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Araştırma Makalesi / Research Article

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

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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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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.

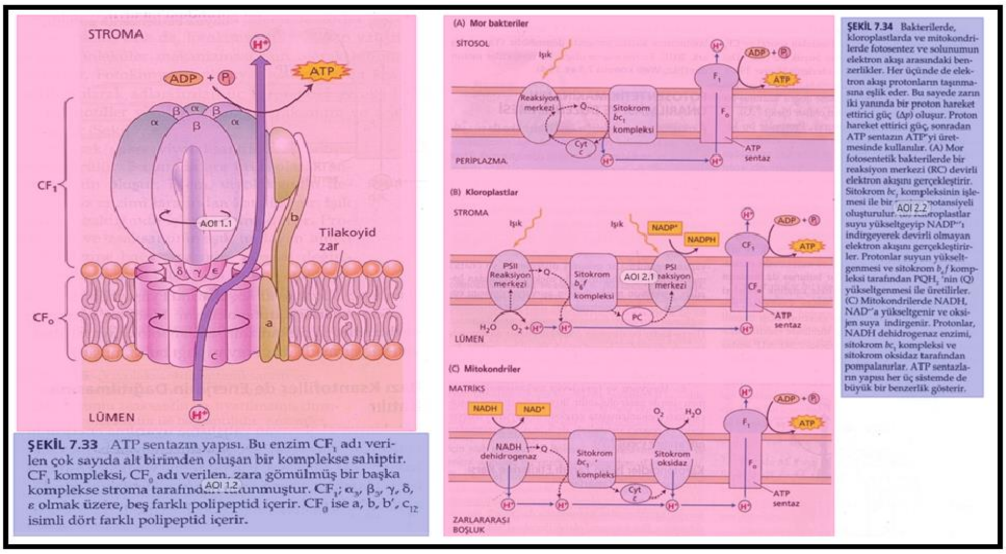

Figure 1 The Visual-Textual Distinction in the Process Diagrams

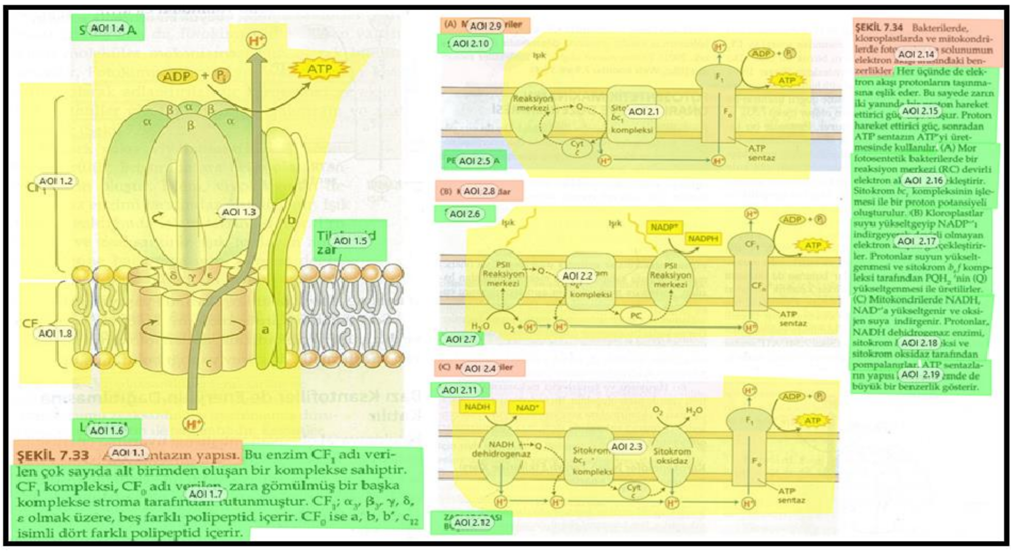

Figure 2 Distinguishing the Areas of Interest (AOI) in the Process Diagrams

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.

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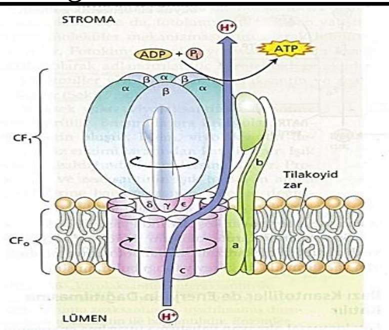
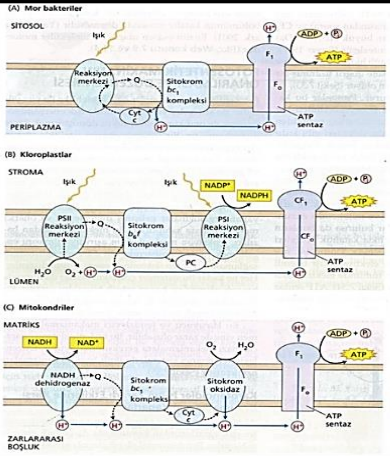
Appendix A. Process Diagram 1



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.