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Abstract

This study investigated the graphing skills and some affective states of middle school students about graphs by their gender, grade level, and the common graph types used in science courses. Participants' line graph skills, self-efficacy beliefs and attitudes toward graphs, and their personal literacy perceptions about different graph types (line, bar, and pie) are explored quantitatively. Qualitative data was collected about the views of participants about graphs in general, as well as about the factors that impact students like/dislike certain graph types. Based on the findings, while participants were found to lack line graph skills, they were found to hold high self-efficacy beliefs and positive attitudes toward graphs. No significant difference among the dependent variables was found based on gender; however, grade level and graph type variables were found to impact students' graph skills and personal graph literacy perceptions. Among the commonly used graphs in middle schools, a vast majority of students favored bar graphs, mostly due to the simplicity of them, and disliked pie charts, as finding them difficult to draw.

Introduction

In a rapidly increasing world of knowledge, gaining graphing skills is essential because graphs act as an entrance gate to scientific studies. From sports to politics or from news to scientific publications, various types of graphs come across almost in every area of our lives (Matuk, Zhang, Uk, & Linn, 2019). Graphs have the advantage of summarizing data in a practical and visually comprehensible manner, and therefore they are often used in teaching processes as well (Fry, 1981; Shah & Hoeffner, 2002; Wainer, 1992). After the famous three Rs (Reading, wRiting, aRithmetic), graph skills are recently started being called the fourth R (Aldrich & Sheppard, 2000); however, even the simplest graphs are considered as difficult by many people (Galesic & Garcia-Retamero, 2011). Although some preliminary skills about graphs are acquired during elementary school years, students' graphing skills are mostly acquired during the middle and secondary school years (Lai, Cabrera, Vitale, Madhok, Tinker, & Linn, 2016; Phillips, 1997; Yinkang & Yoong, 2007). For this reason, middle school years hold significant importance in students' future efficiency in dealing with graphs.

Science courses are a natural field of application for graphs (Gioka, 2007; Keller, 2008; Matuk et al., 2019) and therefore graphs are a part of the curriculum standards, such as the Next Generation Science Standards (NGSS) in the United States (National Research Council, 2012). Like many other countries, the Turkish Ministry of National Education (MEB) requires the middle school science curricula to comprehend the scientific process skills that will allow students to present their data in scientific ways, as well as analyze different types of graphs. The ultimate goal of Turkish science education was defined as "regardless of any personal differences, preparing all students to be scientifically literate" (MEB, 2005; 2013; 2017; 2018). Scientific literacy not only comprehends understanding the scientific concepts, but it also requires gaining scientific process skills to be able to use these skills in daily life as well. Therefore, graphing skills are a crucial part of scientific literacy (Beichner, 1994; Matuk et al., 2019). One of the indicators of the importance of graphs in today's international education is the frequency of the graph questions used in international tests. For example, Program for International Student Assessment (PISA), which examines the scientific literacy levels of students in the areas of science, mathematics, and reading, and Trends in Mathematics and Science Study (TIMSS) frequently use questions requiring graph reading and drawing skills (Kramarski, 2004; Ludewig, 2018; Ludewig, Lambert, Dackermann, Scheiter, & Möller, 2020).

Instructional Problems Related to Graphs

Graphs are a necessary part of many other school courses, such as mathematics and social sciences too (Friel, Curcio, & Bright, 2001; Lowrie & Diezmann, 2011). Although graphs come across to students on many occasions, past studies reported that students experience various problems related to graphs (Gioka, 2007; Matuk et al., 2019). One of the most evident findings supporting this argument is that student achievement was found to be negatively correlated with the number of graphs used in exams (Bektaşlı & Çakmakçı, 2011; Beler, 2009; Coştu, 2007). It is well documented that students have problems in almost all aspects of graphs; such as reading graphs, drawing graphs, interpreting graphs, and converting one type of graph to another type (Boote, 2014; Capraro, Kulm, & Capraro, 2005; Koparan & Güven, 2013; Matuk et al., 2019; Oruç & Akgün, 2010). An important cause of the lack of graphing skills of students is shown as the failure of the educational systems to deliver the necessary graphing skills at schools (Bowen & Roth, 1998; Gioka, 2007; Greenberg, 2014; Hotmanoğlu, 2014; Tairab & Al-Naqbi, 2004).

Graphical Literacy

The concept of “graphical literacy” or “graphicacy” is defined in different ways by several researchers. In earlier definitions, Wainer (1980) and Fry (1981) stated graphicacy as the ability to read and draw graphs, whereas later definitions comprehend more details. For example, Friel and Bright (1995) defined graphical literacy at three levels: reading the data (reading visible values in the graph), reading the link between the data (explaining the general information in the graph), and reading beyond the data (making comments and inferences about the graph). Gan, Scardamalia, Hong, and Zhang (2010) expressed the same concept as the ability to create, prepare, present, read, and interpret graphs; while Ludewig (2018) defined it as the ability to understand graphs independently of the specific content domain. Based on these definitions, graphical literacy can be defined as the ability to read the variables and data in a given graph, to interpret the variables and relations in a given graph in a scientific manner, to create appropriate graphs according to the available data, and to convert a graph into different graph types.

