objects moving at speeds close to the speed of light.
Simultaneity	Scientific Concept/Lucky Guess Low Confidence	6	Two events that are concurrent (simultaneous) according to one observer may not occur concurrently to another observer.		Misconception / Incomplete Concept	18	At speeds close to the speed of light, kinetic energy is converted into mass.
	Misconception (False Positive) / Incomplete Concept	7	The speed of light is affected by the speed of the source. But it is negligible.		Misconception / Incomplete Concept	19	The mass changes at speeds close to the speed of light.
					Misconception / Incomplete Concept	20	By doing work on an object, it is not possible to transfer more energy past a certain energy value.

* The numbers of the categories are not successive because this paper addresses categories related to the three questions of the Theory of Special Relativity–Diagnostic Test.

The research data on the students' distribution to above categories and subcategories before and after the course are presented in the findings section.

Analysis of the Semi-Structured Interview Form Data: Content analysis was used for analysis of the Semi-Structured Interview Form data. The interview records with students before and after the course were transcribed. Students' opinions repeated frequently and highlighted were taken into account. Reasonable and meaningful opinions of students converted into subcategories as in the diagnostic test.

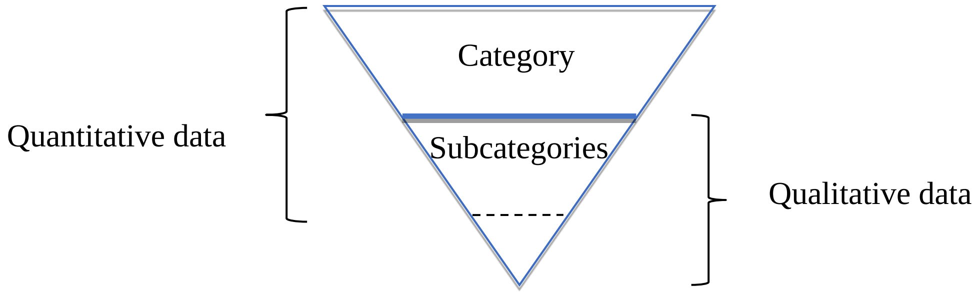

Figure 2 Combining qualitative and quantitative data

Qualitative data were used in the study to verify and elaborate the quantitative data as shown schematically in Figure 2. All of the subcategories that are determined by responses to interview form take place subcategories that are determined by the diagnostic test. In this case, it can be claimed that detected subcategories with these data collection tools are valid. The student opinions were distributed according to the subcategories shown in Table 6. The change between the students' response categories before the course and their categories after the course is shown schematically.

Analysis of the data from the self-efficacy and metacognition learning inventory—science (SEMLI-S) scale: Descriptive statistics and difference tests were utilized for analysis of Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S) Scale data. Students' responses were scored as follows: never 1 point; rarely 2 point; occasionally 3 point; often 4 point and always 5 point. According to this scoring, maximum point to be obtained from this scale is 150. The data from this scale were analysed using the SPSS 16.0 statistical package platform. When analysing the scale data, first, the Shapiro-Wilk test of normality was carried out. Significance levels for the pre-test and post-test responses given to the Self-Efficacy and Metacognition Learning Inventory scale were calculated as .12 and .75 respectively. Since these values are greater than .05, it is assumed that the data is normally distributed. After the normal distribution of the data was tested, dependent samples t-test was applied to examine the change in scale scores depending on the instruction. In the t-test, the significance was tested at the 0.05 level. In addition, mean scores for the factors of the scale were determined. The average scores before the instruction and the average scores after the instruction were also compared.

Findings

Research results are presented in this section.

Findings Obtained Through the Theory of Special Relativity–Diagnostic Test

Below are the percentage distributions of the student responses obtained from the Theory of Special Relativity–Diagnostic Test before and after the course according to the categories.

Table 7 Distribution of the Students' Responses to the Categories

Concepts	Scientific Concept (%)		Misc. (False Positive) (%)		Misc. (False Negative) (%)		Misc. (%)		Lucky Guess Low confidence (%)		Incomplete Concept (Superficial Knowledge) (%)	
	BC	AC	BC	AC	BC	AC	BC	AC	BC	AC	BC	AC
Speed of Light	9	47	12	34	1	2	32	1	7	1	39	6
Simultaneity	2	31	15	33	7	7	7	7	11	4	58	18
Mass and Energy	15	13	2	14	1	0	14	21	12	5	33	25
Overall Average	9	30	10	27	3	3	18	10	10	3	43	16

Misconceptions are abbreviated as Misc. Before the course is abbreviated as BC and after the course is abbreviated as AC.

When the overall average in Table 7 is examined, it can be concluded that the course reduced the students' misconceptions, their responses with lucky guess/low confidence and their incomplete concepts, and it increased their scientific concepts and false positive concepts. This situation shows that the teaching approach was effective in transforming misconceptions and incomplete concepts into scientific concepts. In addition to that, the fact that the number of false negative responses was low shows that the results are reliable. Considering the changes in concepts on an individual basis, it was concluded that the course contributed most frequently to the formation of the correct concept related to the speed of light. The course also contributed positively to the conceptual change regarding simultaneity. However, the course caused the students' correct concepts related to the concepts of energy and mass to turn into misconceptions. It is therefore necessary to examine the categories in detail in order to understand the cause of this situation. Below are the percentage distributions of the student responses obtained from the Theory of Special Relativity–Diagnostic Test before and after the course according to the subcategories.

Table 8 Distribution of the Students' Responses into Subcategories

Concept	Subcategory	BC Response (%)	AC Response (%)
Speed of Light	1	15	47
	2	6	0
	3	11	22
Simultaneity	6	13	35
	7	14	19
Energy/Mass	15	50	12
	16	4	24
	17	6	4
	18	4	52
	19	6	4
	20	22	40

The conceptual changes about three subcategories were identified for the concept of speed of light. Descriptions of these subcategories are presented in Table 6. Subcategory 1 contains a correct explanation, and Subcategory 2 contains an incorrect explanation. The frequency of Subcategory 1 increased and the frequency of Subcategory 2 decreased, indicating that the students learned through the effect of the course that the speed of light was independent of the speed of the observer and the source. Moreover, Subcategory 3 contains an incorrect explanation. The frequency of this subcategory increased with the effect of the course, revealing that some of the students over-generalized the situation and incorrectly learned the case of the speed of light moving at a constant speed in space as the rule of light moves at the same speed in all environments.

The conceptual changes about two subcategories for the simultaneity were examined. Subcategory 6 contains a correct explanation, and Subcategory 7 contains an incorrect explanation. The increase of the frequency of Subcategory 6 due to the effect of the course indicates that the students learned that events that happened at the same time according to one observer may not happen at the same time according to another observer. The increase in the number of responses to Subcategory 7 suggests that, despite the impact of teaching, some of the students still hold the idea that 'the speed of light is affected by the speed of the source but is negligible'.

When the conceptual changes concerning six categories related to energy and mass concept were investigated, the increase in the frequency of Subcategory 16 that contains a correct explanation indicates that the course helped students learn that objects' masses could not reach the speed of light. Subcategory 15 contains another correct explanation, and Subcategory 18 contains an incorrect explanation. The decrease of the frequency of Subcategory 15 and the increase of the frequency of Subcategory 18 due to the effect of the course shows that the course transformed the idea that "mass is the amount of matter that does not change" some students had into the idea that "kinetic energy turns into mass at speeds close to the speed of light." On the other hand, one of the notable findings of this research is related to Subcategory 20. There is an increase in students' responses in this subcategory after teaching. This increase shows that the students have learned that there is a limit to the speed at which the particles accelerated by applying a force.

Findings Obtained through the Semi-Structured Interview Form

The findings obtained as a result of the interviews conducted within the scope of the research are presented in Figure 3.

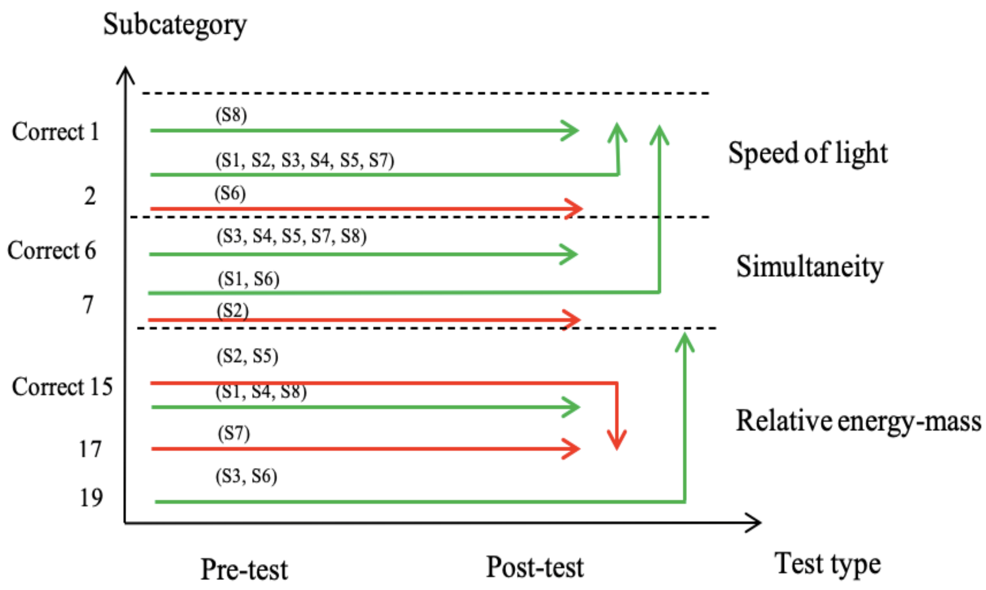

Figure 3 Changes in students' interview responses by subcategories

The codes in the form of S1, S2, etc. ... represent the students who were interviewed. The numbers in the form of 1, 2, 6, etc. ... in the vertical axis represent the subcategories explained in Table 6. Figure 3 specifies the students' response subcategories before and after the course. The change in the subcategories of each interviewed student before and after the course is expressed in lines. Red lines show the changes in subcategories in conceptually undesirable directions or subcategories that did not change after the course. However, green lines show the changes in the subcategories in the desired direction.

