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Fen Bilgisi Öğretmen Adaylarında Bir Çizgi Grafiğinin Görsel ve Bilişsel Yapılandırılması[1]

Evaluation of Pre-Service Science Teachers' Visual and Cognitive Constructions of A Line Graph

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Özet

Bu araştırma, öğretmen adaylarının biyoloji konusuna ilişkin bir çizgi grafiği oluşturma sürecini açıklamak ve böylece çizdikleri grafikle ilgili yorumlarını anlamak amacıyla yapılmıştır.Bu kapsamda araştırma bir devlet üniversitesinin ikinci sınıfında öğretim gören 2013-2014 güz döneminde 55, 2015-2016 güz döneminde 66 ve 2016-2017 güz döneminde 59 olmak üzere toplam 180 fen bilgisi öğretmen adayı ile yürütülmüştür. Araştırma doküman analizi çerçevesinde yürütülmüştür. Verilerin kaynağını üç yıl boyunca toplanan genel biyoloji laboratuvar dersinin dönem sonu değerlendirme kağıtları oluşturmaktadır. Değerlendirilen açık uçlu sorularda öğretmen adaylarından bir probleme yönelik çizgi grafik çizmeleri ve bu grafiği yorumlayarak mantıksal çıkarım yapmaları beklenmiştir. Fen bilgisi öğretmen adaylarının yanıtları çizgi grafiğini çizmedeki görsel ve bilişsel yapılandırmalarının değerlendirilmesi çerçevesinde yapılmıştır. Elde edilen bulgulara göre, öğretmen adaylarının görsel ve bilişsel yapılandırma becerilerinin zayıf olduğu, grafikten mantıksal çıkarımlar yapabilmelerinin grafik çizme ve yorumlama becerilerine göre daha yetersiz olduğu söylenebilir.

Anahtar Kelimeler: Bilişsel yapılandırma, Görsel yapılandırma, Çizgi Grafiği, Grafik Çizme

Abstract

This research was conducted in order to explain the process of creating a line graph on the subject of biology by pre-service teachers and thus to understand their comments about the graph they drew. In this context, the research was conducted with 180 pre-service science teachers, 55 in the 2013-2014 fall semester, 66 in the 2015-2016 fall semester, and 59 in the 2016-2017 fall semester, who were studying in the second year of a state university. The research was carried out within the framework of document analysis. The data source is the end-of-term evaluation form of the general biology laboratory course collected for three years The answers of the pre-service science teachers were made within the framework of evaluating their visual and cognitive construction in drawing the line graph. According to the findings, it can be stated that pre-service teachers have poor visual construction skills and cognitive construction skills and their ability to make logical inferences from a graph is less efficient when compared to graph drawing and interpretation skills.

Keywords: Cognitive construction, Graph Drawing, Line Graph, Visual construction

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1. Introduction

In the information age, the understanding of new information discovered day by day creates the need to interpret not only verbal but also numerical data and graphs correctly. The use of visual elements in education has increased with printing technology and has allowed the use of more graphs and pictures in textbooks (Landin, 2011). Glazer (2011) mentioned that reading a graph is a complex activity even though it is a crucial skill to be literate in today's information age. Berg and Smith (1994) implied that graphs are widely used in newspapers, magazines and presidential press conferences because of graph-illustrated concepts influencing people in daily life, such as population growth, the spread of contagious diseases, and amounts of carbon dioxide. If we do not possess the ability to interpret graphs or to recognize the mistake in the graph, we will be left with the interpretation or accuracy of the person who presented the graph to us.

In scientific studies, data is initially collected in tables or databases and then displayed in graph form to help scientists visualize and interpret their data to help make sense of numbers (Glazer, 2011). According to Wavering (1985), graphing is a tool used in science to display data and aid in the analysis of relationships between variables. In addition, he tried to demonstrate a relationship between graphing and interpretation and the development of logical thinking. Similarly, Berg (1989) investigated the connection between logical thinking abilities and the ability to construct and interpret graphs. Shah (1997) emphasized that a graph model is unique and can be distinguished from partially abstract diagrams because it represents some quantitative property of either concrete objects or abstract concepts. She added that the relation between a represented concept and graph is based on an analogy between quantitative scales and visual dimensions in which the visual dimensions are usually analogue representations of this quantitative information. According to Cleveland and McGill (1984), graphic perception is the visual decoding of the information process encoded in graphics. The first part of the process is explained as a set of elementary perceptual tasks when people extract quantitative information from graphs. The second process is ordering the tasks according to how accurately they were done.

Glazer (2011) suggests that more studies be conducted on teaching graph knowledge and skills in the context of science, as well as studies in the context of abstract or mathematics. Biology topics have content based on making logical inferences. In fact, teachers often make use of graphs in presenting the information. Graphs are frequently used as an explanatory and visualizing tool in situations where logical inferences are required, such as evaluating respiratory and lung capacity or explaining the mechanism in the secretion of hormones. In addition, McKenzie and Padilla (1986) mentioned that graph construction and interpretation are essential skills in science and mathematics education. Moreover, they emphasized that line graphs construction and interpretation are critical to science instruction because of an integral part of experimentation, the heart of science. According to Wavering (1985) line graphs display the relationship between two continuous variables in pictorial form and, promote the communication of complex concepts and ideas. Besides, line graphs are used to visualize the relationship between variables and allow logical inferences, it would help science teachers to understand the logical reasoning processes students use when making graphs. Yayla and Özsevgeç (2014) revealed in their study with 6,7, and 8-grade students that there is a relationship between the ability to create and interpret line graphs. Incekabı et al. (2015) state that among the graph drawing skills, reading, creating and interpreting skills are the most important. In the studies, it is understood that students still have problems with reading and interpreting graphs and have some misconceptions in the process from primary school to university (Aydan & Dönel Akgül, 2021; Berg & Smith, 1994; Erbilgin et al., 2015; Ercan et al., 2018; Kali, 2005; Kıranda & Akpınar, 2020; Wavering, 1985; Yelken, 2020). Studies reveal that students have difficulties structuring and interpreting the line graph, especially concerning its function (Dunham & Osborne, 1991, Dündar & Yaman, 2014; Ercan et al., 2018; Aydan & Dönel Akgül, 2021). Graph competency includes both graph creation and graph interpretation skills. These processes need to be handled simultaneously and complement each other (Glazer 2011).

Erbilgin et al. (2015) consider the determination of students' ability to interpret and create line graphs as one of the first steps to be taken in order to overcome the learning difficulties experienced by students in this regard. In this respect, teachers are expected to be aware of the importance of graphs and to include them in education. Kali (2005) pointed out that graphing skills seem to be very difficult to master, and great care needs to be taken to design a package that effectively teaches these skills. Berg (1994) remarks that open-ended graph problems will allow the understanding of the underlying logic of the subject. Using open-ended problems and answers from the underlying logic of the subject indicates that the subject can provide answers as to how the content affects the learning process.

The current three-year-long study aims to explain pre-service teachers' process of constructing a line chart related to biology subject, thus understanding their comments about the graph they draw. For this purpose, the process of constructing a line graph of pre-service teachers and their logical reasoning about the graph they drew were questioned.

2. Methods

2.1. Research Design

The research was examined within the framework of document analysis, a research design in which the analysis of written materials containing information about the targeted phenomenon or phenomena is conducted for the purpose of "examination", "information development" and "making meaning" (Bowen, 2009; Corbin & Strauss, 2008; Yıldırım & Şimşek, 2013). Document refers to any kind of information that exists in some type of written or printed form (Bowen 2009; Fraenkel et al., 2012). In this study, document analysis was carried out in order to obtain in-depth information about pre-service teachers' skills in visual construction and cognitive construction of a graph. The document of the research consisted of 180 pre-service science teacher’s answers: 55 (9 males and 46 females) in the second year in the fall semester of 2013-2014, 66 (15 males and 51 females) in the fall semester of 2015-2016, and 59 (9 males and 50 females) in the fall semester of 2016-2017 of a state university in the Marmara Region in Turkey. In this study, convenience (easily accessible) sampling, non-random sampling, was used. A convenience sample is any group of individuals who are available for study (Fraenkel et al., 2012).

