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Examination of the Sixth-Grade Students' Performances in Graphical Languages

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Abstract: Graphical languages are helpful for students as they facilitate the understanding of the given data. Understanding these graphical languages is also important as students encounter tasks containing graphics when compared to the tasks in the past (Diezmann & Lowrie, 2008). The current study aims to investigate whether sixth-grade students' graphical language performances vary significantly considering gender. It was also investigated whether there is a significant correlation between the sixth-grade students' performances among the six components of the graphical language. The participants were 97 sixth-grade students in an elementary school in Ankara, Turkey. To examine students' performances in graphical languages, a graphical languages test was adapted from Mackinlay's (1999) model of graphical languages. The results of the study showed that total scores of the sixth-grade students' graphical performances did not vary significantly considering gender. However, when the students' scores were examined for each component of the graphical language test individually, it was found that the students' scores in the Axis and Miscellaneous components varied significantly. This difference in the Axis component was found to be in favor of the girls, while it was in favor of the boys in the Miscellaneous component. Furthermore, there were significant correlations among the sixth-grade students' performances in graphical languages.

Keywords: Graphical Languages, Sixth-grade students' performances

Introduction

The increase in the number of graphics in our everyday life makes people exposed to information that requires them to decode these graphics. Graphics including graphs, maps, diagrams, tables, number lines, and flow charts are defined as visual representations and they are used for "storing, understanding and communicating essential information" (Bertin, 1983, p. 2). Although looking at and decoding these graphics are important, understanding what is given in the graphics and making decisions according to these understanding are also important (Tversky & Schiano, 1989). In fact, some researchers explain that graphics are seen as the easiest way to visually give information; however, they may be difficult because of their structure (Parmar & Signer, 2005). Because of its importance, the topic of graphics has gained researchers' attention and is accepted an important topic of elementary school mathematics curriculum (Ministry of National Education [MoNE], 2018). Many content strands, particularly, the data processing content strand can be said to be aiming to equip students with knowledge and skills related to graphics (MoNE, 2018; National Council of Teachers of Mathematics [NCTM], 2000). The topic of graphics is also important as it connects mathematics and science. McKenzie and Padilla (1986) explain the connection in the following way:

"In science, more than in any other subject, students should be involved in predicting relationships between variables and attempting to quantify these relationships. Line graph construction and interpretation are very important to science instruction because they are an integral part of experimentation, the heart of science" (p. 572).

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Since the graphical languages facilitate the understanding of the given data, they are helpful for students. Understanding these graphical languages is also important as students encounter tasks containing graphics when compared to the tasks in the past (Diezmann & Lowrie, 2008; Gagatsis & Elia, 2004).

Many researchers have examined the meaning of graphics and what is necessary for being accepted as graphics (Bertin, 1980; Fry, 1984; Guthrie, Weber, & Kimmerly, 1993). While Bertin (1983) explains that graphics are used to store, understand, and communicate the given data by means of visual representations, Fry (1984) states that graphics are used to transmit the given data by means of "line or area on a two dimensional surface" (p. 5). Although there are different types of graphics and different definitions of them, graphics in this article refer to the visuals or representations which contain the necessary information to solve the questions.

Mackinlay (1999) states that all kinds of graphics can be categorized into six different graphical languages and his categorization of graphical languages is used as the theoretical framework for this article. These graphical languages are Axis, Opposed-Position, Retinal List, Map, Connection, and Miscellaneous. The first of these graphical languages, Axis, is used to encode information by the position of a mark on a vertical or a horizontal axis. The second one, Opposed-Position, is used to encode information by marks on both vertical and horizontal axes. That is, while a student decodes the information just by focusing on either vertical or horizontal axis in Axis language, s/he decodes the information by looking both vertical and horizontal axes in Opposed-Position language such as line graphs and bar graphs. Retinal List, the third of the graphical languages, does not require students to focus on the mark(s) on axes. Since Retinal List language is related to rotation or reflection, it requires visualization. The fourth one, Map language, is used to encode information with respect to the coordinates and road maps and topographic maps are examples of it. Another graphical language, Connection, is used to encode information by means of the connections or links such as tree diagrams and family trees. The last one, Miscellaneous, requires to be able to interpret the different types of graphics such as pie charts and Venn diagrams.