As the conceptual change about the speed of light is considered, six students (S1, S2, S3, S4, S5 and S7) switched from Subcategory 2 to Subcategory 1 due to the influence of the course. This indicates that the students who thought that the speed of light depended on the speed of the source and the observer before the course learned that the speed of light was independent of the speed of the observer and the speed of the source after the instruction. A student, who is S6, in Subcategory 2 maintained his view before and after the course. Before and after the course, this student believed that the speed of light depended on the speed of the source and the observer. Student 8 is the one who responded scientifically acceptable notions and took place in the Subcategory 1 in the pre and post interviews.

When the conceptual change about simultaneity is considered for students interviewed, five students (S3, S4, S5, S7 and S8) gave answers suitable for Subcategory 6 before and after the course. Before and after the course, these students maintained that two events that happened at the same time according to one observer may not happen at the same time according to another observer. Two students (S1 and S6) switched from Subcategory 7 to Subcategory 1 due to the influence of the course. This reveals that prior to the course, the students, who had the idea that the speed of light was affected by the speed of the source but this was negligible, learned that the speed of light was independent of the speed of the observer and the source after the instruction. However, student 2 maintained his view and responded that the speed of light was affected by the speed of the source despite teaching.

When students were interviewed about the concept of energy and mass, three of them (S1, S4 and S8) gave answers suitable for Subcategory 15 before and after the course. The students in this category maintained their scientifically correct views which meant that mass was the amount of matter that did not change. Two students (S2 and S5) switched from Subcategory 15 to Subcategory 17 after teaching. This shift indicates that the students who thought that mass was the amount of matter that did not change before the course altered their ideas due to the effect of the course and believed that it was not possible to measure accurately the mass of objects moving at speeds close to the speed of light. Two students (S3 and S6) switched from Subcategory 19 to Subcategory 15 after instruction. This shift indicates that the students, who had the idea that mass changed at speeds close to the speed of light before the course, started using the acceptable idea of 'mass was the amount of matter that did not change'. Only student 7 preserved his idea that it would not be possible to measure accurately the masses of objects moving at speeds close to the speed of light despite teaching. Below, Table 9 presents the correct interview responses of some of the students before and after the course.

Table 9 Samples from Students' Interview Responses

Concept	Student Code	Student Response Before the Course	Student Response After the Course
Speed of Light	S2	A stationary observer measures it as 3.108 m/s, but a moving observer measures it as 2.108 m/s or 5.108 m/s depending on the direction of the movement.	Don't they both make the same measurement? This is because the speed of light does not depend on the movement of the observer.
Simultaneity	S8	It flashes simultaneously for the first one (referring to the stationary observer). The other (referring to the moving observer) sees that D flashes earlier. This is because he is moving towards the flash.	I remember something like this in the train paradox presented in the class. Both observers came to the same conclusion. But one of them saw Y to flash earlier. It meant that the concept of simultaneity was relative.
Energy/Mass	S3	I think that at speeds close to the speed of light, the mass of objects decreases. Something with a mass that's fast passes very quickly. That's why we measure it lighter. But would it change or not? Is it okay if I don't say anything about it?	The mass of these protons increases. This is because we're moving so fast, you're accelerating it from E=mc2 and F=m.a. You're accelerating it. Its energy has to increase to the speed of light. Because c is constant, the energy is materializing or so. But the mass is actually the same.

The results obtained by the analysis of the interview data are similar to the results obtained by the analysis of the Diagnostic Test. The results obtained with both data collection tools show that the teaching approach of the research has certainly contributed, at least to some extent, to the conceptual change of students. Conceptual change data obtained by both data collection tools were evaluated and interpreted together in the next section.

Findings Obtained through the Self-Efficacy and Metacognition Learning Inventory—Science (SEMLI-S) Scale

The pre-test–post-test comparison of analysis results for the Self-Efficacy and Metacognition Learning Inventory Scale is shown in Table 10. Although 51 students participated in the study, three students were excluded from the scale because they answered only part of the scale. Therefore, 48 students were included in the analysis of the scale.

Table 10 Pre-test–post-test comparison of the Self-Efficacy and Metacognition Learning Inventory Scale

	Average	N	SD	df	t	p
Pre-test	98.02	48	17.16	47	-1.077	.287
Post-test	100.88	48	20.74			

The difference was not significant (significance level: p<.05) Maximum Score = 150

When the table above is examined, it is concluded that the average score of the students after the course was higher than their average scores before the course. However, this difference was not statistically significant.

Table 11 Average Scores for the Self-Efficacy and Metacognition Learning Inventory Scale's Dimensions

Scale Dimensions	Highest Possible Score	Mean Post-Test Score	Mean Pre-Test Score
Constructivist Connectivity	35	23.35	22.02
Monitoring, evaluation and planning	45	29.35	27.77
Self-efficacy in physics learning	30	18.75	18.77
Learning risks awareness	25	19.29	19.43
Control of Concentration	15	10.14	10.02
Total	150	100.88	98.02

Analysis was carried out by tracking the differences in average scores for the scale factors. When Table 11 is examined, it is understood that the students' average constructivist connectivity, monitoring, evaluation and planning, control of concentration factor scores after the course were higher than their average scores before the course. Nevertheless, there was no improvement in the average scores of the students in the factors of self-efficacy in physics learning and learning risks awareness after the course.

In the next section, the findings of the research about conceptual change and metacognition are evaluated and discussed together in terms of the teaching approach adopted in this study.

Conclusion and Discussion

In this study, the effects of an original teaching approach in accordance with the conceptual change theory on conceptual change and metacognition were investigated. When the conceptual change-related findings of this study are examined as a whole, it is concluded that the metacognitive supported argument-based learning approach was effective in transforming the students' misconceptions and incomplete concepts about the theory of special relativity to scientific concepts. The results of the study are in line with the literature. It has been verified by many research studies that instructional approaches involving metacognition contribute to the learning of students (Ültay et al. 2015; Kural 2015; Yıldız, 2008; Seraphin et al. 2012; White and Frederiksen 1998; Anandaraj and Ramesh 2014; Jayapraba 2013).

The speed of light, as a concept, is a prerequisite for learning other concepts of the theory of special relativity (Scherr et al. 2001). It was concluded that the students' pre-conceptions about the speed of light before the course corresponded to the classical relative speed. A majority of the students calculated the speed of light prior to course based on the speed of the observer and the source in accordance with the Galilean transformation equations as reported by Özdemir et al. (2014). After the course, a majority of the students calculated the speed of light independently of the speed of the source and the observer. However, it was found that due to the effect of the course, some of the students adopted a new misconception about the speed of light. This new misconception was that light travels at the same speed in all environments. For these students, the fact that the speed of light was independent of the speed of the source and the observer turned, due to the instruction, into a general idea that light travelled at the same speed in every environment. This result shows that when an existing concept is displaced during conceptual change, it may be replaced by either the correct concept or another misconception. Another finding of the study about the speed of light was that the students used scientific concepts and misconceptions together. A student answered the question about the speed of light after the course as follows: "the speed of light is affected by the speed of the source and the observer." He answered the question about simultaneity as "The speed of light is affected by the speed of the source and the observer, but this effect is negligible." This situation has been interpreted as that students do not abandon their preconceptions during conceptual change and may use their preconceptions and scientific concepts together, depending on the situation (Yıldız, 2008).

Another reason why students use scientific concepts and misconceptions together is that students who find the process of cognitive conflict uncomfortable (Planinic et al. 2005; Kapartzianis, 2012) may not abandon the preconception but accept the scientific concept. When these findings of the study are considered as a whole, it can be stated that it is not an automatic process for conceptual change to abandon a misconception due to the inadequacy of it and to replace it with a scientific concept (Villani and Arruda, 1998).

Another outcome of the study was about the concept of simultaneity. The concept of simultaneity is closely related to the concept of the speed of light. Scherr et al. (2001) have expressed that insufficient knowledge about the concepts of reference systems and the speed of light leads to the lack of knowledge of simultaneity and impede the correct implementation of Lorentz transformation equations. Simultaneity is a concept that is not taught in classical physics (Scherr et al, 2001). In this study, it was concluded that the students who could not give correct answers and explanations about this concept before the course made correct explanations about this concept after teaching.