The term literacy is not just a cognitive concept but has affective and psychomotor dimensions as well. To be graphically literate, a person should have positive attitudes towards graphics (Greenberg, 2014); as well as comprehend the required knowledge and skills necessary to use the graphs scientifically. For example, it had been underlined that some students experience anxiety in reading and interpreting graphs (Beler, 2009). In order to be graphically literate, students also need to gather sufficient self-efficacy beliefs toward graphs and hold positive attitudes about graphs. With reference to Bandura's (1997) definition of self-efficacy beliefs, the self-efficacy belief towards graphs can be defined as the individual's belief in his/her proficiency level in reading, interpreting, drawing and transforming different types of graphics. Similarly, the attitude towards graphs can be defined as the individual's personal response to the importance of graphics and the necessity of their use.

In the literature on the use of graphs in the educational contexts, there is a large body of studies focused merely on the cognitive dimension of graphical literacy. For example, studies both in Turkey (Bektaşlı & Çakmakçı, 2011; Beler, 2009; Coştu, 2007; Hotmanoğlu, 2014; Koparan & Güven, 2013; Oruç & Akgün, 2010) and other countries around the world (Beichner, 1994; Boote, 2014; Capraro et al., 2005; Gioka, 2007; Tairab & Al-Naqbi, 2004) agree on that students experience problems in all processes related to graphs, such as graph plotting, graph reading, and graph interpretation. Compared to the number of research studies conducted on the cognitive dimension of graphing skills, no study has been conducted to measure people's affective characteristics, such as individual's personal graph literacy perceptions, self-efficacy beliefs, and attitudes towards graphs. Since these affective states possibly interact with students' cognitive skills and impact their graphicacy levels, new studies are needed to investigate students' affective states. Only by combining the results of studies focusing on both the cognitive and affective perspectives, the graph-related problems can be better understood.

It is crucial to measure the affective states of students about graphs during the middle school years because students' affective characteristics toward graphs begin to take shape during these years. Also, since science courses are a natural field of application for graphs, (Gioka, 2007; Keller, 2008), students' affective states about graphs should be focused on the graph types that are commonly used in science courses. Therefore, one of the aims of this study is to measure the middle school students' self-efficacy beliefs and attitudes towards graphs.

Implications of Different Graph Types

Some of the most frequently used graphs were first developed by the Scottish economist William Playfair in 1780s (Åberg-Bengtsson & Ottosson, 2006; Friel et al., 2001) but nowadays, with the inclusion of the three-dimensional representations, there are quite numerous graph types. Beginning from the earliest studies on graphs, it has been repeatedly reported that students exhibit quite different skill levels for different graph types (Ali & Peebles, 2013; Friel & Bright, 1995; Maggioni, 1953; Simkin & Hastie, 1987; Wainer, 1980). The reasons for the varying success of students according to graph types are listed as the visuality of the graph, the mathematical background required for drawing or interpreting the graph, and the way in which the variables are included in the graph (Culbertson & Powers, 1959; Johnson, 1971; Shah & Freedman, 2011; Simkin & Hastie, 1987). In light of these findings, it can be concluded that the students' affective states related to graphs may also change according to the graph types. Thus, the second aim of this study is to compare the students' graphical literacy perceptions about the line graphs, bar graphs, and circle (pie) charts which are frequently used in the middle school science courses.

Among the studies focusing on the impact of graph type on students' graphing skills, students often were found to struggle with line graphs compared to bar graphs or pie charts (Culbertson & Powers, 1959; Johnson, 1971; Malter, 1952; Wainer, 1980). For the same reason, students were found to prefer bar graphs instead of line graphs (Belar, 2009; Friel & Bright, 1995; Kranda & Akpınar, 2018; Shah & Freedman, 2011). The case for line graphs bears a great significance because line graphs are the most frequently used graph type in textbooks or international tests, such as PISA and TIMSS (Ali & Peebles, 2013; Patahuddin & Lowrie, 2019). For example, Peebles and Ali (2015) reported that among the two most common graph types of line and bar graphs, line graphs are used about three times more than the bar graphs in school textbooks. Therefore, another aim of this study will be to investigate the line graph skills of Turkish students to be able to spot the common problems, as well as to explore whether students' line graph skills are related to their affective states about graphs.

The research questions investigated in this study are:

1. Do middle school students' line graph skills differ by their grade level and/or gender?
2. Do middle school students' self-efficacy beliefs and attitudes toward graphs, in general, differ by their grade level and/or gender?
3. Do middle school students' graph literacy perceptions differ according to the graph type (line graph, bar graph, pie chart), participants' grade level, and/or gender?
4. Are middle school students' line graph skills related to their self-efficacy beliefs, attitudes toward graphs, and line graph literacy perceptions?
5. What factors impact middle school students' views about graphs in general and specifically about line graphs, bar graphs, and pie charts?

Method

Research Design

This study has employed an exploratory mixed-method design, where a quantitative data collection phase was followed by a qualitative data collection phase (Creswell & Plano Clark, 2011). In the first phase of this study, quantitative data were collected by using a graph achievement test and also two scales related to participants' self-efficacy beliefs and attitudes toward graphs, and their personal literacy perception levels about different graph types. In the second phase of the study, qualitative data were collected by using open-ended questions about participants' opinions and preferences about different graph types.

Participants

The participants of the quantitative phase of the study consisted of 137 Turkish middle school students. Since the line graphs are taught during the 6th grades of the Turkish middle schools, the participants were chosen from 7th and 8th grades, in order to secure that they had formal school instruction about all of the graphing types (line graph, bar graph, pie chart) investigated in the study. Among the 137 participants, 64 (47%) were male and 73 (53%) were female, whereas 67 (49%) of them were in 7th grade and 70 (51%) were in 8th grade. All students were informed verbally and in writing that participation in any part of the study was voluntary. The open-ended questions in the qualitative phase of the study were administered to all participants; however, due to the number of voluntary students, the qualitative data was collected from 72 participants.