2.2. Data Collection

Data were collected through the researchers' documents. The source of the raw data is the end-of-term evaluation form of the general biology laboratory course collected for three years. The documents consist of the answers given to the same questions asked to the pre-service science teachers participating in the general biology laboratory course every year about the experiment they do in the laboratory. The documents were limited to three years due to the fact that the science teaching Undergraduate program in our country was updated by the Higher Education Council in 2018, and Biology laboratory lessons were removed. In the evaluated open-ended problem, pre-service teachers are expected to draw a line graph for a problem representing the effect of the relationship between surface area to volume ratio in the cells on substance transfer, and to interpret this graph and make logical inferences. The problem is a developed Turkish version of a problem in the Biology for the IB diploma book (Clegg, 2010). After the problem developed, it was read to three students and its intelligibility was checked. The problem posed to the pre-service teachers in the study is presented in Figure 1.

Figure 1. *The Problem Posed to The Pre-service Teachers*

Slightly alkaline gelatine cubes containing an acid-alkali with different sizes are left in the concentrate acid solution, and the colour change is observed. The colour change time in these cubes is measured. (The acid-alkaline indicator is red in alkali but yellow in acid).

Dimension /mm	Surface area/mm^2	Volume /mm^3	Time /minutes
10x10x10	600	1000	12
5x5x5	150	125	4,5
4x4x4	96	64	24,2
2x2x2	24	8	4

a. For each block, **calculate** the ratio of surface area to volume (SA/V). Then, plot a graph of the time taken for the colour change against the SA/V ratio where the horizontal axis shows (Y axis) the surface area/volume ratio and the vertical axis (X axis) shows the colour change time.

b. **Explain** why the colours change more quickly in some blocs than others.

This problem was selected because the questioning about the relationship between the surface area/volume ratio enabled students to comprehend various subjects such as starting the cell cycle, diffusion rate, balance of body temperature in the living organism at the poles, and expanding some organs' surface area.

2.3. Data Analysis

In this study, the graphs drawn by the pre-service teachers were evaluated according to visual and cognitive construction based on literature (Berg & Smith, 1994; Cleveland & McGill, 1984 and 1987; Glazer, 2011; Shah & Carpenter, 1995; Shah & Hoeffner, 2002). Graphs are accepted as an essential tool in terms of visualizing the relationships between data and facilitating the understanding of complex concepts and relationships (Berg & Smith, 1994). Cleveland and McGill (1984, 1987) have developed a paradigm for graphical perception that begins with the isolation of elementary codes of graphs. These are: positions along a common scale; positions along identical, nonaligned scales; lengths; angles; slopes; areas; volumes; densities; colour saturations; colour hues.

According to researchers, visual perception is highly relevant to graphical perception. Graphical perception is the visual decoding of information encoded on graphs. The graph is constructed successfully only if our visual systems perform the graphical perception with accuracy and efficiently. The graphical perception begins with elementary codes of graphs which are fundamental geometric, colour and textural aspects that encode the quantitative information on a graph. The first part is an identification of a set of elementary perceptual tasks that are carried out when people extract quantitative information from graphs. Thus, highly cognitive tasks such as scale reading are not meant to be addressed. This theory provides a guideline for graph construction.

Shah and Carpenter (1995) and Shah and Hoeffner (2002) identified three essential components of graph comprehension that are particularly relevant to the interpretation of line graphs. First, viewers must encode the visual patterns and identify the important visual features (such as curved line). Second, viewers must relate the visual features to conceptual relations that are represented by those features by encoding of visual features. Viewers might encode the relevant information accurately. However, their ability to map between different visual features and the meaning of those features may differ as a function of experience. In some cases, viewers can derive what a particular visual feature means through a simple pattern-matching process (for example, a viewer knows that a curved line implies an accelerating relationship). The third component process of graph comprehension is that viewers must determine the referent of the concepts being quantified and associate those referents to the encoded functions.

Glazer (2011) implied that graphing competence includes both graph construction (creation) and graph interpretation (analysis) skills. He suggested that they are inextricably linked and need to be addressed simultaneously and in a complementary way. In the literature, we can identify two critical attributes of graphing skills; the ability to visual construction and the ability to cognitive construction of graphs. In these circumstances, we can presume that the visual construction of graphs is the mental representation of the viewers' data set that involves the ability to convert quantitative information to drawings. In addition, the cognitive construction of graphs involves logical meaning and interpretations by decoding data in a graph. Themes and explanations of the categories related to the themes are presented in Table 1.

Table 1. *Graphic Evaluation Themes*

Themes	*Categories*	*Explanation*
Visual construction of the graph	Dotting properly	Considering the “y” and “x” axes data, dotting properly in the graph
	Merging the dots.	After dotting the data pairs, merge the appropriate dots lines in the graph.
	Illustration of the endpoints of the line	Illustrate the endpoints of the line as inferred beyond the data or in the graph.
Cognitive construction of the graph	Calculation	Use of mathematical operation skill
	Scaling the graph axis	Scaling the data pairs properly in the graph axis according to calculation results.
	Interpretation	Making interpretations in terms of the relationships between the axes in the graph.
	Logical reasoning	Making logical reasoning in accordance with graphical variables or problem variables.

The visual construction of the graphic was evaluated in the sub-categories of "*dotting properly, merge the dots, illustration of the endpoints of the line*". The cognitive construction of the graphic was evaluated according to the sub-categories of "*calculation, scaling the axis, interpretations, logical reasoning*". The graphics drawn by the pre-service teachers and their interpretations were analysed separately, and the frequencies of the categories constituting the themes were calculated and presented in tables.

2.4 Ethical Consideration

In line with this paper's subject, ethical consideration issued by the Higher Education Council was taken throughout the research.

2.5. Reliability

The necessary conditions have been provided to ensure the validity and reliability of the research. The criteria of "credibility", "transferability", "consistency" and "confirmability" (Lincoln & Guba, 1985; Merriam, 2009) were used to ensure the validity and reliability of the research. The credibility of the research was obtained from the evaluation of the participants' problems, which were answered individually in the research and the process was supervised by the researcher. The researcher's diversity was achieved by the inclusion of more than one researcher in the data collection process of the research and the analysis of the data. In order to ensure the transferability of the research, data collection tools, data collection and analysis process are described in detail and explained. In addition, detailed descriptions were made in the findings section, and direct quotations from the documents were included. For the consistency of the study, the analysis of the data was carried out by two researchers, and the consistency in the coding was tested by making a comparative analysis. For the confirmability of the research, data sources, data collection tools, data acquisition stages, and data interpretation stages were explained in detail. Confirmability was increased by archiving all data collection tools and raw data. For the sake of research ethics and at the same time to ensure impartiality in the analysis and reporting process, documents are coded in the form of D1, D2, and D3.

3. Findings

Pre-service science teachers graphing drawing skills were evaluated as visual construction and cognitive interpretation. These main skills are presented under two headings.

3.1. Findings Concerning the Visual Constructions of Pre-Service Teachers

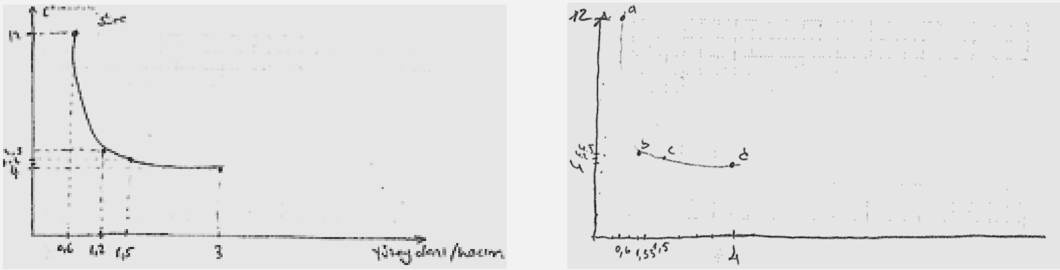
The visual construction processes of the pre-service teachers were evaluated in three categories as "Dotting properly", "Merging the dots" and "illustration of endpoints of the line". Firstly, by considering the “y” and “x” axes data, the category of dotting properly was defined according to the codes of "placing a dot on the line intersection", “placing a dot not using the line intersection”. The findings are presented in Table 2.