Finally, the conceptual change of the students regarding the concepts of energy and mass was examined in the study. Prior to the course, the students defined mass as the amount of matter that did not change. After the course, the students stated that mass was converted into energy at speeds close to the speed of light. This result means that the students had an increased number of misconceptions about mass at the end of the course. Turgut et al. (2013) have also reported that there is an increase after teaching in the number of students who think that mass increases at speeds close to the speed of light. Selçuk (2011) has stated that this misconception increases due to students' inaccurate generalizations and intuitive ideas. As an outcome of this study, the increase in the number of misconceptions related to the mass concept can be interpreted as that the students conceptualized "mass internal energy equivalence," which is used for referring to particles moving at speeds close to the speed of light, as a mass increase (Selçuk and Çalışkan, 2010). During the study, the students were not informed about a concept of mass that varied depending on speed, as stated in the 10th-Grade Physics Curriculum (2009), to avoid causing a misconception like "kinetic energy transforms into mass" (Turkey Ministry of National Education, 2008). But popular science publications, internet-based non-scientific sources, and even textbooks present information that mass varies depending on speed as also emphasized by Selçuk (2011). Such an unacceptable view, which affects the conceptual ecology of students, can be said to be directly related to the fact that the relationship between the rest mass energy ($\mathrm{E_0}$) and the speed of light (c) in Einstein's equation of $\mathrm{E_0} = \mathrm{mc}^2$ evokes the relationship between kinetic energy and speed in students' minds.

As a result of this study, four different situations have emerged for the students' conceptual change. Students can preserve their non-scientific preconceptions, switch to a scientific concept, use two concepts together, or create a new non-scientific concept when learning a concept. In which of these situations a student may be included after teaching varies depending on many variables. These variables create the conceptual ecology (Duit and

Treagust, 1998; Posner et al, 1982; Pintrich et al, 1993). To reduce the negative influence of conceptual ecology during teaching, it is proposed first to change students' concepts made up of intuitive, metaphysical or incomplete knowledge into classical physics concepts. Therefore, when teaching special relativity, it is suggested to incorporate the transformation of preconceptions to classical physics concepts into the instructional approach of this study as the first step. Moreover, the cognitive conflict needs to be strong to achieve conceptual change (Villani and Arruda, 1998). Since it is not possible to experiment on the subject of this study, teaching materials such as virtual laboratories, simulations and animations should be developed to teach the theory of special relativity. These materials can contribute to the implementation of cognitive conflict by improving the credibility of scientific knowledge.

In this research, it was concluded that there was an increase in the metacognition levels of students with the effect of teaching. However, this increase was low. When the sub-dimensions of the scale were examined, it was found that the increase observed in the metacognition scale scores was mainly due to the monitoring, evaluation and planning dimension of the scale. Considering that the strategies used in the teaching approach of the research are also related to these dimensions of metacognition, it can be said that the teaching made stimulates the students' organization of cognitive skills. It was observed that at the beginning of the course, the students were not very enthusiastic to implement metacognitive strategies and had difficulty using metacognitive strategies in the subsequent weeks. Based on the experiences obtained from this study, it was understood that it was not easy to activate the students' metacognitive abilities. Considering the difficulty of stimulating metacognition, which is also emphasized by other researchers (Yıldız, 2008; Özkan and Bümen, 2014), it can be argued that there will be significant improvements in metacognitive skills if teachers and researchers use metacognitive strategies for a long time in class discussions to allow students to be able to use their metacognitive strategies effectively. Additionally, it can also be said that the addition of the activities related to the sub-dimensions of metacognition such as constructivist connectivity, self-efficacy, awareness of learning risks and control of concentration to the teaching plan implemented in this study will strengthen teaching in terms of its contribution to metacognition.

When the results of this research are evaluated as a whole, the metacognitive supported argument-based learning approach contributed to the conceptual change of the students about special relativity theory and increased the students' metacognitive thinking skills especially for regulation of cognition. Additionally, this research contains information about how students will accept a scientific concept during conceptual change and how this concept should be presented to students. With this aspect of the study, it is thought that it will be beneficial for both researchers and teachers.

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Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi (EFMED)
Cilt 15, Sayı 1, Haziran 2021, sayfa 186-215. ISSN: 1307-6086

Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Vol. 15, Issue 1, June 2021, pp. 186-215. ISSN: 1307-6086

Araştırma Makalesi / Research Article

ARCS Kategorileri İle Bütünleşmiş Bilişsel Öğrenme Modelinin Öğrencilerin Çokgenler ve Üçgenler Konusundaki Öğrenme Düzeylerine ve Motivasyonlarına Etkisi

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Gönderme Tarihi: 01.04.2021 Kabul Tarihi: 21.04.2021

Doi: 10.17522/balikesirnef.907736

Özet – Bu araştırmada, ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modelinin beşinci sınıf öğrencilerin çokgenler ve üçgenler konusundaki öğrenme düzeylerine ve motivasyonlarına etkisinin belirlenmesi amaçlanmıştır. Araştırmada son test kontrol gruplu model kullanılmıştır. Deney grubu 137 ve kontrol grubu 137 öğrenciden oluşmuştur. Deney grubu öğrencilerine, çokgenler ve üçgenler konusu ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeline dayalı olarak, kontrol grubu öğrencilerine geleneksel öğretim yöntemine dayalı olarak işlenmiştir. Araştırmada, geometri başarı testi ve geometri kavram algılama testi kullanılmış ve geometri motivasyon ölçeği ve geometri motivasyon profili ölçeği geliştirilerek veriler toplanmıştır. Verilerin analizinde t testinden yararlanılmıştır. Araştırma verilerinin analizi sonucunda, deney grubu öğrencilerinin kontrol grubu öğrencilerine göre başarı ve kavram algılama düzeylerinin daha yüksek olduğu görülmüştür. Kontrol grubundaki öğrencilerin deney grubundaki öğrencilere kıyasla geometri dersinde kendilerini yetersiz gördüğü ve korkularının daha fazla olduğu tespit edilmiştir. Diğer bir sonuç ise deney grubu öğrencilerinin kontrol grubu öğrencilerine kıyasla doyum puanlarının yüksek olması ve geometri dersine yönelik dikkatlerinin daha fazla olmasıdır.

Anahtar kelimeler: ARCS kategorileri, Bilişsel öğrenme modeli, başarı düzeyi, kavram algılama düzeyi, motivasyon

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Geniş Özet

Giriş

Geometri dünya çapında önemli bir alan olup birçok bilim dalında yaygın olarak kullanılmaktadır. Geometride, matematikte olduğu gibi öğrenciler farklı bakış açıları sayesinde problemleri analiz ederek çözebilir, ilişkiler kurup soyut kavramları geometrik gösterimler yoluyla daha basit şekilde anlaşılır kılabilir. Öğrenciler ilköğretim üçüncü sınıfta geometri ile tanışmakta ve öğretim yıllarının ilerlemesi ile geometri ile ilgili kavramları daha karmaşık bir şekilde öğrenmektedir. Burada önemli olan öğrencilerin olası bir yanlış kavrama ve hataya düşmemeleri için geometrik kavramları hiyerarşik bir sıra halinde öğrenmeleri gerektiğidir. Öğrenciler ilköğretim düzeyinde iken geometri öğretimi iyi kavratılmaz ise ortaöğretim düzeyinde geometri öğretiminde büyük sıkıntılar meydana gelebilir. Ülkemizde geometri alanında yeterli çalışma bulunmamasına rağmen, yapılmış olan çalışmalardan geometri öğretiminin öğrenciler tarafından anlaşılmasının büyük bir problem olduğu bilinen bir gerçektir.

ARCS Motivasyon Modeli

Keller, bu motivasyon modelini öğrencilerin öğrenme ortamlarında motivasyonlarını sağlayarak sürekliliğini ortaya koyan ve öğrencileri motive edecek ortamları tasarlayan bir model olarak tanımlamıştır (Keller, 1983). Keller'in ARCS Motivasyon Modelinin öğretim alanına en önemli katkısı, modelin yalnızca güdüleme kategorilerinin belirlenmesi ve sınıflandırılması ile kalmayıp her kategori ve alt kategorilere ilişkin öğretim stratejilerine de yer verilmiş olmasıdır. Bu şekilde ARCS Motivasyon modeli öğretim alanlarında daha kolay bir şekilde kullanılabilecek ve her alt stratejide öğrenci özelliklerinin tanımlanması sağlanacaktır (Tahiroğlu, 2015).

Bilişsel Öğrenme Modeli

Bilişsel Öğrenme Modeli (Öğe Gösterim Teorisi) Merrill (1983) tarafından bir kavramı, ilkeyi veya işlemi öğreterek öğrencilerin öğrenme kapasitelerini arttırmak için geliştirilen bir öğretim teorisidir. Literatürde Öğe Gösterim Teorisi olarak adlandırılmakta olup yalnızca bilişsel öğrenmeleri içeren ve mikro düzey stratejileri ile ilgilenen bir kuram olduğu için araştırmacı tarafından çalışmada bilişsel öğrenme modeli olarak adlandırılmıştır. Bilişsel öğrenme alanı ile sınırlandırılıp duyuşsal ve psikomotor öğrenme alanlarını kapsamadığı için model öğretmen ve öğretim tasarımcılarına daha çok rehberlik olanağı sağlamaktadır (Dede, 2003).