Though some emphasis is put on knowledge and skills related to the graphical languages in curricula, it was found that decoding and understanding these graphics and graphical languages were difficult for students (McKenzie & Padilla, 1986). Students' difficulties can result from their readiness level, mathematical level, and the features of the graphical languages (Shah & Hoeffner, 2002). Being not successful in mathematics may result in interpretation difficulties of graphical languages (Gal, 1993). Furthermore, Roth and Bowen, (1994) emphasize that traditional mathematics classrooms in which students are not encouraged to discuss and explain their thinking can be another reason for their difficulties. Students with learning difficulties do not consider the graphics' features such as labels or axis and hence they cannot understand the purpose of these graphics (Parmer & Signer, 2005). For example, Parmer and Signer (2005) mention that even fourth and fifth-grade students have difficulties in focusing on the labels or in understanding the scale of the graphics. Furthermore, they think that if the scale of the graphics changes, then the results have to change which is not correct. Moreover, students' grade levels are not an important factor in their success in graphical languages (Berg & Philips, 1994). Although much is known about students' difficulties in different countries, according to our recent research on literature, there was no research investigating students' performances in graphical languages in Turkey. Thus, the aim of this study is to answer the following research questions.

1. Do the sixth-grade students' graphical language performances vary significantly depending on gender?
2. Are there any significant correlations between the sixth-grade students' performances in the six components of the graphical language?

Method

In order to investigate students' performances in graphical languages in Turkey and to examine whether or not a significant correlation among the components of the graphical languages exists, a quantitative research method was employed. Specifically, the current study employed a cross-sectional, descriptive survey design. The cross-sectional, descriptive survey studies are primarily used "to describe what is going on or what exists" (Trochim, 2001, p. 5). Similarly, survey studies are employed to show the present conditions considering different variables (Fraenkel, Wallen, & Hyun, 1993).

This study was conducted at three sixth-grade classes of an elementary school in Ankara, Turkey. Participants of the study, 97 sixth-grade students, were selected by convenience sampling method. Before delivering the instrument, the students were informed about the purpose of the study and confidentiality of their answers. To gather the data, a graphical languages test was adapted from Mackinlay's (1999) model of graphical languages.

Throughout the adaptation process, the sixth-grade objectives of mathematics curriculum of Turkey were considered. Before the pilot study, experts in mathematics education were asked to comment on the items to ensure content and face validity of the test. In the final version of the test, there were 18 questions related with all six different kinds of graphical languages involving 3 Axis, 3 Opposed-Position, 3 Retinal List, 3 Map, 3 Connection, and 3 Miscellaneous. The first of the questions for each graphical languages were easy, the second ones were medium, and the last ones were difficult. The authors of this paper, themselves, collected the data in case the participants of the study would ask questions related to the test items. The data was collected in normal class time and it took approximately 40 minutes for the students to answer the items. The items examining the sixth-grade students' performances in graphical languages were scored as correct or incorrect. As there were three items in each category, 3 is the maximum score for each category and 18 in total. The Statistical Packages for Social Sciences (SPSS) 23.0 were used to record and analyze the data collected via the test.

Results and Discussion

One of the purposes of the current study is to examine whether the sixth-grade students' graphical language performances vary significantly considering the students' genders. For this purpose, the Mann-Whitney U test was conducted as the data collected from the students were normally distributed.

Table 1. The students' graphical language performances based on gender

Gender	n	Mean Rank	Rank Sum	U	p
Girl	47	48.17	2264.00	1136.00	.776
Boy	50	49.78	2489.00		

As shown in Table 1, no statistically significant difference exists between boys and girls considering their graphical language performances in total, $U=1136.00$, $p>.05$. However, when their graphical language performances were examined for each component of the graphical language test, it was found there were significant differences between the students' performances in the Axis and Miscellaneous components based on their gender. In the tables below, Table 2 and Table 3, detailed Mann Whitney U test results for the students' performances in the Axis and Miscellaneous components, respectively, are shown.