Table 2. Percentage and Frequency Table of “Dotting Properly” Codes

	Group 1		*Group 2*		*Group 3*		*Total*	
	f	*%*	*f*	*%*	*f*	*%*	*f*	*%*
Placing a dot on the line intersection.	48	87.3	39	59.1	32	54.2	119	66.1
Placing a dot, not using the line intersection	3	5.5	21	31.8	27	45.8	51	28.3
No graph drawings	4	7.3	6	9.1	59	100.0	10	5.6
Total	55	100.0	66	100.0	27	45.8	180	100.0

It was observed that the pre-service science teachers place a dot on the line intersection using the axes data at a total rate of 66.1% in their graphic drawings. Samples of students’ drawings about placing a dot in the graph are given in Figure 2.

Figure 2. *Samples of Pre-Service Teachers "Dotting Properly" Choices in A Line Graph*



A B

Note. A. Placing a dot on the line intersection, B. Placing a dot not using the line intersection

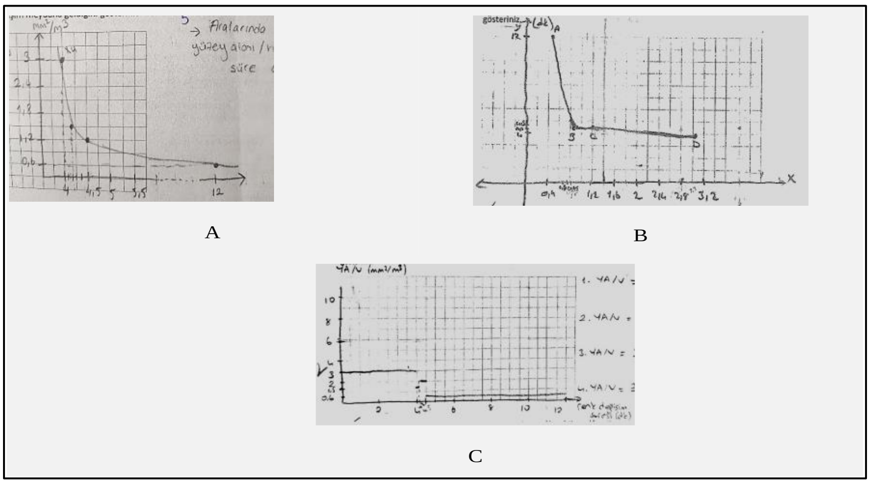
In Figure 2, in form B, it is seen that the pre-service teachers who prefer to create the points visually without considering the axes line draw a graph that does not seem correct. However, in form A, those who consider the axes line might draw correctly. After the pre-service teachers dotting the data pairs in the graph, the category of their choice of merging the appropriate dots line under the codes of drawing a "Curve function graph", " Linear function graph" or Piecewise continuous line graph". The findings are presented in Table 3

Table 3. *Frequency and Percentage Table of "Merging The Dots" Codes"*

	Group 1		*Group 2*		*Group 3*		*Total*	
	f	%	f	%	f	%	f	%
Curve function graph	31	56.4	53	80.3	47	79,7	125	69,4
Linear function graph	17	30,9	6	9,1	8	13,6	39	21,7
Piecewise continuous function graph	2	3.6	1	1.5	-	-	3	1.7
No drawing	5	9.1	6	9.1	4	6.8	13	7.2
Total	55	100.0	66	100.0	59	100.0	180	100.0

It is noticed that the pre-service teachers' choice of connecting the points is mostly (69.4%) curved function graph. However, it is seen that 21.7% of the students also prefer the linear function graph. Samples of student drawings about merging dots in the graph are given in Figure 3.

Figure 3. *Samples of Pre-service Teachers "Merging Dots" Choices in A Line Graph*



Note. Pre-service teachers' choice of connecting the points: A curved function graph, B line function graph, C Piecewise continuous line graph.

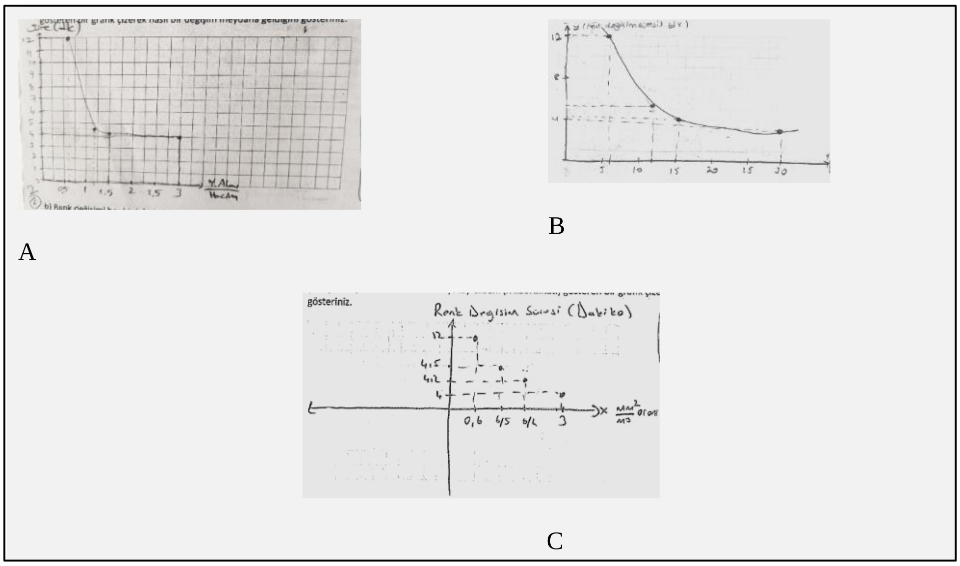
In Figure 3, it is noticed that pre-service teachers made three different choices as "curved function graph" in A drawing, "line function graph" in B drawing, and " piecewise continuous line graph " in C drawing. The pre-service teachers' choices to continue the end points of the line in the graph were evaluated under the codes of " Restricted ", "Extended" and "Discrete point", and the data obtained are presented in Table 4.

Table 4. *Frequency and Percentage Table of "Illustration of The End Points of The Line in The Graph" Codes*

	Group 1		*Group 2*		*Group 3*		*Total*	
	f	*%*	*f*	*%*	*f*	*%*	*f*	*%*
Restricted	20	36.4	33	50.0	22	37.3	75	41.7
Extended	28	50.9	26	39.4	35	59.3	89	49.4
Discrete point	2	3.6	1	1.5	-	-	3	1.7
No drawing	5	9.1	6	9.1	2	3.4	13	7.2
Total	55	100.0	66	100.0	59	100.0	180	100.0

It is understood that the pre-service teachers' choice of continuing the points is 41.7% of the restricted and 49.4% of the extended points. Samples of student drawings about the endpoints of the line in the graph are given in Figure 4.

Figure 4. *Samples of Pre-service Teachers "Illustration of The End Points of The Line" Choices in A Line Graph*



Note. A restricted, B extended, C discrete points

In Figure 4, the pre-service teachers did not continue the graphic drawing in the A drawing but continued in the B drawing. In the C drawing, however, the student only identified the points and did not connect them.

3.2. Findings on the cognitive configurations of pre-service teachers

The cognitive structuring processes of the pre-service teachers' graph were evaluated in four categories as "calculation", "scaling the graph axis", "interpretation" and " logical reasoning". Pre-service teachers' ability to calculate graphic data was evaluated under the codes of "accurate-calculation, partially- calculation, miscalculation" and the findings regarding the data are presented in Table 5.

Table 5. *Frequency and Percentage Table of* Calculation of Graph Data

	Group 1		*Group 2*		*Group 3*		*Total*	
	f	*%*	*f*	*%*	*f*	*%*	*f*	*%*
Accurate calculation	38	69.1	43	65.2	35	59.3	116	64.4
Partly calculation	9	16.4	10	15.2	15	25.4	34	18.9
Miscalculation	5	9.1	8	12.1	3	5.1	16	8.9
No response	3	5.5	5	7.6	6	10.2	14	7.8
Total	55	100.0	66	100.0	59	100.0	180	100.0

It is noticed that the pre-service teachers who make accurate calculations are similarly 69.1%, 65.2% and 59.3% in the three groups. It is understood that the pre-service teachers were successful in calculating 64.4% in total. The scaling of the graph axis was defined according to the codes of "correct scaling of both axes", "wrong scaling of both axes"," correct scaling of the x axis" and "correct scaling of the y axis the findings are presented in Table 6.