Çalışmada ARCS kategorileri ile bütünleşmiş Bilişsel öğrenme modeli bir arada kullanılarak öğrencilerin çokgenler ve üçgenler konusundaki öğrenme düzeylerine ve motivasyonlarına etkisini ortaya koymak amaçlanmıştır. Bu amaç doğrultusunda aşağıdaki problemlere yanıt aranmıştır;

1. ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan deney grubu öğrencileri ile geleneksel öğretim uygulanan kontrol grubu öğrencilerin geometri başarı düzeyleri arasında anlamlı bir fark var mıdır?
2. ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan deney grubu öğrencileri ile geleneksel öğretim uygulanan kontrol grubu öğrencilerin kavram algılama düzeyleri arasında anlamlı bir fark var mıdır?
3. ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan deney grubu öğrencileri ile geleneksel öğretim uygulanan kontrol grubu öğrencilerin geometri motivasyon puanları arasında anlamlı bir fark var mıdır?
4. ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan deney grubu öğrencileri ve geleneksel öğretim uygulanan kontrol grubu öğrencilerinin son test geometri motivasyon profili puanları arasında anlamlı fark var mıdır?

Yöntem

Araştırma Modeli

Araştırmada son test kontrol gruplu model kullanılmıştır (Büyüköztürk, Çakmak, Akgün, Karadeniz ve Demirel, 2012). ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan öğrenciler deney grubu, geleneksel öğretim modeli uygulanan öğrenciler kontrol grubu olarak seçilmiştir. Bu gruplar yansız bir seçimle oluşturulmuştur. Grupların her ikisine de deney sonrası son test uygulanmıştır. Deneysel çalışma öncesi grupları benzer olduğu gruplar arası farklılık olmadığı kabul edilmiştir (Karasar, 2012).

Çalışma Grubu

Çalışma grubu 2020-2021 eğitim-öğretim yılında Kırklareli ilinin Lüleburgaz ilçesinde bulunan 274 5. sınıf öğrencisidir. Bu kapsamda 137 öğrenci deney grubu 137 öğrenci kontrol grubunu oluşturmuştur. Çalışma grubunu oluşturan öğrenciler tesadüfi örnekleme yöntemi ile belirlenmiştir.

Veri Toplama Araçları

Bu çalışmada öğrencilerin çokgenler ve üçgenler konusundaki başarı ve motivasyon düzeylerini belirlemek için Geometri başarı testi ve Geometri motivasyon ölçeği kullanılmıştır. Uygulama için Milli Eğitim Bakanlığı'ndan gerekli izinler alınmıştır.

Verilerin Analizi

Veriler SPSS 21.0 paket programı kullanılarak analiz edilmiştir. Deneysel işlem sonrası ARCS kategorileri ile bütünleşmiş Bilişsel öğrenme modeli uygulanan deney grubu ile geleneksel öğretim uygulanan kontrol grubunun başarı düzeyleri ve kavram algılama düzeylerinde anlamlı farklılık olup olmadığını belirlemek için t-testi yapılmıştır. ARCS kategorileri ile bütünleşmiş Bilişsel öğrenme modeli uygulanan deney grubu ve geleneksel öğretim uygulanan kontrol grubunun motivasyon ölçeği alt boyutları ve motivasyon profili ölçeği alt boyutlarına ilişkin farkın anlamlılığını tespit etmek için t-testi uygulanmıştır.

Bulgular

Bu bölümde deneysel işlem sonrasında toplanmış olan verilerin istatistiksel çözümlemelerine ilişkin araştırma sonucunda elde edilen bulgular yer almaktadır.

Deney ve kontrol grubu öğrencilerinin geometri başarı düzeylerine ilişkin bulgular

ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan deney grubu öğrencileri ile geleneksel öğretim yöntemi uygulanan kontrol grubu öğrencilerinin çokgenler ve üçgenler başarı testi puan ortalamaları farklılık göstermektedir. ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan deney grubu öğrencilerinin geleneksel öğretim yöntemi uygulanan kontrol grubu öğrencilerine göre başarı düzeyinin daha yüksek olduğunu göstermektedir.

Deney ve kontrol grubu öğrencilerinin kavram algılama düzeylerine ilişkin bulgular

ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan deney grubu öğrencileri ile geleneksel öğretim yöntemi uygulanan kontrol grubu öğrencilerinin çokgenler ve üçgenler kavram algılama testi puan ortalamaları farklılık göstermektedir. ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan deney grubu öğrencilerinin geleneksel öğretim yöntemi uygulanan kontrol grubu öğrencilerine göre kavram algılama düzeyinin daha yüksek olduğunu göstermektedir.

Deney ve kontrol grubu öğrencilerinin motivasyon düzeylerine ilişkin bulgular

Geleneksel öğretim yöntemi uygulanan kontrol grubundaki öğrencilerin ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan deney grubu öğrencilerine göre geometri dersine yönelik kendini yetersiz görmeleri ve geometri dersine yönelik korkuları daha yüksektir.

Deney ve kontrol grubu öğrencilerinin motivasyon profili düzeylerine ilişkin bulgular

ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli uygulanan deney grubu öğrencilerinin geleneksel öğretim yöntemi uygulanan kontrol grubu öğrencilerine göre geometri dersine yönelik dikkatlerinin daha fazla olduğu görülmektedir. Ayrıca kontrol grubundaki öğrencilerin deney grubundaki öğrencilere kıyasla edindikleri deneyimlere bağlı olumlu düşünceleri daha fazladır.

Sonuç ve Tartışma

Çalışmaya katılan öğrencilerin çokgenler ve üçgenler konusundaki başarı düzeylerine ilişkin bulgular incelendiğinde, ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli yaklaşımı uygulanan deney grubu öğrencilerinin geleneksel öğretim uygulanan kontrol grubu öğrencilerine göre çokgenler ve üçgenler konusu öğreniminde daha başarılı oldukları ortaya çıkmıştır. Ayrıca ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modelinin konunun öğrenilmesinde etkili olduğu olumlu yönde sonuç verdiği söylenebilir. Bu çalışmanın sonuçlarına benzer Dede (2003) tarafından yapılan araştırmada da görülmektedir. Dede (2003) çalışmasında ARCS Motivasyon Modeli ve Öğe Gösterim Teorisine dayalı yaklaşımın değişken kavramının öğrenci başarısına etkisinin olup olmadığını araştırmış ve araştırma sonucunda öğrencilerin öğrenme düzeyleri bakımından deney grubu lehine anlamlı bir farklılık elde etmiştir. Aynı şekilde Yeşiltepe (2019) ve Narmanlı (2019)'da çalışmalarında ARCS Motivasyon modeline göre tasarlanmış bir öğretim uygulayarak öğrenci başarısını incelemiş ve çalışma sonucunda modelin akademik başarıyı arttırdığı sonucu elde edilmiştir. Bu araştırmalar çalışmanın bulguları ile paralellik göstermektedir.

Çalışmaya katılan öğrencilerin çokgenler ve üçgenler konusundaki kavram algılama düzeylerine ilişkin bulgular incelendiğinde, ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli yaklaşımı uygulanan deney grubu öğrencilerinin geleneksel öğretim uygulanan kontrol grubu öğrencilerine göre çokgenler ve üçgenler konusunda kavram algılama düzeylerinin daha yüksek olduğu söylenebilir. Yani, ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli öğrencilerin konuyu kavramasında olumlu yönde sonuç göstermiştir.

Çalışmaya katılan öğrencilerin geometri dersi motivasyon düzeylerine ilişkin bulgulara bakıldığında, geometri motivasyon ölçeği alt boyutları olan geometri yetersizliği ve geometri korkusu puan ortalamalarında istatistiksel olarak anlamlı fark ortaya çıkmıştır. Geleneksel öğretim yöntemi ile öğrenim gören kontrol grubu öğrencilerinin geometri dersinde kendini yetersiz gördüğü söylenebilir. Ayrıca geleneksel öğretim yöntemi ile öğrenim gören kontrol grubu öğrencilerinin ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli yaklaşımı ile öğrenim gören deney grubu öğrencilerine kıyasla geometri dersine yönelik korkularının daha fazla olduğu söylenebilir. Benzer olarak Balantekin ve Bilgin (2017) çalışmasında ARCS Motivasyon Modelinin öğrencilerin motivasyon düzeylerini etkilediği sonucuna ulaşmıştır. Narmanlı (2019)'da yaptığı araştırmada benzer bulgulara ulaşmıştır. Çalışmasında ARCS Motivasyon Modelinin öğrencilerin motivasyon düzeyine etkisini incelemiş ve modelin öğrencilerin motivasyonunu arttırdığını, süreçte öğrencileri aktif kıldığını ve süreç boyunca öğrencilerin dikkatinin korunduğunu tespit etmiştir. ARCS Motivasyon Modelinin öğrenci motivasyonuna etkisinin olmadığı sonucuna ulaşan çalışmalarda mevcuttur. Örneğin, Dede (2003) araştırmasında ARCS Motivasyon Modelinin öğrencilerin matematik dersine yönelik motivasyon etkisini incelemiş ve öğrencilerin motivasyon son test puanları arasında anlamlı bir fark olmadığını tespit etmiştir.