Data Collection Instruments

In the quantitative phase of the study, Test of Graphing in Science (TOGS), Graph Self-Efficacy Beliefs and Graph Attitudes (GSEBGA) scale, and Graph Literacy Perceptions according to Graph Types (GLPGT) scale were used.

TOGS consisted of 26 multiple-choice test items about line graph skills and was developed by McKenzie & Padilla (1986) for students in grades 7 and above. In the original study, TOGS was administered to students between the 7th and 11th grades and a Kuder-Richardson reliability coefficient of $KR_{20}=.83$ was reported (McKenzie & Padilla, 1986). In this study, firstly the TOGS was adapted to Turkish. The adaptation process started with the translation of TOGS items to Turkish. Four different science and mathematics education experts, who are fluent both in English and Turkish checked the translated version and provided feedback. The pilot study was conducted with 97 middle school students at 7th and 8th grades, who were different from the participants of the main study. A KR_{20} value of .75 was calculated for the pilot study; however, seven of the TOGS items were determined to decrease the overall reliability. The adapted full version of the TOGS test was administered to 137 participants of the study and the same items in the pilot study were found to reduce the overall reliability of the test. Thus, seven TOGS items having item-total score correlations lower than .40 are eliminated and the Turkish version of the TOGS is reduced to 19 test items. The KR_{20} value for the adapted version of the TOGS was calculated as .80; which indicates that the data from the Turkish version of the TOGS provided scientifically reliable data.

Participants' self-efficacy beliefs about graphs and attitudes toward graphs are investigated with the GSEBGA scale (Bursal, 2019). GSEBGA scale consists of 12 items, under two factors of Graph Self-Efficacy Beliefs (GSEB) with 7 items, and Graph Attitudes (GA) with 5 items. In the original scale development study, the GSEBGA was administered on two separate samples with two different scaling options (the first sample responded on a 4-point Likert scale without a medium option and the second sample responded on a 5-point Likert scale). The exploratory factor analyses were conducted separately for both cases and only the items that significantly contributed to both scaling options were allowed to stay in the scale. In this way, future researchers are allowed using either scaling options for the same GSEBGA items (Bursal, 2019). This study used the 5-point Likert type scale (1: Strongly Disagree, 2: Disagree, 3: Partially Disagree/Partially Agree, 4: Agree, 5: Strongly Agree) version of the GSEBGA. While all items in the GA factor were positive, the GSEB items were all negative and therefore the GSEB item scores are reverse (1→5, 2→4, 4→2, 5→1) coded. Thus, higher GSEB and GA scores, indicate stronger graph self-efficacy beliefs and positive graph attitudes. The Cronbach alpha reliability coefficients are calculated as .80 for the GSEB factor scores and .68 for the GA factor scores in this study.

The graph literacy perceptions of participants according to three graph types are measured with the GLPGT scale (Bursal, 2019), which consisted of four items that are responded separately for each of the three graphing types (line graph, bar graph, pie chart). GLPGT is similar to a shortened version of the GSEBGA scale; however, while the GSEBGA scale was designed to measure the general views of participants on graphs, GLPGT was designed to compare participants' views on the line graphs, bar graphs, and pie charts. Thus, the four items of the GLPGT scale served as a 12-item instrument in total. Similar to the GSEBGA scale, the GLPGT is developed in a way that future researchers could use either a 4-point or 5-point Likert scaling (Bursal, 2019). This study used the 5-point Likert type scale version of the GLPGT. The scores of participants for each graph type (line graph, bar graph, pie chart) is calculated separately and therefore three dependent variables of Line Graph Literacy Perception (LGLP), Bar Graph Literacy Perception (BGLP) and Pie Chart Literacy Perception (PCLP) are measured with the GLPGT scale. All GLPGT items were positively worded, so no reverse coding was needed. Higher scores in any factor of the GLPGT indicate that participants hold high personal graph literacy perceptions about that graph type. The Cronbach alpha reliability coefficients were calculated as .83 for the LGLP scores; .75 for the BGLP scores; and .82 for the PCLP scores in this study.

In the qualitative data collection phase of the study, students' opinions about graphs were explored through two sets of open-ended questions. All open-ended questions included two tiers. In the first tier, participants were asked to select among multiple options (e.g. I like/dislike graphs) and then they were asked to write in detail why they selected the option in the first tier. The first set of open-ended questions was about what students like/dislike about the graphs in general. In the second set of open-ended questions, participants are asked to choose a graph type among the line graph, bar graph, or pie chart as to indicate they like or dislike that graph type the most. Then, participants are asked to write the reasons why they like or dislike any particular graph type.

Data Analysis

Participants' TOGS scores were determined by the number of their correct responses; thus, TOGS scores varied between 0 and 19. When calculating the factor scores from the GSEBGA and GLPGT scales, factor scores are standardized for the ease of interpretation. To calculate the standardized scores, the total of the item scores in a factor, is divided by the number of items in that factor. For this reason, the participants' overall factor scores varied in a 1 to 5 scale for all factors of the GSEBGA and GLPGT scales. Depending on the number of the dependent and independent variables, factorial design models were developed and analyzed to investigate the first four research problems using quantitative data. When the factorial models are formed, the sample sizes in each cell were conserved to be larger than 25, which provides robustness for the violation of normality (Pallant, 2007; Tabachnick & Fidell, 2007). The significance alpha level of .05 was used in all statistical tests. In addition to the statistical significance analyses, partial eta-squared values are also reported to interpret the practical significance of the findings.