Table 6. *Frequency and Percentage Table of Scaling The Graph Axis*

	Group 1		*Group 2*		*Group 3*		*Total*	
	f	*%*	*f*	*%*	*f*	*%*	*f*	*%*
Correct scaling of both axes	4	7.3	27	40.9	21	35.6	52	28.9
Incorrect scaling of both axes	37	67.3	19	28.8	24	40.7	80	44.4
Incorrect scaling of the X-axis	8	14.5	6	9.1	4	6.8	18	10.0
Incorrect scaling of the Y-axis	1	1.8	8	12.1	7	11.9	16	8.9
Both axes not scaled	5	9.1	6	9.1	3	5.1	14	7.8
Total	55	100.0	66	100.0	59	100.0	180	100.0

It is noted that pre-service teachers' ability to scale axes correctly is 7.3%, 40.9% and 35.6%, and 28.9% in total. It is noticed that pre-service teachers make mistakes in the scaling of the x-axis, y-axis or both axes. When the periods are examined, it is noticed that this situation is similar. Samples of student drawings about scaling the axis in the line graph are given in Figure 5.

Figure 5. *Samples of Pre-service Teachers "Scaling The Graph Axis" Choices in A Line Graph*

- A

B

Note. A incorrect scaling, B incorrect scaling

In Figure 5, the effect of students' axis scaling errors on graphic drawings is noticed. In Figures A and B, pre-service teachers made incorrect scaling on both the X and Y axis. Due to the scaling error, the slope of the graph decreases linearly in drawing A, while the graph decreases linearly in drawing B.

Pre-service teachers' interpretations according to their use of the surface-volume relationship in the graph were evaluated in two categories as "depending on the axis relationship and independent from the axis relationship". The logical reasoning used by the pre-service teachers in explaining the graph was evaluated based on "According to the graph drawing" and "According to the data of the problem". The frequencies of the answers are presented in Table 7.

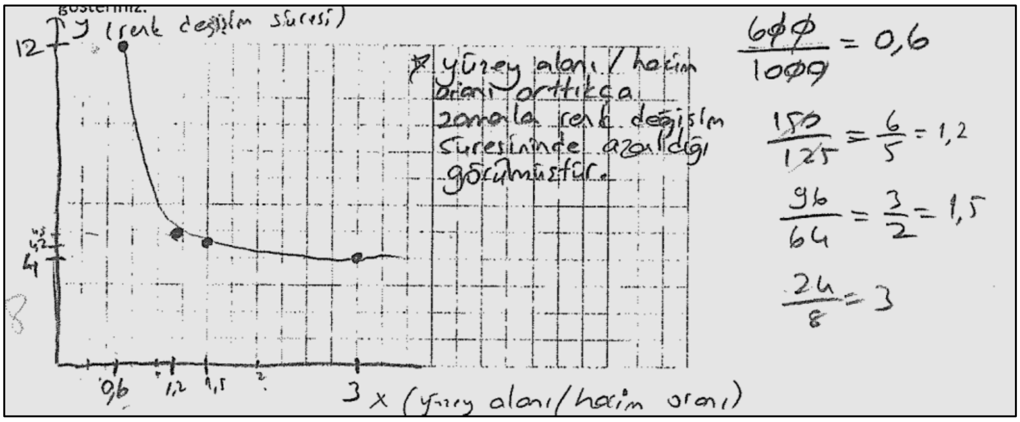
Table 7. *Frequency and Percentage Table of Pre-service Teachers Interpretation and Logical Reasoning Skills*

Drawing	*Interpretation of axes*	*Reasoning*	*Group 1*	*Group 2*	*Group 3*	*Total*
Correct drawing 53% (n=96)	Ability to interpret 28.9% (n=52)	Reasoning from graph	2.2% (n=4)	2.2% (n=4)	1.7% (n=3)	6.1% (n=11)
		Reasoning from variables	1.7% (n=3)	3.9% (n=7)	2.8% (n=5)	8.3% (n=15)
		Incorrect reasoning from graph	0.6% (n=1)	0.6% (n=1)	-	1.1% (n=2)
		Incorrect reasoning from variables	-	-	-	-
		Unrelated reasoning	5% (n=9)	4.4% (n=8)	3.9% (n=7)	13.3% (n=24)
	Inability to interpret 1.1% (n=2)	Correct reasoning	-	-	-	-
		Incorrect reasoning	-	-	1.1% (n=2)	1.1% (n=2)
	Unable to interpret 11.1% (n=20)	Correct reasoning	3.3% (n=6)	1.7% (n=3)	1.1% (n=2)	6.1% (n=11)
		Incorrect reasoning	0.6% (n=1)	2.8% (n=5)	1.7% (n=3)	5% (n=9)
	Other		1.7% (n=3)	2.8% (n=5)	5% (n=9)	9.4% (n=17)
	No respond		-	1.7% (n=3)	1.1% (n=2)	2.8% (n=5)
Correct representati on 22.3% (n=41)	Ability to interpret 11.7% (n=21)	Reasoning from graph	1.7 %(n=3)	-	-	1.7% (n=3)
		Reasoning from variables	0.6% (n=1)	1.1% (n=2)	0.6% (n=1)	2.2% (n=4)
		Incorrect reasoning from graph	-	-	0.6% (n=1)	0.6% (n=1)
		Incorrect reasoning from variables	-	-	-	-
		Unrelated reasoning	1.1% (n=2)	2.8% (n=5)	3.3% (n=6)	7.2% (n=13)
	Inability to interpret 2.2% (n=4)	Correct reasoning	0.6% (n=1)	-	-	0.6% (n=1)
		Incorrect reasoning	1.1% (n=2)	0.6% (n=1)	-	1.7% (n=3)
	Unable to interpret 5 (n=9)	Correct reasoning	0.6% (n=1)	1.7% (n=3)	1.1% (n=2)	3.3 %(n=6)
		Incorrect reasoning	-	1.7% (n=3)	-	1.7% (n=3)
	Other		0.6% (n=1)	-	1.7% (n=3)	2.2% (n=4)
	No response		-	1.7% (n=3)	-	1.7 %(n=3)
Incorrect Drawing 16.7% (n=30)	Ability to interpret 1.7% (n=3)	Reasoning from graph	-	-	-	-
		Reasoning from variables	-	-	0.6% (n=1)	0.6% (n=1)
		Incorrect reasoning from graph	-	-	-	-
		Incorrect reasoning from variables	-	-	-	-
		Unrelated reasoning	0.6% (n=1)	0.6% (n=1)	-	1.1% (n=2)
	Inability to interpret 2.8% (n=5)	Correct reasoning	0.6% (n=1)	0.6% (n=1)	1.1% (n=2)	2.2% (n=4)
		Incorrect reasoning	-	-	0.6% (n=1)	0.6% (n=1)
	Unable to interpret 5 (n=9)	Correct reasoning	0.6% (n=1)	1.1% (n=2)	1.1% (n=2)	2.8% (n=5)
		Incorrect reasoning	0.6% (n=1)	1.1% (n=2)	0.6% (n=1)	2.2% (n=4)

Drawing	*Interpretation of axes*	*Reasoning*	*Group 1*	*Group 2*	*Group 3*	*Total*
	Other		2.8% (n=5)	0.6% (n=1)	2.2% (n=4)	5.6% (n=10)
	No respond		1.1% (n=2)	-	0.6% (n=1)	1.7% (n=3)
No drawing 7 % (n=13)			3.3% (n=6)	3.3% (n=6)	0.6% (n=1)	7.2% (n=13)
Total			30% (n=55)	26.7% (n=66)	32.8% (n=59)	100% (n=180)

When Table 7 is evaluated, it is seen that 53% of the pre-service teachers can realize the drawing correctly. Sample student response is presented in Figure 6.

Figure 6. *Student Answer Accepted as Correct*



As shown in Figure 6, it was understood that the pre-service teachers who drew correctly explained their graph information correctly and correctly associated this information with the problem, with the answer that "as the surface area/volume ratio increases, the colour change time decreases over time". It was understood that 6.1% of the students who drew and interpreted correctly were able to make accurate judgments. Sample student answers from documents are presented below.

"*As the surface area/volume ratio increases, the amount of time taken for colour change decreases. Because when large volumes have a small surface area, the time required for the reaction to pass into the cube increases. Therefore, as the ratio increases, the colour change accelerates*." (D44)

"*There is an inverse proportion. As the volume/surface increases, the time gets shorter. Since the surface area is small, it takes less time for the brace to touch all surfaces*." (D140).