Öğrencilerin geometri dersi motivasyon profili etkisine ilişkin bulgulara göre geometri motivasyon profili ölçeği alt boyutları doyum ve dikkat puan ortalamalarında istatistiksel olarak anlamlı fark saptanmıştır. Geleneksel öğretim yöntemi ile öğrenim gören kontrol grubu öğrencilerinin geometri dersine yönelik doyum puanları daha yüksektir. Ayrıca deney grubu öğrencilerinin derste dikkatini sürdürme konusunda kontrol grubu öğrencilerine göre daha başarılı oldukları söylenebilir. Dinçer (2020) motivasyon ile ARCS modeline göre tasarlanan materyaller arasında ilişkiyi inceleyen bir meta-analiz çalışması yapmış ve çalışma sonucunda materyallerin motivasyon üzerinde olumlu etkisi olduğu sonucuna ulaşmıştır. Materyal kullanım süresinin artması ile öğrencilerin motivasyonunun arttığını tespit etmiştir. Koon Wah (2015) çalışmasında, dikkat, ilişki, güven ve doyum stratejilerini entegre ederek Geogebra kullanıp öğretim yapmış ve lise öğrencilerinin motivasyon ve başarılarına etkisini araştırmıştır. Öğretim öncesi ve sonrası öğrencilerin motivasyon ve başarısında anlamlı farklılık tespit etmiştir. Bu araştırmalar modelin motivasyon üzerinde olumlu etkisinin olduğunu göstermekte ve çalışmanın bulguları ile örtüşmektedir.

Özetle, bu çalışmanın bulguları doğrultusunda beşinci sınıf öğrencilerinin çokgenler ve üçgenler konusunun öğretiminde uygulanan ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli yaklaşımının öğrenme düzeyinde mevcut öğretim yöntemine kıyasla daha etkili olduğu ve motivasyonu olumlu yönde etkilemiştir. Çokgenler ve üçgenler konusunun birçok matematiksel kavramı ve geometrik öğeleri barındırması, ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modelinin bir öğretim ortamında kullanılarak öğrenci motivasyonunun sağlanıp devam ettirilmesi ve göz ardı edilen güdüleme boyutunun ele alınması çalışmanın önemini ön plana çıkarmakta olduğundan literatüre ve teoriye katkı sağlayacaktır.

Öneriler

Bu araştırma sonuçları göz önüne alınarak eğitimciler ve araştırmacılara modelin çalışma örneklerine az rastlanıldığı için bu konuda daha fazla çalışma yapılması önerilebilir. Modelin farklı derslerde ve farklı sınıf düzeylerine uygulanarak etkisi araştırılabilir. Araştırmada, ARCS kategorileri ile bütünleşmiş bilişsel öğrenme modeli yaklaşımı uygulanarak öğrencilerin öğrenme düzeylerine ve motivasyonlarına etkisi incelenmiştir. Bu değişkenlerden farklı tutum, bilginin kalıcılığı gibi farklı değişkenler ele alınarak modelin etkisi araştırılabilir. Model geometri alanında farklı konulara uyarlanabilir.

The Effect Of The Cognitive Learning Model Integrated With ARCS Categories On The Learning And Motivation Levels Of Students About Polygons And Triangles

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Received : 01.04.2021 Accepted : 21.04.2021

Doi: 10.17522/balikesirnef.907736

Abstract – In this study, it is aimed to determine the effect of the integrated cognitive model of learning with ARCS categories on the learning and motivation levels of fifth grade students about polygons and triangles. The post-test control group model was used in the study. Both the experimental group and the control group consisted of 137 students. The subject of polygons and triangles was taught to the experimental group students based on the integrated cognitive model of learning with ARCS categories, and to the control group students based on the traditional method of teaching. In the present study, geometry achievement test and geometry concept perception test were used, and the data were collected by developing the geometry motivation scale and the geometry motivation profile scale. Thus, t test was utilized in the analysis of the data. As a result of the analysis of the research data, it was seen that the experimental group students had higher levels of achievement and concept perception compared to the control group students. Moreover, it was determined that the students in the control group considered themselves insufficient and had more fear towards geometry lessons compared to the students in the experimental group. Furthermore, the satisfaction scores of the experimental group students were higher and they paid more attention to the geometry lessons than the control group students accordingly.

Key words: ARCS categories, Cognitive model of learning, achievement level, concept perception level, motivation

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Introduction

Geometry is an important field worldwide and is widely used in many disciplines. In geometry, as in mathematics, students can analyse and solve problems from different perspectives, establish relationships and make abstract concepts more easily understood through geometric representations. Geometry learning begins at a very young age with the students examining their environments by familiarizing themselves with. Therefore they perceive the differences among the shapes by examining the objects they see in their environments and try to find the common aspects. As the age gets older, they go into the system more and continue their geometric thinking learning at a high level from the point of view of induction and deduction. While learning process continues, students may fall into many misconceptions and mistakes. Students are introduced to geometry in the third grade of elementary education and learn more complex concepts related to geometry as the school years progress. The students should learn geometric concepts in a hierarchical order in order to avoid any possible misunderstanding and mistake. If the teaching of geometry is not well understood while students are at primary education level, there may be serious problems in teaching geometry at secondary education level. Although there is not enough study in the field of geometry in our country, geometry teaching is rather difficult to be grasped by the students.

ARCS Model of Motivation

Motivation is a force initiates and directs behaviour and directly affects the success factor. Keller has done a lot of research on the topic of motivation. In 1987, he developed the ARCS Model of Motivation as a result of his studies on human motivation. Keller defined motivational model as a model that sets students' motivation in learning environments and designs environments that will motivate students (Keller, 1983). According to Keller (1987b), what is quintessential to boost people's motivation is the thing that students should figure out what the concept of motivation is and that the way to be followed in order to increase motivation should be planned and programmed while being transferred to the lesson environments.

The most important contribution of Keller's ARCS Motivation Model to the field of teaching is that the model is not only determined and classified by the motivation categories, but also includes teaching strategies for each category and subcategories. The ARCS Motivation Model will be used more easily in teaching areas and it will be provided to define student characteristics for each sub-strategy (Tahiroglu, 2015). ARCS motivation model strategies and sub-strategies are given in Table 1 below.

Table 1 Strategies and sub-strategies of the ARCS Motivation Model

Strategies and Sub-Strategies	Method Questions on Sub-Strategies in the Design Process
Attention	
❖ Perceptual Arousal	How can I get students' attention?
❖ Inquiry Arousal	What kind of attitude do I need to display to warn?
❖ Variability	How can I keep the students' attention for a long time?
Relevance	
❖ Familiarity	How can I provide the subjects that students will learn by adding my own experiences?
❖ Goal Orientation	How can I best identify the needs of the students?
❖ Motive Matching	How and in what way can I determine the time when students should make choices and take responsibilities?
Confidence	
❖ Success Opportunities	How and in what way can I determine the time when students should make choices and take responsibilities?
❖ Personal Control	How can I ensure that students' expectations of success are positive?
❖ Performance Requirements	How can I explain that students need to use their efforts and abilities in order to be successful?
Satisfaction	
❖ Intrinsic Reinforcement	How can I provide opportunities for students to apply their newly acquired knowledge and skills?
❖ Extrinsic Rewards	How can I reward students' achievements by encouraging them?
❖ Equity	How can I help students to have a positive emotion in their achievement?

Table 1 shows the questions about the strategies and sub-strategies of the ARCS Motivation Model. The explanations for each sub-strategy of the model are given below.

Attention

Attention is the model's first and most important strategy. In addition the attention strategy considers as attracting the students' attention at the beginning of the lesson and throughout the lesson. The attention strategy consists of three sub-strategies as follows:

1. *Perceptual Arousal:* It is to attract students' attention by making them curious, along with surprise and interesting environments.

2. *Inquiry Arousal:* It is to ensure the continuity of the student's attention by revealing the problem situation (Keller, 1987a).

3. *Variability:* It is to use different methods and strategies in teaching in order to sustain students' interest towards the lesson and to prevent them from getting bored.

Relevance

Attention, interest and curiosity are indispensable but not sufficient to motivate students to the lesson. In addition to these, instruction must be consistent, clear and apprehensible with its goals for motivation. The relevance strategy consists of three sub-strategies (Keller, 1987a and Keller, 1987b) as follows:

1. *Familiarity:* The fact that the examples and concepts presented in the learning process are from the close environment enables students to be closer to the subjects (Kurt, 2012).

2. *Goal Orientation:* The goals, objectives of the lesson, explaining where and how to use the knowledge provide some orientation to the goal itself.

3. *Motive Matching:* It is not about what to teach the student, but rather how to teach it.

Confidence

The goal of the confidence strategy is to help students to feel positive by having positive expectations. Keller (1987a) explained the confidence strategy in three sub-strategies as follows:

1. *Success Opportunities:* It is the state of informing students about success and evaluation criteria.

2. *Personal Control:* Creating opportunities for students to be successful by setting goals according to their level of success.

3. *Performance Requirements:* It is to ensure that students achieve success by supporting their efforts and abilities.

Satisfaction

In the ARCS Motivation Model, the prerequisites for motivation in the learning process are attention, relevance and confidence strategies. The satisfaction strategy is that students have the necessary positive thinking in the process of gaining learning experience. Keller (1987a) explained the satisfaction strategy in three sub-strategies as follows:

1. *Intrinsic Reinforcement:* It is to provide the opportunity to use students' newly acquired knowledge and skills in real or virtual situations help themselves to realize what they do and what kind of problems they ought to solve accordingly.
2. *Extrinsic Rewards:* It is the continuation of the desired behaviour by giving reinforcement and feedback in order to motivate the student to the lesson externally.
3. *Equity:* It is to ensure the conformity of the results together with the goals that emerge in order to achieve success (Keller & Kopp, 1987).