The first research problem was investigated with a 2x2 Factorial Analysis of Variance (ANOVA) design, where participants' TOGS score was the dependent variable, and their grade level (7th and 8th) and gender were the factors (independent variables) included in the model. The second research problem included two dependent variables of participants' self-efficacy beliefs (GSEB factor scores) and attitudes toward graphs (GA factor scores), so a parsimonious statistical model, which allows analyzing these two variables simultaneously, was developed. Since the correlation between the GSEB and GA factor scores ($r=.31$) was found not to violate the multi-collinearity assumption, a Two-Way (2x2 Factorial) Multiple ANOVA (MANOVA) design was used, where participants' grade level and gender were the factors (independent variables) included in the model. Additionally, the multivariate normality of the dependent variables (GSEB and GA factor scores) was investigated by calculating Mahalanobis distances. The maximum Mahalanobis distance value (10.73) was lower than the recommended limit (13.82) for MANOVA models with two dependent variables (Pallant, 2007); thus, it is verified that the factorial MANOVA model satisfied the multivariate normality assumption.

The third research problem required a within and between-group comparison of participants' graph literacy perceptions about three different graph types (line graphs, bar graphs, pie charts); therefore, a Three-Way ANOVA (2x2x3) for Mixed-Measures were used. Participants' grade level and gender were used as the between-group factors, whereas participants' LGLP, BGLP, and PCLP scores were used as the within-group factor in this model. The sphericity assumption for this model was checked with Mauchly's Test of Sphericity and after the significant result of the Mauchly's Test ($p=.04$), the Sphericity assumption was verified to be violated. Therefore, the results of the multivariate tests, which do not require the sphericity assumption, were used.

The equality of error variances assumptions for all factorial models, developed for the first three research questions are checked with the Levene's test. Also, the equality of covariance matrices assumption for the second (Factorial MANOVA) and third (Three-Way Mixed-Measures ANOVA) research questions, where more than a single dependent variable were included in the models, was checked with the Box's test. The statistically insignificant ($p>.05$) results of the Levene's and Box's tests indicated that these assumptions were satisfied in all conditions. Pearson correlation coefficients between the participants' line graph achievement (TOGS scores), self-efficacy beliefs (GSEB factor scores), and attitudes toward graphs (GA factor scores), as well as their line graph literacy perception scores (LGLP) are calculated for investigating the fourth research problem.

The fifth research question, which included the analyses of qualitative data from the open-ended questions, was explored by using the content analysis method. Since the questions used in the study consisted of two tiers, the main themes were formed as the options given to the participants in the first tier, and a deductive analysis method (Patton, 2002) was used for forming the themes. Data from the second tier of the questions, where participants have written their personal reasons for further detailing their responses in the first tier, were used to form sub-themes by using the inductive analysis method (Patton, 2002). Frequencies for each sub-themes are reported and finally, findings from the qualitative data are compared with the findings from the quantitative data.

Results and Discussion

Participants' descriptive statistics for TOGS scores by their gender and grade levels are summarized in Table 1. As seen in Table 1, the overall success of the participants in the TOGS is below 50% ($9.3/19=.49$). The correct responses to the TOGS items varied between a maximum of 68%, where students were asked to interpret the

relationship of linearly increasing data points in a scatter plot, and a minimum of 26%, where students were asked to interpret two separate curvilinear graphs together.

Table 1. TOGS Scores of Participants by Grade Level and Gender

	Grade 7		Grade 8		Total	
	\bar{X}	s	\bar{X}	s	\bar{X}	s
Male	7.4	3.47	11.5	4.51	9.6	4.53
Female	8.2	4.17	9.9	3.97	9.1	4.13
Total	7.8	3.87	10.7	4.28	9.3	4.31

Compared to the relatively small mean differences between males and females in Table 1, the differences in TOGS scores by the grade levels are larger. The 8th graders (overall success 10.7/19=56%) have given almost three more correct responses to TOGS items than the 7th graders (overall success 7.8/19=41%). The mean TOGS score difference between the 7th and 8th graders is considerably small (1.7) across females; however, it is about 4.1 points across the males. It is interesting that while 7th grader females outperformed their male peers; on the contrary, the 8th grader males outperformed their female peers. A 2x2 factorial design ANOVA was run to test the interaction and main effects of the gender and grade level variables on the TOGS scores. The results of the 2x2 factorial design ANOVA are reported in Table 2.

Table 2. Factorial ANOVA Statistics for the Gender and Grade Level Effects on TOGS Scores

Effect	df	F	p	η^2_{Partial}
Gender	1	0.24	.63	.00
Grade Level	1	17.54	<.01	.12
Gender*Grade Level	1	3.05	.08	.02

Table 2 shows that the interaction effect of the gender and grade level (Gender*Grade Level) is not statistically significant [$F(1,133)=3.05$; $p=.08$], which indicates that the TOGS score trends across the grade levels are similar for both males and females. The main effect of gender variable is also found to be statistically insignificant [$F(1,133)=0.24$; $p=.63$], indicating that the overall mean TOGS scores of the males and females do not significantly differ. On the other hand, the grade level variable was found to have a statistically significant [$F(1,133)=17.54$; $p<.01$] main effect on the TOGS scores, indicating that 8th graders have significantly higher TOGS scores than the 7th graders. The partial eta-squared value ($\eta^2_{\text{Partial}}=.12$) calculated for the grade level main effect, suggests that the grade level variable has a medium effect size on the TOGS scores.

