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Abstract

This survey design study was designed to test whether the graph skills and affective states of middle school students about graphs differ by their gender, grade level, and graph types (line, bar, and pie). The data collection instruments consisted of two scales developed by the authors and a Graph Skills Test, which consisted of graph questions from the previous TIMSS and PISA exams. Based on the findings, while middle school students were found to succeed at reading the data level graph questions, they were found to struggle in questions requiring higher graph skills, such as graph interpretation and graph construction. As for the affective states investigated, participants were found to hold high self-efficacy beliefs and positive attitudes toward graphs. No significant difference among the dependent variables (graph skills, self-efficacy beliefs about graphs, attitudes toward graphs, and graph literacy perceptions) was found by gender; however, grade level and graph type variables were found to impact students' graph skills, graph attitudes, and personal graph literacy perceptions. Middle school students with less school experience with graphs (seventh graders) were found to hold more positive attitudes toward graphs than the eighth graders. On the contrary, eighth graders were found to perform better at graph questions requiring interpretations of the graph data. Also, participants in all subgroups were found to hold significantly higher personal graph literacy perceptions for the bar graphs, than the line graphs and pie charts. Based on the findings of the study, while middle school students were found to hold positive affective states about graphs, they were found to lack advanced graph skills. In agreement with the previous literature, it is recommended that graph literacy should become a dedicated part of the school curriculum.

Introduction

Graph skills are among the most essential data processing skills in today's world since the rapidly growing data can efficiently be visualized only by using graphs. Graphs have become a standard means of communication in the transmission of information because even the large amounts of data can be summarized practically and understandably through graphs (Fry, 1981; Shah & Hoeffner, 2002; Wainer, 1992). Although other visual representations were also used to summarize the data in the history, the first examples of the today's most commonly used graph types of line graphs, bar graphs, and pie charts were developed by the Scottish economist William Playfair in the 18th century (Friel, Curcio, & Bright, 2001).

Through the increasing number of academic journals during the 19th century, graphs have become more and more used in scientific publications (Åberg-Bengtsson & Ottosson, 2006). For example, Shah and Freedman (2011) note that the mean number of graphs in academic journals nearly doubled between 1984 and 1994. Nowadays, graphical representations are frequently used not only in academic publications but also in written and visual media for the general public (Patahuddin & Lowrie, 2019; Zhang, 2016). Therefore, people both in daily life and in academic life are increasingly being encountered with graphs. Due to the increasing importance of graphs, graph skills have become one of the basic 21st-century skills to be acquired at early age, such as reading, writing, and basic mathematical skills (Aldrich & Sheppard, 2000; Ludewig, 2018; Patahuddin & Lowrie, 2019).

Graphs in Education

Graphs are usually considered merely as a part of the mathematics and science courses but they hold a crucial aspect for understanding other courses as well (Lowrie & Diezmann, 2011; Shah & Hoeffner, 2002). For example, international exams, such as Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) frequently use graph questions, not only for measuring the mathematics and science literacy, but also investigating the reading literacy (Kramarski, 2004; Ludewig, Lambert, Dackermann, Scheiter, & Möller, 2020). Because of the increasing importance and usage of graphs in almost all school courses, students need to be competent in graphs. For this reason, special curriculum objectives were defined about graphs in various course programs, such as mathematics, science, and social sciences all around the world, including Turkey (Çelik & Sağlam-Arslan, 2012; Friel et al., 2001; Lowrie & Diezmann, 2011).