"*The smaller the surface area/volume ratio, the greater the colour change duration. So, there is a reverse link here. From here, as the surface area increases, the colour change time is less. The higher the surface, the faster the reaction, that is, the colour change*." (D152).

It was noticed that 8.3% of the pre-service teachers who drew correctly could establish a connection between the graph variables but made their judgments using the table's data in the problem. Sample student answers are presented below.

"*When we look at the table, the more the cube is in terms of size, surface area and volume, according to the values given, the time becomes proportionally larger.*" (D59)

It is seen that the pre-service teachers do not use graph data in their reasoning, but they can make correct judgments from the data. Inferences based on the data presented in the problem were also found among the pre-service teachers who could not draw the graph correctly (0.6%). It is noticed that the pre-service teachers' reasoning statements made from the data in the table in the problem instead of the graph such as "because the dimensions of each gelatine cube are different", "the larger the volume of the cube, the longer the colour change period".

It was understood that 14.4% of the pre-service teachers who drew correctly could establish a correct relationship between the graph variables but made wrong or irrelevant reasoning while explaining the reason.

Sample student answers from documents are presented below.

"As the surface area/volume ratio increases, the amount of time taken for colour change decreases. Because when large volumes have a small surface area, the time required for the reaction to pass into the cube increases. Therefore, the higher the ratio, the faster the colour change." (D43)

"It has changed according to the durability of the cubes. Smaller objects are more durable, and the less space they need to change, the less time it takes." (D50)

"As the surface area/volume ratio increases, the colour change time decreases. Because the smaller or thinner the substance is, the faster it is dyed." (D58)

"As the surface area/volume ratio increases, the time taken for colour change decreases. Because as the surface area/volume ratio increases, the substance reacts more quickly. Increasing the surface area/volume ratio increases the reaction rate. Because the more extensive the surface area/volume ratio, the faster the colour change. Because the space between the particles is large." (D61)

According to students' explanations, it was noticed that the students' pre-service teachers explained the reason for the colour speed with incorrect or irrelevant reasoning, such as the cube being small and thin or the reaction speed in the given responses.

4. Discussion

When the findings of the visual construction of the research were evaluated, it was determined that 66.1% of the pre-service teachers made a proper doting the data pairs in the graph. This result shows that comprehension of dotting the data pairs is above the average. It has been observed that 69.4% of pre-service teachers preferred merging the dots as a curve function graph. However, the other pre-service teachers' preference of linear and piecewise continuous line graphs made us assume that they could not develop a complete comprehension of the graph type. When the line continuance choices in the graph were evaluated, it was determined that 41.7% of the line continence was partial construction, and 49.4% of them was open construction. Hence, it was observed that the continuance of the graph drawing merging the dots could not be comprehended entirely as a visual construction of the graph. Bayazıt (2011) emphasized that, according to the studies in the literature, the difficulties and misconceptions about graph drawing are related to three main areas. These are; reading and interpreting graphs, drawing graphs and understanding the semantic relationship between graphs and other representations and being able to switch back and forth between these representations. It was noticed that at the very beginning of the misconceptions about graph drawings, pre-service teachers were inclined to draw linear graphs. Ercan et al. (2018) emphasizes that if the merging of the dots appropriate lines is not done correctly, the tendency of the graph cannot be determined precisely, and it may cause a great mistake. Therefore, in this study, it was seen that this mistake emerged as an error in interpreting the graph. Similarly, Glazer (2011) summarized the difficulties with graph drawing as follows; confusing the slop and the high, conceiving a graph as a constructed of discrete points, conceive considering a graph as a picture or map, Adams and Shrum (1988) found that college-level students performing biology experiments did not label the graph axes exactly. They also found that these students rarely pointed the dots and stated that they did not find it necessary to complete the line graph. Ercan et al. (2018) stated that pre-service science teachers were similarly weak in presenting the expected performance in the criteria of axis scaling, correct placement of data pairs on the axis, and bounding the points in their study with pre-service science teachers. Yayla and Özsevgeç (2014) found a positive relationship between students' drawing and interpretation of graphs in their study with secondary school (6,7, and 8th grade) students. The students stated that they had the most difficulty in bounding points and labelling axis, creating curves or lines by connecting points, and determining the place of dependent and independent variables. Observing similar results at the primary education level suggests that it is important to gain graph drawing skills at an early age.

The result of pre-service teachers' mathematical calculation success rate was found 66.4%. However, it was determined that they could only use the results they found as correct scaling in both axes at a rate of 28.9%. Gültepe (2016) found that 11th grade students have problems transferring mathematics formulas into a line graph. The fact that they are wrong in scaling not only in particular axes but also in both axes reveals their inadequacy in comprehending this situation. According to Kali (2005), scaling axes are problematic for students, and they have problems with answering questions requiring multiple skills, including variables. In addition, it was noticed that the pre-service teachers' graph drawings were not correct. Therefore, it is clear that this situation might affect their misinterpretations. This situation was observed as only 1.7% of the 16.7% pre-service who drew incorrectly could make a correct interpretation. In addition, it was observed that the correct interpretation rate was 11.7% for the 22.3% of students with correct graph representation and 28,9 % for the 53,0% of students with correct drawing. İlkörücü-Göçmençelebi and Tapan (2010) mentioned that the structure of the concept might be visually drawn correctly, as had been taught in the lesson as visual iconic. Therefore, Cleveland and McGill (1987) suggested that the direct purpose of the chart is not to show data to as many decimal places as possible. The goal is to see patterns in the data and understand the overall behaviour. But the more accurately the data is visually decoded, the better our chances of detecting and properly understanding the patterns and behaviour of the data.

When the pre-service teachers' reasoning in the graph they correctly drew was examined, it was seen that the pre-service teachers answered, "The time taken for the colour change in the gelatine cubes becomes longer as the surface to volume ratio gets decreases". Hence, based in the graph, they could make a correct interpretation in terms of the large surface area compared to the volume.

Pre-service teachers were expected to be logical, and the reasoning statement was, "When the surface area to volume ratio is large, the colour change will be observed in a shorter time because the surface area is larger than the volume. In this respect, the acid will affect and disperse more on the surface and allow us to observe quick colour change". However, it was noted that their answers were associated with table data, irrelevant biology information, or different answers. It was understood from the pre-service teachers' drawing graphs that they were inefficient in constructing logical reasoning.

Glazer (2011) emphasized that interpreting graphs is not an easy task and reading a graph is a complex activity even though it is a crucial skill to be literate in today's information. He added that graph interpretation competence is affected by many factors, including aspects of graph characteristics that are format, type and visual features, aspect ratio, scale and legend/labels), the viewer's expectations about, or familiarity with, the graph's content and their prior knowledge. He noted that the use and transparent data as a visual presentation help readers to understand the meaning of the visual message. According to Glazer, the display format affects viewers' ability to describe and explain quantitative relations within data. Different ways of presenting data affect what is easy to recall and, therefore, what viewers are likely to comprehend. If the data is not displayed properly, this might lead to misinterpretation, failure to see trends or to inefficient reasoning. In addition, it is understood that the students had difficulties in drawing the graph of the diffusion experiment that was conducted and making inferences from the graph. Students' inadequate ability to draw the graph may have affected this situation.

However, it is seen that students who draw the graph correctly cannot make acceptable reasoning. Therefore, it can be said that the reasoning skills with the help of graphics are different, and the relationship between them is poor. In the study of Batur et al. (2019) with 223 university students studying in the fields of social and science, it is revealed that they tend to read the data presented in the graph clearly, but they do not have sufficient skills to critically look at the data and make inferences. Dündar and Yaman's study with 220 classroom teachers revealed that students with high mathematical reasoning skills have high graph interpretation performance. However, in this study, it was noticed that pre-service teachers were inefficient in making logical reasoning from the graph, although their mathematical reasoning, which they used to solve problems in cognitive construction, conducted an above-average performance. According to the reasoning skills mentioned by Lithner (2006), the pre-service teacher may have made the preference of strategy in reasoning in solving the problem as memorized reasoning by remembering an answer in his memory, or as algorithmic reasoning by remembering the given rule for the solution. In this respect, it is crucial to evaluate problem-solving skills as mathematical reasoning in terms of making inferences from a problem as logical reasoning.