The mean GSEB and GA factor scores of participants from the GSEBGA scale by their gender and grade level are reported in Table 3.

Table 3. GSEB and GA Mean Scores of Participants by Grade Level and Gender

	Grade 7		Grade 8		Total	
	GSEB	GA	GSEB	GA	GSEB	GA
Male	3.58	3.71	3.67	3.44	3.63	3.57
Female	3.65	3.69	3.62	3.69	3.64	3.69
Total	3.62	3.70	3.65	3.57	3.63	3.63

Considering the score range of 1 to 5, the participants seem to have relatively high GSEB and GA scores and also the mean scores were similar across the subgroups. The item frequency analysis showed that students' self-efficacy beliefs and attitudes toward graphs depended on the context. For example, while 77% of the participants agreed that they would like to learn new information about graphs, only 45% agreed that they enjoy working on graph questions. Similarly, compared to the 40% disagreement with the item "I would have trouble when expressing data values in graphs." 73% of the participants disagreed with the item that "I can't formulate my ideas on graph questions."

The statistical significance of the interaction and main effects of participants' gender and grade levels on the GSEB and GA scores are investigated with a 2x2 factorial design MANOVA and the findings from this analysis are reported in Table 4.

Table 4. Factorial MANOVA Statistics for the Gender and Grade Level Effects on GSEB and GA Scores

Effect	Wilk's Λ	df	F	p	η^2_{Partial}
Gender	.995	2	0.30	.74	.00
Grade Level	.990	2	0.61	.54	.01
Gender*Grade Level	.987	2	0.82	.44	.01

The MANOVA results in Table 4 show that neither the interaction effect nor the main effects of the gender and grade level variables on the GSEB and GA scores are statistically significant. Therefore, it can be concluded that participants' self-efficacy beliefs and attitudes toward graphs do not change by their gender and grade level.

Participants' descriptive statistics of their graph literacy perceptions for line graphs (LGLP), bar graphs (BGLP), and pie charts (PCLP) by their gender and grade level are summarized in Table 5. Table 5 data indicates that regardless of the gender and grade level, participants' BGLP scores are higher than their corresponding LGLP and PCLP scores. Also, the 7th graders consistently expressed slightly higher literacy perceptions for all graph types than the 8th graders.

Table 5. LGLP, BGLP, and PCLP Mean Scores of Participants by Grade Level and Gender

	Grade 7			Grade 8			Total		
	LGLP	BGLP	PCLP	LGLP	BGLP	PCLP	LGLP	BGLP	PCLP
Male	3.84	4.31	3.88	3.42	4.05	3.54	3.62	4.17	3.70
Female	3.84	4.52	3.64	3.28	4.15	3.18	3.54	4.32	3.39
Total	3.84	4.42	3.75	3.35	4.11	3.34	3.58	4.25	3.53

The differences between gender groups in Table 5 is more complicated and indicates an interaction effect. Although the BGLP scores are always the highest graph literacy perception score among the gender subgroups, females had higher BGLP scores than the males in all cases. On the contrary, females consistently exhibited lower LGLP and PCLP scores than males. The statistical significance of the graph type factor on the graph literacy perception scores, as well as the interaction and main effects of participants' grade levels and gender on the LGLP, BGLP, and PCLP scores are investigated with a three-way (2x2x3) ANOVA design for mixed-measures and the findings for all within-subject effects and between-subject effects are reported in Table 6a and 6b.

Table 6a. Mixed-Measures ANOVA Within-Subject Effect Statistics

Within Subject Effect	Wilk's Λ	df	F	p	η^2_{Partial}
Graph Type	.559	2	46.17	<.01	.44
Graph Type * Gender	.946	2	3.37	.04	.05
Graph Type * Grade Level	.991	2	0.56	.57	.01
Graph Type * Gender * Grade Level	1.00	2	0.01	.99	.00

Table 6b. Mixed-Measures ANOVA Between-Subject Effect Statistics

Between Subject Effect	df	F	p	η^2_{Partial}
Gender	1	0.33	.56	.00
Grade Level	1	10.07	<.01	.08
Gender * Grade Level	1	0.23	.63	.00

For the within-subject effects given in Table 6a, the significant main effect of the graph type [Wilk's Λ =.559; $F(2,117)$ =46.17; p <.01] shows that participants' overall literacy perception scores for line graphs (LGLP), bar graphs (BGLP), and pie charts (PCLP) significantly differ. Based on the partial eta-squared value (η^2_{Partial} =.44), the graph type has a very large effect size on the graph literacy perception scores. To investigate, which of the LGLP, BGLP, and PCLP scores significantly differ from each other, a follow-up pairwise comparison test with a Bonferroni adjustment, was conducted. The pairwise comparisons yielded that participants' BGLP scores were significantly (p <.01) higher than their LGLP and PCLP scores, whereas there was no significant difference between the LGLP and PCLP scores. These results verify that participants had significantly higher literacy perception scores for the bar graphs than the line graphs and pie charts.