Cognitive Model of Learning

Cognitive Model of Learning (Item Representation Theory) is a teaching theory developed by Merrill (1983) to increase students' learning capacity by teaching a concept, principle or process. It is named as Item Representation Theory in the literature and is named as *Cognitive Learning Model* in the current study by the researcher. Because the theory includes only cognitive learning and deals with micro-level strategies. Since it is limited to the cognitive learning area and does not include affective and psychomotor learning areas, the model provides more guidance opportunities for teachers and instructional designers as a result (Dede, 2003).

According to Merrill, Cognitive Learning Model is a theory developed in relation to the inadequacy and the highlighting approach in Gagne's Learning Hierarchy (1977) which is from the piece to the whole (Reigeluth, 1983, Reigeluth, 1987). Cognitive Learning Model is not a method based on the classification of achievement levels and content types, but a theory consisting of the components of teaching delivery. Cognitive Learning Model is a model consisting of three-phase forms with matrix representation as follows:

a) Two-dimensional performance-content (P/C) classification system,

b) Presentation forms (cognitive power forms),

c) Solutions created by the classification of presentation forms (relationship between forms).

Performance-Content Matrix representation is given in Figure 1 below.

	EVENT	CONCEPT	PROCEDURE	PRINCIPLE
FIND				
USE				
GENERAL PERCEPTION				
REMEMBRANCE OF THE SAMPLE				

Figure 1: Representation of the Performance-Content Matrix (P/C).

The representation of the Performance-Content Matrix is given in Figure 1 above. The event, concept, procedure and principle components of the Performance-Content Matrix constitute the abscissa axis, while the components of remembrance of the sample, general perception, use and find constitute the ordinate axis. There is a relationship between the horizontal and vertical components against a point on the coordinate axis. For example, when the event component is taken on the abscissa, it is not possible to make a match with the components of find and use corresponding to the ordinate (Adir, 2011).

a) Performance-Content Matrix: While it does not include emotional and psychomotor factors, it presents a two-dimensional classification valid for cognitive results. These dimensions are as follows:

1. Student Success: Remembrance of the sample, general perception, using, finding.
2. Subject Content: Event, concept, procedure, principle (Merrill, 1987a; Merrill, 1987b).

b) Presentation Forms: Presentation forms are in four different forms as follows:

1. Primary presentation forms: It is a presentation form based on the principle of different results and the necessity of different learning situations proposed by Gagne.
2. Secondary presentation forms: It is a more detailed type of the primary presentation forms. First presentation forms are a basic tool used in teaching, while secondary presentation forms are a method used to facilitate the learner's process of structuring information (Merrill, 1983).

3. Tertiary presentation forms: The process is includes how the presented information should be processed and how information should be considered accordingly.

4. Quaternary presentation forms: It covers the instructions on how to operate the equipment used while presenting materials to students.

c) Relationship Between Forms: It consists of relations related to the way the representation in the whole is affected by a different representation of the same size (Eryılmaz, 2009).

Consequently, geometry is an important tool in problem solving strategies, gaining knowledge and skills. Polygons and triangles are an important subject of geometry because they contain many mathematical concepts and geometric elements. Therefore, there are many studies on the teaching of polygons and triangles. For example, in his study, Budak (2010) examined the effect of geometry activities on polygons prepared with Geometer’s Sketchpad on students’ success in computer use, and as a result, it was revealed that processing the subject of polygons with computer-aided instruction affected students’ success. Moreover, Fujita (2012) aimed to reveal the skills of teachers to define and classify quadrilaterals. At the end of the study, the research found teachers had difficulties in establishing relationships between quadrilaterals. Firstly students evaluated the quadrilaterals by thinking about the prototype patterns and shapes despite knowing their definitions. Furthermore, Bernabeu in his study with Moreno and Llinares (2021) investigated how students make sense of the concept of a polygon and the relationships between polygons. As a result of the study, he determined that learning the concept of a polygon depends on how students grasp the properties of the definition of a polygon.

In the literature, there are also studies that examine the effect of students’ achievement and motivation by applying the ARCS Motivation Model. Balantekin (2014) analysed the effect of constructivist learning approach that was designed according to the ARCS Motivation Model on students’ motivation, attitude and achievement and concluded that the motivational performances of students in the experimental and control groups differ in the intrinsic motivation dimension, and that the ARCS Motivation Model has a significant effect on increasing success. In addition, Lacinbay and Yilmaz (2019) used the ARCS Motivation Model in the course material development process, and as a result of the research, they found no significant difference in the attitude, motivation and curiosity levels of the students before the experimental process, but a significant difference was found in the attitude towards the lesson, motivation and knowledge-based curiosity after the experimental process accordingly. Moreover, Yeşiltepe (2019) investigated the effect of students’ achievement and motivation by applying the learning approach that was designed according to the ARCS Motivation Model and revealed that the model increased student success considerably, but had no effect on motivation. It should be noted that considering the studies on the cognitive learning model, Eryılmaz (2009) aimed to reveal the effect of concept teaching that was designed according to the Item Representation Theory in the web environment on student achievement, attitude and learning retention. The study determined that the web-based student group to which applied the Item Representation Theory was more successful than the traditional teaching group. The students had higher attitudes towards the course and more successful in permanence measurements thus permanence in students' learning was made. Cevher (2019) investigated the effect of concept teaching based on Item Representation Theory on student achievement. The research stated that the student group which was taught the concept teaching based on Item Representation Theory was successful and students had a positive perspective towards the theory. Dinçer's (2020) study examined the relationship between motivation and materials that were designed and the study reached the conclusion of the ARCS model increased motivation. Chang, Hu, Chianh, and Lugmayr (2019), on the other hand, aimed to verify the learning skills of students by applying the ARCS Motivation Model with mobile augmented reality technology and the experimental group students using mobile augmented reality technology showed a higher learning performance than the control group students accordingly. Last but not least, in his research, Koon Wah (2015) investigated the effects of students' achievement and motivation who have applied teaching with the Geogebra program by integrating the strategies of the ARCS Motivation Model. The study found there was a significant difference after the instruction he applied compared to the previous instruction as a result. It is essential that the studies conducted are studies that include a single model on the ARCS Motivation Model or Cognitive Learning Model. Hence, there are very few studies carried out dealing with the Geometry field. In the present study, it was aimed to reveal the effect of the Cognitive Learning Model integrated with ARCS categories on the learning levels and motivation of the students about polygons and triangles. The research questions are as follows:

1. Is there a significant difference between the geometry achievement levels of the experimental group students who were applied cognitive learning model integrated with ARCS categories and the control group students who were applied traditional teaching?
2. Is there a significant difference between the concept perception levels of the experimental group students who were applied cognitive learning model integrated with ARCS categories and the control group students who were applied traditional teaching?

3. Is there a significant difference between the geometry motivation scores of the experimental group students who were applied cognitive learning model integrated with ARCS categories and the control group students who were applied traditional teaching?
4. Is there a significant difference between the post-test geometry motivation profile scores of the experimental group students who were applied cognitive learning model integrated with ARCS categories and the control group students who were applied traditional teaching?

Method

Research Model

The post-test control group model was used in the current study (Buyukozturk, Cakmak, Akgun, Karadeniz, & Demirel, 2012). The students who were applied the cognitive learning model integrated with ARCS categories selected as the experimental group, and the students who were applied the traditional teaching model selected as the control group accordingly. These groups were formed by a neutral election. Post-test was applied to the both groups after the experiment. It has been accepted that there was no difference between the groups before the experimental study and the groups they were similar to (Karasar, 2012).

Working Group

The research was conducted with 274 fifth grade students in Luleburgaz district of Kirklareli Province for the academic year 2020-2021. There were 137 participants in the experimental group and 137 participants in the control group in the study. Random sampling was used in the study.

Data Collection Tools

In the study, Geometry achievement test and Geometry motivation scale were used. The aim of the research to find about the achievement and motivation levels of students about polygons and triangles. Necessary permissions have been obtained from the Ministry of National Education for the practice.

Geometry Achievement Test

Geometry achievement test was developed by the researcher in a way to cover the achievements of the students on polygons and triangles. The opinions of four mathematics teachers and two faculty members who are experts in the field of mathematics were obtained for the reliability of the geometry achievement test. The geometry achievement test was consisted of 20 questions in the test. Each question in the test is a multiple choice with 4 options and has only one correct answer. Each correctly answered of the questions in the test were given 1 point, and ortherwise were given 0 points. The test was administered to 5th grade students in 30 minutes to answer.

Geometry Concept Perception Test

The geometry concept perception test was developed by the researcher to measure the students' level of learning concepts about polygons and triangles. The test questions were prepared, concept perception studies on polygons and triangles had been examined in the literature. The expert opinion was received for the prepared geometry concept perception test. The geometry concept perception test consisted of 14 questions. Each question in the test is a multiple choice with 4 options and has only one correct answer. Each correctly answered of the questions in the test were given 1 point, and ortherwise were given 0 points. The test was administered to 5th grade students in 20 minutes to answer.