5. Conclusions

As a result, we can say that drawing a line graph is as difficult as the cognitive construction of this graph. It was understood that while the pre-service teachers misinterpreted the graphs due to the x and y axes being scaled in different ways, some of them made mistakes because they tried to answer the problems without considering the scale of the graph. Besides, some of them do not have adequate skills in drawing graphs, and they were not even able to draw graphs. Therefore, this situation was also effective in the fact that they could not correctly interpret the surface area to volume ratio relationship related to the problem. Furthermore, we noted that the logical reasoning skills related to the problem remained inefficient in the pre-service teachers who interpreted the graph data relation correctly. Shah and Hoeffner (2002) highlighted the importance of graph comprehension as a science or social science reasoning. They emphasized that when interpreting graphs, expert graph readers might foster students' ability to explain information and asked to draw graphs predicting results based on specific theories may promote their later ability to explain data and relate data to theories and hypotheses. In addition, this research verity suggests that interpretation of graph information may be due to cognitive recall of visual information. In this circumstance, the situation can be considered as visual memorization. Therefore, visually structured information may not be learned meaningfully. In this respect, it is important to evaluate their logical reasoning.

6. Implications and Recommendations

In this research we argued pre-service science teachers' ability to construct a line graph in terms of visual and cognitive construction. Although graph construction and interpretation are recognized as valuable skills (Berg & Smith, 1994; Cleveland & McGill, 1987; Glazer, 2011; McKenzie & Padilla, 1986; Shah & Carpenter, 1995; Wavering 1985) in this research indicate that many students have still not acquired these skills. In Aydan and Dönel Akgün's (2021) research, pre-service science teachers who took the courses "General Biology 1 and 2 laboratories still have problems reading, interpreting and drawing related to a line graph, including biology subjects. The results of the research provide perspective for teachers not only to help their students to draw correct graphs but also to make necessary interventions so that they can reason logically for their future drawings. According to the findings, we might say that pre-service teachers’ visual construction skills and cognitive construction skills can give information about their graph drawing skills. Moreover, their ability to make logical inferences from a graph is rather inefficient compared to graph drawing and interpretation skills. Therefore, a student's drawing correctly shows that they can make correct logical inferences and that an incorrect drawing can cause them to make an incorrect interpretation. For this reason, students' cognitive construction, especially graph interpretation and logical reasoning skills, should be examined through open-ended evaluation.

This study can contribute to researchers’ comprehension of where pre-service teachers who draw line graphs can make mistakes and evaluate their logical reasoning in a graph. In this context, it is recommended to include more graph drawings in the pre-service science course content in the teaching of biology subjects, and to support them to interpret the graph correctly and make logical inferences by providing discussion environments.

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Geniş Özet

Giriş

Günümüz bilgi çağında her geçen gün keşfedilen yeni bilgilerin anlaşılması sadece sözel değil, aynı zamanda sayısal veriler ve grafiklerin doğru yorumlanması ihtiyacını yaratmaktadır. Eğitimde görsel öğelerin kullanımı baskı teknolojisi ile artmış ve ders kitaplarında daha fazla grafik ve resim kullanılmasına imkân sağlamıştır (Landin, 2011). Glazer (2011), bir grafiğin okunmasının karmaşık bir etkinlik olduğunu ve günümüz bilgi çağının okuryazarı olmak için çok önemli bir beceri olduğunu belirtmektedir. Berg ve Smith (1994), grafiklerin, özellikle dergilerde, resmi yayınlarda, gazetelerde ve konferanslarda yaygın olarak kullanılmakta olduğunu, bu grafikleri yorumlama veya grafikteki hatayı tanıma yeteneğine sahip olmazsak, bunları sunan kişilerin yorumuna veya doğruluğuna sahip olacağımızı belirtmektedir. Shah (1997), bir grafik modelinin benzersiz olduğunu, somut nesnelerin veya soyut kavramların bazı nicel özelliklerini temsil etmesi nedeniyle kısmen soyut diyagramlardan ayırt edilebileceğini vurgulamaktadır. Temsil edilen bir kavram ile grafik arasındaki ilişkiyi, nicel ölçekler ve bu nicel bilginin eşdeğer temsilleri olan görsel boyutların arasındaki benzerliğe dayandığını eklemektedir. Cleveland ve McGill'e (1984) göre grafik algısı, grafiklerde kodlanmış bilgi sürecinin görsel olarak çözülmesidir. Sürecin ilk kısmı, insanlar grafiklerden nicel bilgi çıkardığında bir dizi temel algısal görev olarak açıklanır. İkinci süreç, görevlerin ne kadar doğru yapıldığına göre sıralanmasıdır. Biyoloji konuları mantıksal çıkarımların yapılmasını temel alan bir içeriğe sahiptir. Nitekim öğretmenler bilgilerin sunulmasında grafiklerden sık sık yararlanmaktadır. Örneğin solunum ve akciğer kapasitesinin değerlendirilmesi veya hormonların salgılanmasındaki mekanizmanın açıklanması gibi mantıksal çıkarım gerektiren durumlarda grafiklere, açıklayıcı ve durumu görselleştiren bir araç olarak sık sık yer verilmektedir. Wavering'e (1985) göre bir çizgi grafiği, verilerin görünür olmasını sağlayan, değişkenler arasındaki ilişkilerin analizine yardımcı olmak için bilimde kullanılan bir araç olarak tanımlanmaktadır. Çalışmalarda ilköğretimden üniversiteye kadar olan süreçte öğrencilerin grafik okuma ve yorumlamada sorun yaşadıkları ve bazı kavram yanılgılarına sahip oldukları anlaşılmaktadır (Aydan & Dönel Akgül 2021; Berg & Smith 1994; Erbilgin vd., 2015; Ercan vd., 2018; Kali 2005; Kıranda & Akpınar 2020; Wavering 1985; Yelken 2020). Yayla ve İncikabı vd. (2015), grafik çizme becerileri arasında okuma, oluşturma ve yorumlama becerilerinin en önemlisi olduğunu belirtmektedirler. Erbilgin vd., (2015), öğrencilerin çizgi grafiği yorumlama ve oluşturma becerilerinin belirlenmesinin bu konuda öğrencilerin yaşadığı öğrenme güçlüklerinin giderilmesi adına atılacak ilk adımlardan birisi olarak ele almaktadırlar. Bu açıdan öğretmenlerin grafiklerin öneminin farkında olması ve eğitimde yer vermesi beklenmektedir. Bu üç yıllık araştırma, öğretmen adaylarının biyoloji konusuna ilişkin bir çizgi grafiği oluşturma sürecini açıklamak ve böylece çizdikleri grafikle ilgili yorumlarını anlamak amacıyla yapılmıştır. Bu amaçla öğretmen adaylarının çizgi grafiklerini yapılandırma aşamaları ve çizdikleri grafiğe ilişkin mantıksal muhakemeleri tanımlanmaya çalışılmıştır.

Yöntem

Araştırma nitel araştırma yöntemlerinden doküman analizi çerçevesinde incelenmiştir. Doküman analizi, "inceleme", "bilgi geliştirme" ve "anlam çıkarma" amacıyla hedeflenen olgu veya olgular hakkında bilgi içeren yazılı materyallerin analiz edilmesidir (Bowen, 2009; Corbin & Strauss, 2008; Yıldırım & Şimşek, 2011). Araştırmanın dokümanlarını Bursa'da bir devlet üniversitesinin ikinci sınıfında 2013-2014 güz döneminde öğrenim gören 55 (9 erkek ve 46 kız), 2015-2016 güz döneminde öğrenim gören 66 (15 erkek ve 51 kız) ve 2016-2017 güz döneminde öğrenim gören 59 (9 erkek ve 50 kız) olmak üzere toplam 180 fen bilgisi öğretmen adayının dönem sonu değerlendirme kağıtları oluşturmaktadır.

Ham verilerin kaynağını üç yıl süresince toplanan genel biyoloji laboratuvar dersinin dönem sonu sınav kağıtları oluşturmaktadır. Değerlendirilen açık uçlu soru ile öğretmen adaylarından hücrelerdeki yüzey alanı ve hacim oranı ilişkisinin madde geçişine etkisini temsil eden bir probleme yönelik çizgi grafik çizmeleri ve bu grafiği yorumlayarak mantıksal çıkarım yapmaları beklenmektedir. Bu soruda yer alan yüzey alanı/hacim oranı arasındaki ilişki, hücre bölünmesinin başlatılması, difüzyon hızı, kutuplarda yaşayan canlılarda vücut ısısının korunması ve bazı organlarda yüzey alanının arttırılması gibi çeşitli konularda öğrencilerin yararlandığı bir bilgi olması nedeniyle tercih edilmiştir.