Table 2. The students' performances in the Axis component based on gender

Gender	n	Mean Rank	Rank Sum	U	p
Girl	47	54.66	2569.00	909.00	.041
Boy	50	43.68	2184.00		

As it is seen in Table 2, there is a significant difference between the mean scores of the boys (Mean: 0.96) and girls (Mean: 1.3617) in the Axis component of the graphical language test, $U=909.00$, $p<.05$. When the mean ranks are considered, it is seen that the girls' mean score for the Axis component is higher than that of the boys.

Table 3. The students' performances in the Miscellaneous component based on gender

Gender	n	Mean Rank	Rank Sum	U	p
Girl	47	41,64	1957,00	829.00	.007
Boy	50	55,92	2796,00		

Contrary to the Axis component, the girls' mean score (Mean: 0.4681) in the Miscellaneous component is lower than that of the boys (Mean: 0.98) and this difference is statistically significant. That is, there is a significant difference between the boys' and girls' performances in the Miscellaneous components, $U=829.00$, $p<.05$.

Therefore, it can be concluded that there was a significant difference for the boys' and girls' performances in the Axis and Miscellaneous components of the graphical language test. But no significant difference was found considering the gender in the other components of the graphical language test (Opposed-Position, Retinal List, Map, and Connection).

The second purpose of the current study is to investigate whether or not there is a significant correlation between the sixth-grade students' performances among the six components of the graphical language. For this purpose, Spearman's Rank Correlation, one of the non-parametric tests was used, as the data were not normally distributed. The results are presented in Table 4.

Table 4. Correlations among the six components of the graphical language

Graphical Language Components	Axis	Opposed Position	Retinal List	Map	Connection
Axis					
Opposed Position	-.102				
Retinal List	.176	.005			
Map	.222*	.110	.116		
Connection	.028	.175	.144	.207*	
Miscellaneous	.131	.147	.139	.300**	.240*

* p < .05 level ** p < .01 level

As can be seen in Table 4, there is a low, positive, and significant correlation between the students' performances in the Map and Axis components of the graphical language test, $r=.222$, $p<.05$. Since the correlation is positive, it can be inferred that the students whose performances are high in the Map component would also perform better in the Axis component.

Similarly, there is a low, positive, and significant correlation between the students' graphical language performances in the Map and Connection components of the graphical language test, $r=.207$, $p<.05$. Thus, it can be inferred that with the students' increasing graphical language performances in the Map component, their graphical language performances in the Connection component would also increase.

There is a medium, positive, and significant correlation between the students' graphical language performances in the Map and Miscellaneous components of the graphical language test, $r=0.300$, $p<.01$. The students whose performances are high in the Map component would also perform better in the Miscellaneous component as the correlation between these two components is positive.

Moreover, there is a low, positive, and significant correlation between the students' graphical language performances in the Miscellaneous and Connection components of the graphical language test, $r=0.240$, $p<.05$. Thus, it can be inferred that with the students' increasing graphical language performances in the Miscellaneous component, their graphical language performances in the Connection component would also increase.

Conclusion

It was found that there is no significant difference between the boys' and girls' mean scores taken from the graphical language performance test. However, when the scores taken from each component were examined considering gender, it was found that significant difference occurred between the mean scores of the boys and girls for the Axis and Miscellaneous components. Contrary to the literature, this difference is in favor of the girls for the Axis component. Specifically, this difference was found to be in favor of boys in a study conducted by Lowrie and Diezmann (2005). Lowrie and Diezmann (2005) also found that there is no gender-based significant difference in the Miscellaneous component. However, in this study, there was a significant difference in the favor of boys in the Miscellaneous component.

Considering the second purpose of the study, it was found that there were positive and significant correlations between the students' performances in the Map and Axis, and Connection and Miscellaneous components. That is, the students whose performances are high in the Map component would also perform better in the Axis, Connection and Miscellaneous components. This finding is also valid for the Miscellaneous and Connection components. Some studies in the literature reported significant correlations among all the components of the graphical language (Lowrie & Diezmann, 2005, 2007). Thus, in general, it can be concluded that the development of knowledge and skills of one component would positively affect the other components. Thus, it can be suggested that teachers can plan activities that help students improve their knowledge and skills.

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