Geometry Motivation Scale

Geometry motivation scale was developed by Shia (1998) as a mathematics motivation scale and adapted again by Dede (2003). The scale developed by Dede (2003) was adapted to the geometry motivation scale by the researcher after the necessary permissions. By the researchers geometry motivation scale was redeveloped to determine students' motivation towards geometry. The scale is a 5-point Likert type scale and consists of 26 questions. Thus, scoring process was conducted in the following form: 'Strongly Disagree = 1', 'Disagree = 2', 'Undecided = 3', 'Agree = 4' and 'Strongly Agree = 5'. Items in the scale were grouped under 3 factors as a result of factor analysis. These factors were named as inadequacy of geometry, geometry effort and fear of geometry. As a result of the reliability analysis of the scale, the Cronbach Alpha Coefficient was calculated as 0.914 for the inadequacy of geometry dimension, 0.755 for the geometry effort dimension and 0.606 for the fear of geometry dimension. The Cronbach Alpha Coefficient for the whole scale was calculated as 0.753 as a result.

Geometry Motivation Profile Scale

The geometry motivation profile scale was developed by the researchers to determine the motivation profiles of the students towards geometry in accordance with the ARCS Motivation Model strategies. The mathematics motivation profile scale was developed by Dede

(2003) and was adapted to the geometry motivation profile scale by the researcher after necessary permissions. The scale is a 5-point Likert type scale and consists of 21 questions. The scale was scored as “strongly disagree (1)”, “disagree (2)”, “undecided (3)”, “agree (4)”, “strongly agree (5)”. Items in the scale were grouped under 2 factors as a result of factor analysis. These factors were named as satisfaction and attention. As a result of the reliability analysis of the scale, the Cronbach Alpha Coefficient was calculated as 0.981 for the satisfaction dimension and 0.520 for the attention dimension. The Cronbach Alpha Coefficient for the whole scale was calculated as 0.954 as a result.

Experimental Operations

The teaching steps of the cognitive learning model integrated with the developed ARCS categories are given below.

Table 2 Cognitive learning model steps integrated with ARCS categories

Steps	Strategies	Sub-Strategies
Introduction	**Strategies that provide and maintain attention**	**Perceptual Arousal** In order to draw the attention of the students to the subject of polygons and triangles, they were attracted by showing pictures from daily life using visual shapes on the smart board. In order to keep the students’ attention throughout the lesson, non-functional shapes and expressions related to the subject were avoided.
		Inquiry Arousal Students were provided with in-depth knowledge of polygons and triangles, solving questions and receiving feedback on the subject. While providing feedback to the answers given by asking questions during the lesson, much care was taken to increase the interest shown in the subject.
		Variability Tutoring was organized in a way to ensure active participation of students in the lesson, far from being monotonous and without boring the student. Pictures and visual materials related to the subject were included on the smart board. Much care was taken to use pictures and visual figures that would appeal to students in daily life, which would attract the attention and interest of the students.
Learning Process	**Strategies that build and maintain**	**Familiarity** In order for the students to behave comfortably during the lesson and not to show hesitation in participating in the lesson, much care was taken to use students’ names or some pronouns. In order not to make the subject unfamiliar to the student, the

	the relevance	pictures and visual figures shown on the smart board were chosen from the classroom environment and the student’s immediate environment. With the help of pictures and visual figures, the subject of polygons and triangles was concretized, helping the student to understand the subject more easily. **Goal Orientation** In the introductory phase of the lesson, the importance and objectives of the lesson were clearly expressed in order to enable the student to achieve the desired level of success, and the importance of the subject was comprehended. In addition, the students were explained in detail what they had to do in order to achieve the aim of the lesson. Later on, suitable environments were created for students to make choices for their own goals. **Motive Matching** Students were given the opportunity to choose goals that fit the goals they had set. As a result of the achievement tests and concept perception tests, the test questions were answered together and then the students were informed about their performances.
	Strategies that increase confidence and confidence	**Performance Requirements** The students were explained in detail about the objectives of the lesson and what they would learn about polygons and triangles. Preliminary information and skills were given to the students, which would require them to have knowledge on subject. At the end of the lecture, students were informed about the content of the tests to be applied. It was stated how many questions were found in the tests and how long it should be completed. **Success Opportunities** In order to achieve success and avoid boredom at the beginning of the learning process, the teaching of the lesson is planned from easy to difficult and from simple to complex. It was aimed to provide permanent information with reinforcements in the face of the answers given by asking questions to the students. **Personal Control** An appropriate language was used to encourage students in both their success and failure. Appropriate examples were given for the mistakes students could make about polygons and triangles.
Evaluation	**Satisfaction and strategies that provide satisfaction**	**Intrinsic Reinforcement** Students are aimed to gain the skills and abilities in the subject of polygons and triangles. Except for the exercises made during the lecture, practices were included at the end of the subject. The exercises were made to the students as questions-answers forms as educational games.

	Extrinsic Rewards It was said that the students would be motivated in response to the correct answers solved during the lesson. As a feedback to the students who gave wrong answers to the questions, their deficiencies were expressed with appropriate words in order not to lose their interest in the lesson.
	Equity The lecture was prepared by paying attention to the outcomes in order to be suitable for the aims and objectives of the subject. The applied achievement test and concept perception test were prepared in accordance with the polygons and triangles gains and the questions were arranged to include goals and objectives.

The research conducted took place during Covid-19 Pandemic in the academic year of 2020-2021. In the implementation process of the research, firstly, the choice of subject was decided. Secondly, after the model had been determined, tests were prepared with the help of teachers and experts during the material preparation process. A pilot study was conducted after the necessary permissions had been obtained by the Ministry of National Education before the implementation. Thirdly, after the pilot study, the experimental process was started. In the experimental process, the control group students were taught based on the traditional teaching method, and the experimental group students were taught based on the cognitive learning model integrated with ARCS categories accordingly. After the instruction, geometry achievement test, geometry concept perception test, geometry motivation scale and geometry motivation profile scale were applied to the control and experimental group students. The data were collected as a result of the application were analysed.

Data Analysis

The data were analysed using the SPSS 21.0 package program. After the experimental procedure, a t-test was conducted to determine whether there was a significant difference in the achievement levels and concept perception levels of the experimental group to which the cognitive learning model integrated with ARCS categories was applied, and the control group, where traditional teaching was applied. The t-test was carried out to determine the significance of the difference between the motivation scale sub-dimensions and the motivation profile scale sub-dimensions of the experimental group to which traditional teaching was applied and of the control group where the cognitive learning model integrated with ARCS categories was applied as a result.

Findings

The findings that obtained as a result of the research on statistical analysis of the data collected after the experimental process are included as follows: *findings on the geometry achievement levels of the experimental and control group students; findings on the concept perception levels of the experimental and control group students; findings on the motivation levels of the experimental and control group students and findings on the motivation profile levels of the experimental and control group students*

Findings on the geometry achievement levels of the experimental and control group students

In Table 3 below, the t-test results of the experimental and control group students' mean scores that obtained from the polygons and triangles post-test are given.

Table 3 t-Test results for the experimental group students' and the control group students' polygons and triangles achievement post-test mean scores

Groups	N	Mean	ss	t	p
Experimental Group	137	0.7325	0.11829	-16.271	0.000
Control Group	137	0.4887	0.12948		

As seen in Table 3, there is a statistically significant difference between the average scores of the experimental and control group students that were obtained from the polygons and triangles post-test. In other words, the polygons and triangles achievement test mean scores of the experimental group students who were applied cognitive learning model integrated with ARCS categories and the control group students who were applied traditional teaching method differ accordingly. When the polygons and triangles achievement post-test mean scores are examined, it is seen that the average score of the experimental group students (0.7325) is higher than the average score of the control group students (0.4887) who were applied traditional teaching method. Therefore the experimental group students who applied the cognitive learning model integrated with the ARCS categories had a higher level of success compared to the control group students who were applied the traditional teaching method.

Findings on the concept perception levels of the experimental and control group students

Table 4 below shows the results of the t-test for the mean scores of the experimental and control group students that were obtained from the polygons and triangles concept perception post-test.

Table 4 t-Test results for the experimental group students' and control group students' polygons and triangles concept perception post-test mean scores

Groups	N	Mean	ss	t	p
Experimental Group	137	0.7711	0.13112	-14.017	0.000
Control Group	137	0.5261	0.15708		

As seen in Table 4, there is a statistically significant difference between the average scores of the experimental and control group students that were obtained from the polygons and triangles concept perception post-test. In other words, the polygons and triangles concept perception test scores of the experimental group students who were applied cognitive learning model integrated with ARCS categories and the control group students who were applied traditional teaching method differ accordingly. When the mean scores of polygons and triangles concept perception post-test are examined, it is seen that the average score (0.7711) of the experimental group students who were applied the cognitive learning model integrated with the ARCS categories was higher than the average score (0.5261) of the control group students who were applied the traditional teaching method. Hence the experimental group students who were applied the cognitive learning model integrated with the ARCS categories had a higher level of concept perception compared to the control group students who were applied the traditional teaching method.

Findings on the motivation levels of the experimental and control group students

In Table 5 below, t test results for the post-test scores of the sub-dimensions of the geometry motivation scale of the experimental and control group students are given.