Alongside other cognitive skills, it is necessary to have a certain level of mathematical knowledge to reach a certain graph competence (Boote, 2014; Ludewig, 2018; Shah & Freedman, 2011). Therefore, graphs used in school courses vary by grade levels. Highly visual figure graphs are used in the earlier grades and bar graphs are taught as complementary to the figure graphs during the elementary school years, due to their easiness to be read for discrete categorical variables (Arteaga, Batanero, Contreras, & Canadas, 2015). Pie charts and line graphs are also sometimes used in upper elementary years but middle school years are more suitable for teaching these graphs since they require some abstract skills, such as proportional reasoning in pie charts and understanding trends of continuous variables in line graphs (Tiefenbruck, 2007). For these reasons, the middle school years are the earliest time period that one can expect for students to experience the line graphs, bar graphs, and pie charts all together (Lai, Cabrera, Vitale, Madhok, Tinker, & Linn, 2016; Ozmen, Guven, & Kurak, 2020; Phillips, 1997). According to Piaget's cognitive development theory (Woolfolk, 2004), middle school years are also important since students at these ages enter into formal operational stage and constitute their abstract understandings. The personal views, values, and affectional states of the students play a major role during their cognitive processes. Therefore, the affective states of individuals about new topics can affect their future learning in a significant way. For this reason, the affective states of middle school students should be in our interest to be able to predict how their future graph experiences would be impacted by their affective states toward graphs.

Although special curriculum objectives are defined for graphs in several courses, past studies show that students at all levels experience many different problems with graphs (Carpenter & Shah, 1998; Gioka, 2007; Leinhardt, Zaslavsky, & Stein, 1990). These problems differed according to the graph types, but it is common for the majority of studies that students encounter significant problems in terms of graph construction, graph interpretation, and graph transformation (Boote, 2014; Capraro, Kulm, & Capraro, 2005; Oruç & Akgün, 2010; Ozmen, et al., 2020). The most important reason for students encountering these problems is shown as the inefficiency of the school instruction for preparing graph literate individuals (Gioka, 2007; Tairab & Al-Naqbi, 2004; Tortop, 2011; Uk, Matuk, & Linn, 2016). Without gathering the required graph skills, it is not possible to prepare scientifically literate students as an outcome of education programs (Beichner, 1994; Beler, 2009; Freedman & Shah, 2002; Patahuddin & Lowrie, 2019), as was targeted in many countries around the world, including Turkey (Turkish Ministry of National Education [MEB], 2005; 2013; 2018).

Graph Literacy

Graph literacy (graphicacy) is a relatively new concept and defined in several ways in previous studies. Fry (1981) has made one of the first definitions of graph literacy, as the skills for reading and drawing graphs. Gan, Scardamalia, Hong, and Zhang (2010) defined it as the ability to create, prepare, present, read, and interpret graphs. Friel and Bright (1995) made their graph literacy definition based on three levels: reading the data (reading the visible values in the graph), reading between the data (explaining the general information in the graph), and reading beyond the data (making comments and inferences about the graph). Based on these former definitions, graphic literacy is defined by the authors of this study, as the ability to correctly read the data and variables in a given graph, to interpret the changes in the graph data, to construct an appropriate graph for the given data, and to transform a graph into different types of graphs. As is the case in all types of literacy, graph literacy requires positive affective states in addition to the cognitive skills defined above. For example, it has been reported that some students do not like graphs and experience anxiety in reading and interpreting graphs, which in return hurt their graph comprehension (Beler, 2009). Thus, besides the cognitive graph skills, affective states of students, such as their self-efficacy beliefs about graphs and attitudes toward graphs should also be investigated to get a more complete portrait of the graph literacy levels of students.

The previous studies on graphs, conducted both in Turkey (Beler, 2009; Koparan & Güven, 2013; Oruç & Akgün, 2010; Ozmen, et al., 2020) and around the globe (Boote, 2014; Capraro et al., 2005; Shah, Freedman, & Vekiri, 2005; Tairab & Al-Naqbi, 2004) commonly focused on the cognitive graph skills of the participants, such as graph reading, graph interpretation, and graph construction. Since boys are historically labeled as higher achievers in mathematics and science than girls, studies on graphs usually compared both genders according to their graph comprehension levels. Consistent with the previous TIMSS (Martin, Mullis, Foy, & Stanco, 2012; Mullis, Martin, Foy, & Arora, 2012) and PISA ([Organisation for Economic Co-operation and Development] OECD, 2013) reports, the studies on graphs showed that girls have closed the mathematics and science achievement gap and therefore no significant difference due to gender was reported in previous studies on middle school students' graph comprehension (Curcio, 1987; Lai et al., 2016; Ludewig et al., 2020; Oruç & Akgün, 2010). Another variable, commonly used in graph literature is the grade level since students are expected to enhance their cognitive skills by age. Comparisons by students' grade levels also provide insight into the effectiveness of the school instruction on teaching graph skills. The studies on students' cognitive graph skills consistently reported that students in higher grades almost always achieve better than the younger students (Berg & Smith, 1994; Curcio, 1987; Koparan & Güven, 2013; Wainer, 1980).