Another significant result in Table 6a was found for the two-way interaction effect of the graph type and gender variables [Wilk’s $\Lambda=0.946$; $F(2,117)=3.37$; $p=.04$]. This result implies that the changes in the order of the LGLP, BGLP, and PCLP scores among the gender subgroups, as was discussed in Table 5 data, are statistically significant. Table 6a also shows that both the three-way interaction effect of the graph type, gender, and grade level [Wilk’s $\Lambda=1.00$; $F(2,117)=0.01$; $p=.99$] and the two-way interaction effect of the graph type and grade level [Wilk’s $\Lambda=.991$; $F(2,117)=0.56$; $p=.57$] are not significant. These results indicate that the order of the LGLP, BGLP, and PCLP scores do not significantly change among the grade level subgroups.

The between-subject effects reported in Table 6b explores the differences in the overall literacy perception scores (LGLP+BGLP+PCLP) of participants by the main effects and the interaction effect of the gender and grade level variables. The test results in Table 6b, indicate that the interaction effect of the gender and grade level [$F(1,118)=0.33$; $p=.56$], as well as the main effect of gender [$F(1,118)=0.23$; $p=.63$], are statistically insignificant, which means that the overall graph literacy perception scores do not significantly differ among gender subgroups and also among the subgroups formed by the combination of the gender and grade level variables. On the other hand, the grade level variable was found to have a statistically significant [$F(1,118)=10.07$; $p<.01$] main effect on the graph literacy perception scores, indicating that 7th graders have significantly higher overall graph literacy perception scores than the 8th graders. According to the partial eta-squared value ($\eta^2_{\text{Partial}}=.08$) calculated for the grade level main effect, the grade level variable has a medium effect size on the overall graph literacy perception scores.

The relationships between the TOGS scores, the two factors (GSEB and GA) of the GSEBGA scale, and the LGLP factor of the GLPGT scale are explored by calculating the Pearson correlation coefficients. Although the TOGS scores were found to be not related to students’ GA scores ($r=.07$; $p=.42$), positive significant correlations were found between the TOGS and GSEB scores ($r=.41$; $p<.001$) and between the TOGS and LGLP scores ($r=.27$; $p<.01$).

In the qualitative part of the study, participants were first asked whether they liked or disliked the graphs in general and then asked to further explain why they liked/disliked the graphs. The percentages of student responses according to the main themes and the emerging subthemes from the data are reported in Table 7.

Table 7. Factors Influencing Why Students Like/Dislike Graphs

Like graphs because they are...	%	Dislike graphs because they are...	%
Simple	33.3 %	Complicated	12.5 %
Informative & Effective	16.7 %	Difficult	11.2 %
Interesting & Fun	15.3 %	Boring	5.5 %
Visual	5.5 %		
Total	70.8 %	Total	29.2 %

Table 7 data shows that a vast majority (70.8%) of the participants enjoy graphs since they find graphs simple, informative and interesting. Some sample student responses can be listed as;

- They can be easily understood and drawn. (S47)*
- They make the questions simpler. (S19)*
- It is usually fun working with graphs. (S49)*
- I like them because they are both visual and interesting. (S68)*

However, about one-third (29.2%) of the participants considered the graphs as being complicated, difficult and boring. Some sample student responses can be listed as;

- Graphs confuse me. (S8)*
- Graphs seem boring to me. Sometimes it seems like, I am wasting my time. (S53)*
- Sometimes I miss something and cannot analyze the graphs. (S52)*

In the qualitative data collection phase of the study, participants were also asked to choose the graph type they liked/disliked the most among the line graphs, bar graphs, and pie charts. The percentages of the participants’ responses are reported as bar graphs (as being the most liked and least disliked graph type among the participants) in Figure 1.

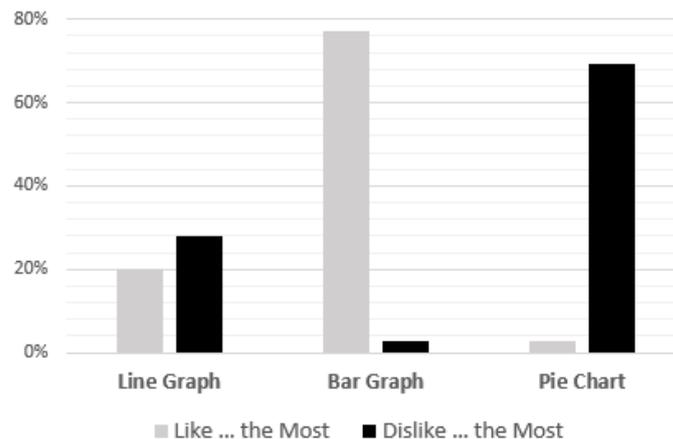


Figure 1. The Percentages for the Participants' Most Liked and Most Disliked Graph Types

The percentages in Figure 1 clearly points out that bar graphs are overwhelmingly the most liked (77.1%) and the least disliked (2.8%) graph type among the participants. Also, it is notice worthy that the percentage of students who disliked the line graphs the most (27.8%) is higher than those who liked the line graphs the most (20.1%). The case for the pie charts is much more worrisome; because it is the least liked (2.8%) and most disliked (69.4%) graph type among the others. The reasons for the differences between the enjoyment of the graph types were further investigated by analyzing the open-ended written responses of the participants, and the factors related to liking or disliking any of these graph types are summarized in Table 8a and 8b.