Öğretmen adaylarının çizdikleri grafikler görsel ve bilişsel yapılanmaya göre değerlendirilmiştir. Temalar ve temalara ilişkin kategorilerin oluşturulmasında literatürden yararlanılmıştır (Cleveland & McGill 1984 and 1987; Berg & Smith, 1994; Shah & Carpenter 1995; Shah & Hoeffner 2002; Glazer 2011). Grafiğin görsel yapılanması, "y" eksenindeki veriler ile "x" eksenindeki veriler doğru kesiştirmesi ve birleştirmesine göre "iki veri arasında ilişki kurarak nokta oluşturma", verileri grafikte işaretledikten sonra noktaların birleştirilmesine göre "noktaları birbiriyle birleştirme", verilerin ötesinin çıkarımına yönelik grafiğin sürdürülmesine göre "birleştirilen noktaları devam ettirme" kategorilerin göre değerlendirilmiştir. Grafiğin bilişsel yapılanması matematiksel işlem becerisinin kullanılmasına göre "hesaplama yapma", hesaplama sonuçlarına göre veri çiftlerini grafik ekseninde uygun şekilde ölçeklendirmesine göre "grafik ekseni ölçeklendirme", grafikteki eksenler arasındaki ilişkilere bağlı olarak yorum yapabilmesine göre "yorumlama", grafik değişkenlere veya problem değişkenlerine bağlı muhakeme yapmasına göre "mantıksal çıkarım yapma" kategorilerine göre değerlendirilmiştir.

Araştırmanın geçerlik ve güvenirliğinin sağlanmasında "inandırıcılık", "aktarılabilirlik", "tutarlık" ve "teyit edilebilirlik" ölçütleri (Merriam, 2009; Lincoln & Guba, 1985) temel alınmıştır. Araştırma etiği gereği ve aynı zamanda analiz ve raporlama sürecinde tarafsızlık sağlamak amacıyla öğretmen adaylarına Ö1,Ö2,Ö3... biçiminde kodlar verilmiştir.

Bulgular

Öğretmen adalarının grafik çizimleri görsel yapılandırma ve bilişsel yapılandırma olarak iki aşamada değerlendirilmiştir.

Öğretmen adaylarının görsel yapılandırmalarına ilişkin bulguları; İlk olarak iki veri arasında ilişki kurarak nokta oluşturma seçimleri kategorisi "nokta oluşturma yok, nokta oluşturma var" kodlarına göre tanımlanmıştır. Öğretmen adaylarının grafik çizimlerinde toplamda %66,1 oranında eksenleri kullanarak nokta oluşturdukları görülmüştür. Öğretmen adaylarının elde ettikleri verileri grafikte işaretledikten sonra noktaları birebirleriyle birleştirme seçimleri kategorisi "Düzgün sürekli doğru çizme", "Düzgün parçalı doğru çizme", "Sürekli eğri çizme" ve" Parçalı eğri çizme" kodları altında değerlendirilmiştir. Öğretmen adaylarının noktaları birleştirme seçimlerinin daha çok (%69,4) eğri fonksiyon grafiği olduğu fark edilmektedir. Ancak %21,7 oranında öğrencilerin doğrusal fonksiyon grafiğini de tercih ettikleri anlaşılmaktadır. Öğretmen adaylarının birleştirilen noktaları devam ettirme seçimleri "parçalı yapılandırma" ve "açık ara yapılandırma" ve "grafik çizgisi yok" kodları altında değerlendirilmiş Öğretmen adaylarının noktaları devam ettirme seçimlerinin %41,7, parçalı yapılandırma, %49,,4 olarak açık ara yapılandırma olduğu anlaşılmaktadır.

Öğretmen adaylarının bilişsel yapılandırmalarına ilişkin bulguları; Öğretmen adaylarının grafik verilerini hesaplama becerileri "doğru hesaplama, kısmen doğru hesaplama, yanlış hesaplama" kodları altında değerlendirilmiştir. Doğru hesaplama yapan öğretmen adaylarının üç grupta benzer olarak %69,1, %65,2 ve %59,3 oranında olduğu fark edilmektedir. Öğretmen adaylarının toplamda %64,4 oranında hesaplamada başarılı olduğu anlaşılmaktadır. Grafik ekseni ölçeklendirme seçimleri kategorisi "iki eksenin doğru olarak ölçeklendirilmesi, iki eksenin yanlış ölçeklendirilmesi, x ekseninin doğru ölçeklendirilmesi, y ekseninin doğru ölçeklendirilmesi ve iki eksenin ölçeklendirilmemesi" kodlarına göre tanımlanmıştır. Öğretmen adaylarının eksenleri doğru ölçeklendirme becerilerinin %7,3, %40,9 ve %35,6 olduğu, toplamda ise %28,9 düzeyinde olduğu dikkat çekmektedir. Öğretmen adaylarının x ekseninde, y ekseninde ya da iki eksenin ölçeklendirmesinde hata yaptıkları fark edilmektedir. Öğretmen adaylarının grafikte yüzey hacim ilişkisini kullanmalarına göre yorumlamaları "eksen ilişkisine bağlı ve eksen ilişkisinden bağımsız" olarak iki kategoride değerlendirilmiştir. Adayların grafiği açıklamada kullandıkları mantıksal muhakemeleri "Grafik çizimine göre" ve "Problemin verilerine göre" olması temel alınarak değerlendirilmiştir. Doğru çizim yapan öğretmen adaylarının "*yüzey alanı/hacim oranı arttıkça zamanla renk değişim süresinin azaldığı*" cevabı ile grafik bilgilerini doğru açıkladıkları ve bu bilgilerini problem ile doğru ilişkilendirdikleri anlaşılmıştır. Doğru çizim yapan ve doğru yorumlayan öğrencilerin ise %6,1'i doğru muhakeme yapabildiği anlaşılmıştır. Doğru çizim yapan öğretmen adaylarının % 8,3'ünin grafik değişkenleri arasında bağlantı kurabildiği ancak sorudaki tablonun verilerinden yararlanarak muhakeme yaptığı fark edilmiştir. Öğretmen adaylarının yaptığı muhakemede grafik verilerini kullanmadığı ancak tablo verilerden doğru muhakeme yapabildiği görülmektedir. Grafiği doğru çizemeyen (%0,6) öğretmen adaylarında da problemde sunulan tablo verilerini temel alarak yapılan çıkarımlara rastlanmış, öğretmen adaylarının bununla ilgili olarak "çünkü her bir jelatin küpün boyutları farklıdır.", "küpün hacmi ne kadar fazla ise renk değişim süresi o kadar uzun sürmüştür" gibi grafik yerine sorudaki tablodaki verilerinden yapılan muhakeme ifadeleri fark edilmiştir. Doğru çizim yapan öğretmen adaylarının %14,4'ünün grafik değişkenleri arasında doğru ilişki kurabildiği ancak nedenini açıklarken yanlış veya ilgisiz muhakeme yaptığı anlaşılmıştır. Örnek öğrenci cevapları aşağıda sunulmuştur. Verilen cevaplarda öğretmen adaylarının renk değişim hızı ile ilgili nedeni, küpün küçük olması ve ince olması veya reaksiyon hızı gibi yanlış veya ilgisiz muhakeme ile açıkladıkları fark edilmiştir.