Compared to this large bulk of studies on the cognitive dimensions of graphs, no previous study has been aimed to measure affective characteristics of students about graphs; such as personal graph literacy perceptions, self-efficacy beliefs, and attitudes towards graphics. Therefore, new studies are needed to measure variables other than cognitive graph skills. As complementary to the cognitive skills, studying students' affective states would provide a significant contribution to the literature since people's affective states would significantly impact the development of their cognitive skills (Greenberg, 2014). Studying the affective states about graphs, opens a new research valley for the graph literature and selecting any affective state would bring its own insight. A starting point for investigating the affective states of students about graphs would be measuring students' graph literacy perceptions, self-efficacy beliefs, and attitudes towards graphs, because these variables are closely related to the cognitive graph skills and would enable us to further analyze the causes of students' lack of cognitive graph skills.

Graph Types and Graph Literacy

In today's scientific literature, there are quite many graph types, most of which are being introduced by the use of three-dimensional representations. However, three common graph types of line graphs, bar graphs, and pie charts are extensively used in school courses. When the effects of graph types on students are examined, it is frequently reported that the students exhibit different skill levels for different graph types (Friel & Bright, 1995; Johnson, 1971; Wainer, 1980; Zacks & Tversky, 1999). The reasons for the changes in student achievement according to different graph types are the mathematical background required for drawing or interpreting the graph, the visuality level of the graph used, and the representation of the variables in the graph (Carpenter & Shah, 1998; Simkin & Hastie, 1987). For example, students were often found to struggle with line graphs compared to bar graphs or pie charts (Culbertson & Powers, 1959; Friel & Bright, 1995; Malter, 1952; Wainer, 1980; Yabanlı, Yıldırım, & Günaydın, 2013). For the same reason, students were found to prefer bar graphs instead of line graphs (Beler, 2009; Johnson, 1971; Kranda & Akpınar, 2018; Shah & Freedman, 2011). In light of this finding in the literature, another purpose of this study is to compare the personal graph literacy perceptions of students about line graphs, bar graphs, and pie charts.

The research questions investigated in this study are:

1. Do middle school students' graph self-efficacy beliefs differ by their gender and/or grade level?
2. Do middle school students' graph attitudes differ by their gender and/or grade level?
3. Do middle school students' graph skills differ by the level of the graph questions or by their gender and/or grade level?
4. Do middle school students' personal graph literacy perceptions differ by the graph type (line graph, bar graph, pie chart), participants' gender, and/or grade level?

Method

Participants

The participants of the study are 127 Turkish middle school students enrolled in seventh and eighth grades. Since some of the test questions and scale items in the study were related to line graphs, which are taught at the 6th grade level in Turkish middle schools, only the students completed the sixth grade were selected for the study. Of the 127 participants, 59 (46%) were male and 68 (54%) were female, whereas 75 (59%) were in seventh grade and 52 (41%) were in eighth grade. It was declared by the researchers both verbally and in writing that participation in any stage of the study was voluntary. Therefore, the number of students who provided full responses to the measurement instruments slightly varied across the study. Also, the data of two students were excluded from the related analysis processes, as being extreme values in the general and subgroup distributions. For these reasons, the numbers of students involved in each analysis were reported separately across the study.