Table 5 t-Test results for the post-test mean scores of the sub-dimensions of the geometry motivation scale of the experimental group students and the control group students

Factors	Groups	N	Mean	ss	t	p
Inadequacy of Geometry	Experimental Group	137	3.0158	1.08477	9.878	0.000
	Control Group	137	4.0122	0.46602		
Geometry Effort	Experimental Group	137	2.6606	0.81391	-0.542	0.589
	Control Group	137	2.6104	0.71664		
Fear of Geometry	Experimental Group	137	3.4015	1.06115	2.814	0.005
	Control Group	137	3.7056	0.68845		

As seen in Table 5, there is no significant difference between the geometry effort sub-dimension scores of the control group and experimental group students (p> 0.05). However, there was a significant difference between the inadequacy of geometry and fear of geometry sub-dimension scores of the control group and experimental group students (p <0.05). The students in the control group who used the traditional teaching method had higher self-inadequacy towards the geometry lesson and had higher fears regarding the geometry lesson compared to the experimental group students who were applied the cognitive learning model integrated with ARCS categories.

Findings on the motivation profile levels of the experimental and control group students

In Table 6 below, t test results for the post-test scores of the sub-dimensions of the geometry motivation profile scale of the experimental and control group students are given.

Table 6 t-Test results for the post-test mean scores of the sub-dimensions of the geometry motivation profile scale of the experimental group students and the control group students

Factors	Groups	N	Mean	ss	t	p
Satisfaction	Experimental Group	137	2.8913	1.35739	11.082	0.000
	Control Group	137	4.2594	0.48129		
Attention	Experimental Group	137	2.8710	0.89502	-3.121	0.002
	Control Group	137	2.5564	0.76557		

As seen in Table 6, there is a significant difference between the satisfaction and attention sub-dimension scores of the students in the control group and the experimental group (p <0.05).

It was observed that the experimental group students who were applied the cognitive learning model integrated with the ARCS categories paid more attention to the geometry lesson than the control group students who used the traditional teaching method. In addition, the satisfaction scores of the students in the control group using the traditional teaching method for the geometry lesson were higher than the experimental group students who were applied the cognitive learning model integrated with ARCS categories. In other words, the students in the control group had more positive thoughts based on their experiences compared to the students in the experimental group as a result.

Conclusion and Discussion

When the findings regarding the achievement levels of the students participating in the study about polygons and triangles were examined, it was found that the achievement post-test scores of the experimental and control groups differed significantly in favour of the experimental group. While the polygons and triangles achievement post-test mean scores of the experimental group students were 0.7325, the polygons and triangles achievement post-test mean scores of the control group students were found to be 0.4887. It means that the experimental group students who were applied the cognitive learning model approach integrated with ARCS categories were more successful in the learning of polygons and triangles than the control group students who were applied traditional teaching. In addition, it can be said that the cognitive learning model integrated with the ARCS categories is effective in learning the subject. It should be noted that similar results can also be seen in the study conducted by Dede (2003). Dede (2003) investigated whether the concept of variable had an effect on student achievement of the approach based on ARCS Motivation Model and Item Representation Theory, and as a result of the research, a significant difference was found in favour of the experimental group in terms of students' learning levels. Moreover, Balantekin (2014) investigated student success according to the constructivist learning approach that was designed based on the ARCS Motivation Model and concluded that the ARCS Motivation Model had an important effect on increasing student success. Similarly, Yesiltepe (2019) and Narmanli (2019), in their studies, examined student success by applying a teaching that was designed according to the ARCS Motivation Model and the results of their studies showed that the model increased academic success accordingly. These studies are in line with the findings of the current study.

When the findings regarding the concept perception levels of the students participating in the study about polygons and triangles were examined, a significant difference was found in the concept perception post-test scores of the experimental and control groups in favour of the experimental group. While the polygons and triangles concept perception post-test mean scores of the experimental group students were 0.7711, the polygons and triangles concept perception post-test mean scores of the control group students were 0.5261. As a result, it can be said that the experimental group students who were applied the cognitive learning model approach integrated with ARCS categories had higher concept perception levels about polygons and triangles compared to the control group students who were applied traditional teaching. In other words, the cognitive learning model integrated with ARCS categories has shown positive results in students' comprehension of the subject. Considering the findings of the geometry lesson motivation levels of the students participating in the study, a statistically significant difference was found in the mean scores of the geometry motivation scale sub-dimensions of the inadequacy of geometry and fear of geometry. While the mean score regarding the inadequacy of geometry subscale was 3.0158 for the experimental group students, it was calculated as 4.0122 for the control group students. The control group students studying with the traditional teaching method considered themselves insufficient in the geometry lesson. While the mean score regarding the fear of geometry subscale was 3.4015 for the experimental group students, it was calculated as 3.7056 for the control group students. As a result, the control group students who study with the traditional teaching method have more fear of the geometry lesson compared to the experimental group students who study with the cognitive learning model approach integrated with ARCS categories. Similarly, Balantekin and Bilgin (2017) concluded that the ARCS Motivation Model affects students' motivation levels. Narmanli (2019) reached similar findings as well. In his study, he examined the effect of the ARCS Motivation Model on the motivation level of the students, and the model increased the motivation of the students and it actively engaged students in the process and therefore he figured out that the students' attention was protected throughout the process. Also, there are studies that conclude the ARCS Motivation Model has no effect on student motivation. For example, Dede's (2003) study examined the motivational effect of the ARCS Motivation Model on students' mathematics lesson and found that there was no significant difference among the motivation post-test scores of the students. Dede's study findings showed that the reasons for this could be the characteristics of the school where the application was made, the surrounding conditions and the personal characteristics of the teacher who was responsible as well. On the other hand, Çalışkan (2017) determined that the ARCS Motivation Model did not make a significant difference among students' motivation post-test scores. Furthermore, Yesiltepe (2019) used the ARCS Motivation Model to investigate the effect on students' motivation to learn science, and as a result, he found out that there was no statistically significant effect on students' motivation to learn science.

According to the findings related to the effect of students' geometry course motivation profile, a statistically significant difference was found in the mean scores of the geometry motivation profile scale sub-dimensions of satisfaction and attention. While the mean score regarding the satisfaction subscale was 2.8913 for the experimental group students, it was calculated as 4.2594 for the control group students. According to the research result, the satisfaction scores of the control group students studying with the traditional teaching method for the geometry lesson were higher. While the average score regarding the attention dimension, the other sub-dimension, was 2.8710 for the experimental group students, it was calculated as 2.5564 for the control group students. The research result shows that the average scores of the experimental group students studying with the cognitive learning model approach integrated with ARCS categories is higher than the control group students studying with the traditional teaching method. In other words, it can be said that the experimental group students were more successful than the control group students in sustaining their attention in the lesson. On the other hand, Dincer (2020) conducted a meta-analysis study examining the relationship between motivation and materials designed according to the ARCS model and he concluded that the materials had a positive effect on motivation. That is, he found out that the motivation of the students was increased with the increase in the duration of the use of the material. Chang, Hu, Chianh, and Lugmayr (2019) applied the ARCS Motivation Model to examine students' willingness and validate their learning skills through mobile augmented reality (MAR) technology. Hence, effective learning indicators such as learning interest, confidence and satisfaction were used to evaluate students' learning motivation using MAR technology. As a result of their study, it was concluded that the experimental group using MAR technology as a learning aid showed a higher learning activity compared to the control group. Last but not least, Yuncu Kurt and Kecik (2017) examined the effects of the ARCS Motivation Model on the motivation of university preparatory students and concluded that the ARCS model had a positive effect on students' course motivation. Moreover, Koon Wah (2015) used Geogebra to integrate attention, relevance, confidence and satisfaction strategies, and investigated the effects on the motivation and success of high school students. He determined a significant difference in the motivation and success of the students before and after the instruction as a result. The other words, Tandogan (2019) investigated the effectiveness of teaching materials that were developed according to the ARCS Motivation Model, along with augmented reality (AR) on students' vocabulary success and motivation in the field of engineering. It was concluded that the experimental group performed significantly better than the control group in vocabulary achievement tests. In addition, it has been determined that when teaching materials are presented with mobile AR applications and developed according to the ARCS Motivation Model, it can be effective for vocabulary success, motivation and positive perceptions of students. It is worth bearing in mind that these studies show that the model has a positive effect on motivation and is consistent with the findings of the current study.

To sum up, the findings of the study indicated that the cognitive learning model approach integrated with ARCS categories applied to the fifth grade students in teaching the subject of polygons and triangles was more effective at the learning level compared to the current teaching method, and it should be noted that it had a positive effect on motivation. Since the subject of polygons and triangles includes many mathematical concepts and geometric elements, providing and maintaining student motivation by using the cognitive learning model integrated with ARCS categories in an educational environment, and addressing the ignored motivation dimension highlighting the importance of the study, they will contribute to the literature and theory accordingly.

Suggestions

Considering the results of the research, it can be recommended for educators and researchers to do more studies on geometry subject since working examples of the model are rare. The effect of the model can be investigated by applying it to different lessons and different grade levels. In the present study, the effect of cognitive learning model integrated with ARCS categories on students' learning levels and motivation was examined. Apart from these variables, the effect of the model can be investigated by considering different variables such as different attitude and permanence of knowledge. The model can be adapted to different subjects in the field of geometry as well.

Notes
Ethical approval for this study was obtained from Balıkesir University Science and Engineering Ethics Committee (29.06.2020 / 25040).

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