Table 8a. Factors Influencing the Most Liked Graph Types

	Line Graph	Bar Graph	Pie Chart
Simple	12.9 %	48.5 %	1.4 %
More informative	-	11.4 %	-
Interesting	7.2 %	8.6 %	-
Has a nice shape	-	8.6 %	1.4 %
Total	20.1 %	77.1 %	2.8 %

Table 8b. Factors Influencing the Least Liked Graph Types

	Line Graph	Bar Graph	Pie Chart
Difficult	15.3 %	1.4 %	48.6 %
Complicated	9.7 %	-	9.7 %
Boring	-	1.4 %	11.1 %
Less visual	1.4 %	-	-
Has a bad shape	1.4 %	-	-
Total	27.8 %	2.8 %	69.4 %

As seen in Table 8a, students liked the bar graphs most for considering them simple and informative. Also, students believed that bar graphs are more interesting and have a better shape than the other graph types. Some of the student responses about bar graphs are listed below;

For me, it is easier interpreting it. (S27)

The increases and decreases are clearer in it. (S21)

It is clear and more obvious. (S5)

It is easy to draw. (S31)

Table 8b data shows that more than half of the participants disliked pie charts because they considered pie charts difficult, complicated, and boring. Some of the student responses about pie charts are as below;

I don't like them because I have a hard time drawing and interpreting them. (S49)

For me, it is the hardest graph type to draw. (S53)

They seem complicated to me. (S55)

I understand nothing about it. (S61)

About a quarter of the students disliked the line graphs with similar reasons for pie charts. Also, though the percentages are not high, it is interesting that some students disliked line graphs because of their shape and their lack of visibility. Sample student responses about line graphs are;

I don't like it because I misinterpret it and it has a few visuals. (S11)

I confuse, it is difficult to draw. (S54)

Conclusion

The first research problem of this study investigated the line graph skills of Turkish middle school students. The participants were found to perform lower than 50% in TOGS instrument, thus this study joins a large body of studies reporting the lack of the graph skills of middle school students in Turkey (Belser, 2009; Hotmanoğlu, 2014; Koparan & Güven, 2013; Oruç & Akgün, 2010), as well as around the world (Boote, 2014; Boote & Boote, 2017; Capraro et al., 2005; McKenzie & Padilla, 1986). Among the TOGS questions, students were found to be relatively successful in questions requiring basic skills, such as reading data from a graph; however, similar to the related literature findings (Capraro et al., 2005; Gioka, 2007; Greenberg, 2014; Kranda & Akpınar, 2018; Lai et al., 2016), students had difficulty in analyzing multiple variables at the same time.

Based on the TOGS scores comparisons, no significant difference was found by gender; however, 8th graders were significantly more successful than the 7th graders. These findings are consistent with the literature since various researchers found no difference due to gender in students' graph skills (Curcio, 1987; Demirci & Uyanık, 2009; Lai et al., 2016; Ludewig et al., 2020). Also, in previous studies on graph skills, students in higher grades were usually found to achieve better than the students in earlier grades (Berg & Smith, 1994; Maggioni, 1953; Wainer, 1980), as a result of their extra schooling process and extra experiences about graphs (Curcio, 1987; Gan et al., 2010). However, it is worrisome that the overall success of 8th graders (56%) in this study is also not very promising, compared to the low success of the 7th graders (41%). The results for the first research question imply that the standard Turkish middle school education is not as effective as proposed in the recently developed science curricula, of which are announced as reform curriculum in every few couple years, for preparing students to handle line graphs. Combining with the consistently lower scores of Turkish students in PISA and TIMSS exams, where graph questions are frequently used, the findings of this study suggest that Turkish educators should design more effective learning environments and processes for students to enhance their graph skills.

Compared to participants' low line graph skills, the findings for the second research problem showed that participants have considerably high graph self-efficacy beliefs and hold positive attitudes toward graphs. The GSEB and GA factor scores of the GSEBGA scale did not significantly change among the subgroups formed by gender and grade level, which imply that the high graph self-efficacy and the positive attitudes toward graphs were common in both gender and grade-level groups. Since these affective states about graphs were not investigated in the related literature before, there is not plenty of previous data to compare; however, these findings are in good agreement with the findings from other research questions in this study.

Participants' having low line graph skills but holding high self-efficacy and positive attitudes toward graphs may seem controversial. However, the findings from the other research questions can clarify this discrepancy. For example, the high graph self-efficacy and positive graph attitudes of students, are consistent with the qualitative data analysis of the fifth research question, where over 70% of the participants expressed that they liked working with graphs. Furthermore; the second set of open-ended questions used for investigating the fifth research question can shed more light on this issue. When participants are asked to select the graph type they liked the most, 77.1% of them expressed that bar graphs are their most favorite. Therefore, when responding to the GSEBGA scale items, which are about graphs in general, participants would have tended to think of the graph types they liked (more likely the bar graphs) and thus received relatively high scores.

The findings of the third research question support the above discussion because when students are asked to respond to GLPGT items separately for each graph type, participants were found to have significantly higher graph literacy perceptions for the bar graphs (BGLP) than the line graphs (LGLP) and/or pie charts (PCLP). No significant difference was found between the LGLP and PCLP scores, indicating that students' literacy perceptions were similar for the line graphs and pie charts. These findings are consistent with the previous studies (Belser, 2009; Culbertson & Powers, 1959; Friel & Bright, 1995; Johnson, 1971; Kranda & Akpınar, 2018), where students were found to be more successful at bar graphs compared to other graphing types.