Data Collection Instruments

The data of the study were collected via the Graph Self-Efficacy Beliefs and Graph Attitudes (GSEBGA) scale (Bursal, 2019), Graph Literacy Perceptions according to Graph Types (GLPGT) scale (Bursal, 2019) and Graph Skills Test (GST), which was designed for this study by selecting sample graph questions from the previous publicly released TIMSS and PISA items.

GSEBGA scale was used for measuring the participants' self-efficacy beliefs about graphs and attitudes toward graphs. The 12-item GSEBGA scale consists of 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 in a 4-point Likert scale without a medium option and the second sample responded in a 5–point Likert scale with a medium option). The exploratory factor analyses were conducted for both applications and only the items that significantly contributed to both scaling options were selected to allow future researchers to use either scaling options for the GSEBGA scale (Bursal, 2019). This study used the 4-point Likert type scale (1: Strongly Disagree, 2: Disagree, 3: Agree, 4: 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 coded (1→4, 2→3, 3→2, 4→1) before the data analysis. Higher GSEB and GA scores indicate stronger graph self-efficacy beliefs and graph attitudes. The reliability of the data from the sample of this study was investigated by calculating the Cronbach alpha coefficients. The Cronbach alpha reliability coefficients of .79 for the GSEB factor scores and .72 for the GA factor scores show that the data of this study meets the reliability criteria.

GLPGT scale was used to measure the graph literacy perceptions of participants according to three graph types. GLPGT is a shortened version of the GSEBGA scale and consisted of four items that are responded separately for each of the three graphing types (line graph, bar graph, pie chart). The main difference of the GLPGT from the GSEBGA scale is providing data for comparing the participants' views on the line graphs, bar graphs, and pie charts, instead of focusing on the general views of participants on graphs. For this reason, the four items of the GLPGT scale, which are separately responded to three graph types, served as a 12-item instrument in total. Similar to the GSEBGA scale, the GLPGT is designed for allowing future researchers to use either a 4-point or 5-point Likert scaling (Bursal, 2019). Similar to the GSEBGA scale, this study used the 4-point Likert type scale version of the GLPGT. Three dependent variables, which are labeled as Line Graph Literacy Perception (LGLP), Bar Graph Literacy Perception (BGLP), and Pie Chart Literacy Perception (PCLP) are measured by calculating the scores of participants for each graph type. Since all GLPGT items were positively worded, no reverse coding was needed. The increase of the factor scores of the GLPGT indicates that participants hold high personal graph literacy perceptions about the relevant graph type. The Cronbach alpha reliability coefficients were calculated as .79 for the LGLP scores, .74 for the BGLP scores, and .77 for the PCLP scores in this study.

The Graph Skills Test (GST) consisted of 8 multiple-choice and open-ended questions and was used for measuring participants' graph skills for three graph types (line graphs, bar graphs, pie charts). The initial form of the GST consisted of 11 questions and the majority of the GST items were selected from the previous TIMSS exams, which are publicized on the official Turkish TIMSS website. One question (Q11) was selected from the 2006 PISA exam (official Turkish version) and another question (Q5) was written by the authors as a supplement to a present question (Q6). The GST questions were classified based on the Friel and Bright's (1996) graphical literacy definition of (i) Elementary level (reading the data), (ii) Intermediate level (reading between the data and (iii) Overall level (reading beyond the data). According to Friel and Bright's (1996) classification of graph skills by graphical literacy levels, the questions (Q1, Q2, Q5, Q8, Q10) requiring reading visible values from graphs and comparison of graph data values are labeled as the "Elementary Level" questions. The questions (Q3, Q4, Q6, Q7, Q9, Q11) are labeled as the "Intermediate Level" questions since they required explaining the general information in the graphs, constructing or completing the missing parts of graphs according to the given information. Considering the grade levels of the participants, no question was used from the "Overall Level". The distribution of the GST questions according to the graph types and graph skill levels are given in Table 1.