Sonuç ve Tartışma

Bu çalışmada fen bilgisi öğretmen adaylarının çizgi grafiği görsel ve bilişsel yapılandırmalarının değerlendirilmesi yapılmıştır. Yapılan araştırmanın görsel yapılandırmalarının bulguları değerlendirildiğinde, öğretmen adaylarının iki veri arasında nokta oluşturan öğretmen adaylarının %66,1 olduğu tespit edilmiştir. Bu durum noktasal kavramanın ortalamanın üstünde olduğunu göstermektedir. Öğretmen adaylarının noktaları birleştirme seçimlerinin %69,4'oranında eğri fonksiyonu olduğu görülmüştür. Ancak diğer öğretmen adaylarının doğrusal ve parçalı sürekli doğru grafiği seçimleri, grafik çeşidi ile ilgili tam bir kavrama geliştiremediklerini düşündürmüştür. Grafik çizimlerinde nokta devam ettirme seçimleri değerlendirildiğinde %41,7 olarak parçalı yapılandırma, %49,4 olarak açık ara yapılandırma olarak çizim yaptıkları tespit edilmiştir. Grafiğin görsel yapılanması olarak grafiğin çiziminin noktalara bağlı olarak devam ettirme durumunun tam olarak anlaşılmadığı görülmüştür. Öğretmen adaylarının matematiksel hesaplamada %66,4 oranında başarı gösterdiği bulunmuştur. Ancak buldukları sonuçları ancak %28,9 oranında iki eksende doğru ölçeklendirme olarak kullanabildikleri tespit edilmiştir. Ölçeklendirmede özellikle belirli eksenlerde değil iki eksende de hatalı olmaları bu durumdaki yetersizliklerini ortaya koymaktadır. Buna ek olarak adayların grafiklerinin yanlış olmasına sebep olduğu fark edilmiştir. Dolayısıyla bu durumun yanlış yorumlar yapmalarını etkileyeceği açıktır. Öğretmen adaylarının çizdikleri grafikte yaptıkları muhakemeleri incelendiğinde, doğru çizdikleri grafiğe dayanarak “Yüzey/hacim oranı küçüldükçe renk değişimi için zaman uzar” olarak doğru yorumlayabilen %28,9 (n=52) öğretmen adayı, bunun nedeni olarak madde geçişinde hacme göre yüzey alanının büyük olmasına yönelik doğru mantıksal muhakeme yapabilmiştir. Ancak beklenen “*Yüzey alanı hacim oranı büyük olduğunda, renk daha kısa sürede gözlenecektir, çünkü yüzey alanı hacme göre büyük olduğu için asit daha fazla yüzeye etki edip dağılacak ve hızlı renk değişiminin gözlenmesini sağlayacaktır*” mantıksal muhakeme içeren ifadelerin kullanılamadığı cevaplarını tablo verileri ile, ilgisiz biyoloji bilgileri veya farklı cevaplarla ilişkilendirdikleri dikkat çekmiştir. Öğretmen adayları çizdikleri grafikten muhakeme yapmada zayıf kaldıkları anlaşılmıştır. Bunun yanında, öğretmen adaylarının bilişsel yapılandırmada problem çözmede başvurdukları matematiksel muhakemeleri ortalamanın üstünde bir performans göstermesine rağmen grafikten mantıksal muhakeme yapmada zayıf oldukları fark edilmiştir. Lithner (2006) belittiği akıl yürütme becerilerine göre, öğretmen adayı problemi çözümündeki akıl yürütmesindeki srateji seçimini hafızasındaki bir cevap üzerinden hatırlayarak ezbere dayalı muhakeme olarak (memorised reasoning) veya çözüm yolunu verilen kuralı hatırlayarak algoritmaya dayalı matematiksel akıl yürtüme (algoritmic reasoning) olarak yapmış olabilir. Bu açıdan matematiksel bir muhakeme olarak problemi çözme becerilerinin mantıksal muhakeme olarak bir problemden çıkarım yapma açısından değerlendirilmesi önemlidir.

Sonuç olarak öğretmen adaylarının *x* ve *y* eksenlerinin farklı şekillerde ölçeklendirilmesinden dolayı grafikleri yanlış yorumlarken kimileri de grafiğin ölçeğini dikkate almadan soruları yanıtlamaya çalıştıkları için hata yaptıkları anlaşılmıştır. Bazı öğretmen adaylarının grafik çizimiyle ilgili yeterli beceriye sahip olmadıkları, hatta grafik çizemedikleri görülmüştür. Dolayısıyla bu durumun öğretmen adaylarının probleme ilişkin yüzey alanı/hacim oranı ilişkisini doğru yorumlayamamalarında da etkili olduğu anlaşılmıştır. Bunun yanında grafik ilişkisini doğru yorumlayan öğretmen adaylarında probleme ilişkin mantıksal muhakeme becerilerinin zayıf kaldığı dikkat çekmiştir. Bu durum grafiği yorumlama bilgilerinin görsel bilgiyi bilişsel olarak hatırlamalarından kaynaklanabileceğini düşündürmektedir. Bu durum görsel bir ezber olarak değerlendirilebilir. Dolayısıyla görsel olarak yapılandırılan bir bilgi anlamlı olarak öğrenilmiş olmayabilir, mantıksal muhakemelerinin değerlendirilmesi bu açıdan önemlidir. Araştırma sonuçları, öğretmenlerin sadece öğrencilerinin doğru grafik çizmelerine yardımcı olmakla kalmayacak aynı zamanda gelecekte yapacakları çizimler için de mantıksal akıl yürütebilmeleri için gerekli müdahaleleri yapabilmeleri için bakış açısı sağlamaktadır. Bulgulara göre öğretmen adaylarının görsel ve bilişsel yapılandırma becerilerinin zayıf olduğu, grafikten mantıksal çıkarımlar yapabilmelerinin grafik çizme ve yorumlama becerilerine göre daha yetersiz olduğu söylenebilir. Bunun yanında, çalışma doğru bir çizgi grafiğinin, doğru mantıksal çıkarıma, yanlış bir çiziminde yanlış yorum yapılmasına neden olabildiğini göstermektedir. Bu nedenle öğrencilerin açık uçlu değerlendirme yoluyla bilişsel yapılandırmaları özellikle grafiği yorumlama ve mantıksal muhakeme bilgisi yoklanmalıdır. Yapılan bu çalışma, araştırmacıların çizgi grafiği çizen öğretmen adaylarının nerelerde hata yapabileceklerini fark etmelerine, bir grafikte öğretmen adaylarının mantıksal muhakemelerini değerlendirmelerine katkı sağlayabilir. Biyoloji konularının öğretiminde, öğretmenlerin grafik çizimine önem vermesi, öğrencilerin daha fazla mantıksal çıkarım öğrenmelerine katkı sağlayabilecektir. Bu bağlamda biyoloji konularının öğretiminde grafik çizimlerine ders içeriğinde daha çok yer verilmesi, tartışma ortamları sağlanarak öğrencilerin grafiği doğru yorumlamalarıyla birlikte buna ilişkin mantıksal çıkarım yapmalarının desteklenmesi önerilmektedir.

Yayın Etiği Beyanı

Araştırma verileri 2013-2017 yılları arasında toplanan dokümanların analizi olduğu için etik kurul raporu bulunmamaktadır. Bu araştırmanın planlanmasından, uygulanmasına, verilerin toplanmasından verilerin analizine kadar olan tüm süreçte "Yükseköğretim Kurumları Bilimsel Araştırma ve Yayın Etiği Yönergesi" kapsamında uyulması belirtilen tüm kurallara uyulmuştur. Yönergenin ikinci bölümü olan "Bilimsel Araştırma ve Yayın Etiğine Aykırı Eylemler" başlığı altında belirtilen eylemlerden hiçbiri gerçekleştirilmemiştir. Bu araştırmanın yazım sürecinde bilimsel, etik ve alıntı kurallarına uyulmuş; toplanan veriler üzerinde herhangi bir tahrifat yapılmamıştır. Bu çalışma herhangi başka bir akademik yayın ortamına değerlendirme için gönderilmemiştir.

Araştırmacıların Katkı Oranı Beyanı

Birinci Yazar %50 ve ikinci Yazar %50 oranında katkı sağlamıştır.

Destek ve Teşekkür

Yazarlar olarak, araştırmanın gerçekleştirilmesi sürecine yönelik herhangi bir destek ya da teşekkür beyanımız bulunmamaktadır.

Çatışma Beyanı

Yayına kabul edilen yukarıda başlığı, yazarları, yayın etiği beyanı ve katkı oranı bilgileri bulunan bu araştırma, alan editörü olarak görev yaptığımız dergide yayına kabul edilmiştir. Tüm değerlendirme sürecinin baş editör tarafından kör hakemlik ile yürütülmüş olduğunu ve sürece sadece yazar olarak müdahil olduğumuzu beyan ederiz. Ayrıca araştırmanın yazarları olarak çalışma kapsamında raporlanan araştırma sonuçlarında dolaylı/dolaysız herhangi bir çıkar/çatışma beyanımız olmadığını ifade ederiz.