Based on the analyses of the within-subject effects for the third research question, the order of the graph literacy perception scores was found similar among the grade level subgroups; however, the gender variable was found to have a significant interaction effect on graph types. While females had higher BGLP scores than the males, they exhibited lower LGLP and PCLP scores than males. This finding indicates that while both females and males, favor the bar graphs over other graphs, this favoring behavior is more apparent among females. The between-subject effects analyses for the third research problem investigated the differences in the overall graph literacy perception scores of participants by their gender and grade level. Although no significant interaction effect (gender*grade level) or gender main effect was determined, the grade level main effect was found to be significant, which showed that the 7th graders have higher graph literacy perceptions about graphs than the 8th graders.

Compared to their low success in TOGS, 7th graders' having high graph literacy perceptions needs more attention. If the 7th graders also had satisfactory success in TOGS, these findings would be promising; however, having high graph literacy perception alone would be misleading. One possible explanation would be encountering less with graphs during the school courses would have resulted in an overrating impact on 7th graders' attitudinal states. Compared to 8th graders, who had an extra year of experience with graphs, 7th graders would have faced lesser problems with graphs, so their high graph literacy perception would have been based on their lack of experience with graphs. Previous literature points out that younger students tend to stick incorrect conclusions about graphs (Asp, Dowsey, & Hollingsworth, 1994; Matuk et al., 2019) and they would feel completely satisfied with their conclusions. It is also reported that students who encounter more complex graphs during the school courses, in this study the 8th graders, tend to see graph questions more difficult and complicated (Beler, 2009). To be able to draw scientific conclusions, future studies are needed on the longitudinal changes in students' opinions about graphs and the factors affecting these changes.

The correlations calculated between the TOGS scores, GSEB and GA factor scores of the GSEBGA, and LGLP factor scores of the GLPGT scale also contribute to the above discussion. Although the TOGS scores were found to have a medium level positive correlation ($r=.41$) with the GSEB scores; its correlation with the LGLP scores was relatively weak ($r=.27$). Moreover, the almost zero correlation ($r=.07$) between the TOGS and GA scores shows that these variables are almost linearly independent of each other. Based on these correlations, the graph self-efficacy (GSEB scores) would be a better predictor of students' line graph skills, compared to their graph attitudes or graph literacy perceptions.

Based on the qualitative data analyses for exploring the fifth research question, a vast majority of the participants were found to enjoy working with graphs, which is consistent with the high GSEB and GA scores calculated for the second research question. Participants' responses to open-ended questions revealed that about 70% of the participants expressed that they like graphs since they believe that graphs are simple, informative, and interesting. On the contrary, about 30% of them considered that graphs are complicated, difficult, and boring. These results draw attention to the need for exploring students' views on the different types of graphs because it is important to see what graphs are especially considered simple versus complicated by students.

The second set of open-ended questions, used for exploring the fifth research question, allowed to gather data about the factors that lead participants' enjoyment states of different graph types. Based on the responses to these open-ended questions, the positive attributes about graphs were found mostly belonged to bar graphs, which is consistent with the findings from the third research question, where BGLP scores were found to be higher than the LGLP and PCLP scores. 77.1% of the participants favored the bar graphs over other graphs; as considering bar graphs simpler, more informative, interesting, and visual. Therefore, consistent with the related previous studies (Beler, 2009; Friel & Bright, 1995; Johnson, 1971; Kranda & Akpınar, 2018; Shah & Freedman, 2011), it can be concluded that bar graphs are more appreciated than the other graph types among middle school students. On the other hand, it is well documented that bar graphs are not used as much as the line graphs in the textbooks or in the international exams (Kramarski, 2004; Ludewig et al., 2020; Patahuddin & Lowrie, 2019; Peebles & Ali, 2015). Therefore, it is also important to know why students dislike any type of graph as well. Participants' responses to open-ended questions revealed that a majority (69.4%) of the participants disliked the pie charts, mostly because they considered pie charts difficult, complicated, and boring. Some students expressed that pie charts are the hardest graph type to draw. As it was previously reported in the literature (Johnson, 1971; Malter, 1952; Simkin & Hastie, 1987), while pie charts are easy for students to read, students encounter several troubles with constructing pie charts since angle values are need to be calculated for determining the correct size of the slices. Also, a considerable portion (27.8%) of the participants expressed that they disliked the line graphs most, since they considered that line graphs are difficult, complicated, and not visual enough. These negative concerns about the line graphs are consistent with the low TOGS scores of students, which was calculated for measuring their line graph skills in the first research question.

Based on the quantitative and qualitative analyses for the five research questions investigated in this study, it can be concluded that Turkish middle school students' affective states about graphs, in general, are at high levels but these affective states are valid mostly for the bar graphs. It is heartening to coincide with students' positive views about bar graphs but it is alarming that the same students dislike the pie charts and line graphs, which are more frequently used graph types in academic texts. The low TOGS scores of the participants suggest that middle school students lack some of the required line graph skills and probably this problem is reinforced by their negative affective states about line graphs.

Limitations and Recommendations

Students' lack of graph comprehension is reported in almost every previous study on graphs, so the low graph skills of middle school students would not a unique contribution of this study to the literature; however, this study makes a significant contribution to the literature by attempting to investigate both the cognitive and affective dimensions of graph literacy. Also, this study provides important data about the differences and the causes of these differences in students' opinions about different graph types. The findings of this study are limited with the Turkish middle school students but similar results from the literature discussed above, suggests that the problems encountered among Turkish students would be seen in other countries as well. This study takes a step into a highly disregarded topic of investigating possible factors that impact some of the affective states of students toward different graph types. However, more studies in different countries are needed to explore the specific details about why students usually fail to use and dislike some of the graph types.

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