Table 1. The Classification of the GST Questions according to the Graph Type, Required Graph Skill Level and Graph Question Source

Graph Type	**Elementary Level**	**Intermediate Level**
Line Graph	Q8 (TIMSS, 2007)	Q9 (TIMSS, 2007) Q11 (PISA, 2006)
Bar Graph	Q2 (TIMSS, 2007) Q10 (TIMSS, 1995)	Q3 (TIMSS, 2007)
Pie Chart	Q1(TIMSS, 2007) Q5(Authors)	
Bar Graph & Pie Chart		Q4 (TIMSS, 2007) Q6 (TIMSS, 2007) Q7 (TIMSS, 2007)

While eight of the GST questions were in multiple-choice format, the remaining three questions (Q2, Q3, Q7) were in open-ended format. Among these open-ended questions, Q2 required labeling the data values in the y-axis of a bar graph, Q3 required drawing a single bar related to the information given, and Q7 required transforming the data given in a pie chart to a bar graph format. When the GST questions were scored, each question had a 2-points score. The multiple-choice questions were scored as; "correct response: 2 points" and "incorrect response: 0 points", whereas the open-ended questions had an extra scoring option of "partial correct response: 1 point". All test questions were reviewed by two experts, one university mathematics educator and one university science educator, and approved by both experts.

The reliability analysis of the GST data indicated that three questions (Q1, Q4, Q11) threatened the overall reliability of the GST, therefore these questions are discarded from the GST and the final version of the GST consisted of 8 questions. A Cronbach alpha reliability coefficient of .65 was calculated for the final version of the GST, which is considered to provide an acceptable level of reliability for short research instruments (DeVellis, 2016). As seen in Table 1, in the final version of the GST, four questions (Q2, Q5, Q8, Q10) were at the elementary graph skills level and the remaining four questions (Q3, Q6, Q7, Q9) were at the intermediate graph skills level.

Data Analysis

In the first phase of the analysis, participants' descriptive statistics were calculated for all dependent variables. For the ease of the interpretation of the scores, participants' factor scores from the GSEBGA and GLPGT scales are standardized by dividing the total factor score by the number of the factor items. Therefore, participants' overall factor scores varied in a 1 to 4 scale for all factors of the GSEBGA and GLPGT scales. The GST scores were calculated by the number of the correct (2 points) and partially correct (1 point) responses of participants. Since the final version of the GST consisted of 8 questions, of which 4 questions were at the elementary level and the other 4 questions were at the intermediate level, the total GST scores varied between 0 and 16; whereas the total scores for the elementary and the intermediate level questions varied between 0 and 8. Before conducting further statistical analyses, all dependent variables were checked for the outliers by calculating z scores for each dependent variable distribution. Based on the normal distribution formula, the cases with an absolute z score larger than three ($|z|>3$) are defined as the extreme values of the distribution, which are cause for concern since they would lead statistical bias (Field, 2018). Therefore, based on the normality analyses on the general group and all possible subgroup distributions, one data among the GA scores ($z=-3.43$) and one data among the GST scores ($z=-3.09$) were determined as the extreme values. These two data points are discarded from the analyses, where the GA and GST scores were used.

Depending on the number of the dependent and independent variables, factorial design models were developed and analyzed to investigate the research problems. 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, second, and third research problems were investigated with 2x2 Univariate Factorial Analysis of Variance (ANOVA) designs, where participants' GSEB factor scores, GA factor scores, and the GST scores were the dependent variables in each model and participants' grade level (seventh and eighth) and gender were the factors (independent variables) of the model. The fourth 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 the insignificant result of the Mauchly's Test (*p*=.84) verified that the sphericity assumption was satisfied. Therefore, the results of the Tests of Within-Subjects Effects, which provide higher statistical power when the sphericity assumption was satisfied, were used.

Results

Results Regarding the First Research Question

The descriptive statistics of the GSEB scores of participants from the GSEBGA scale by their gender and grade level are summarized in Table 2. Participants' mean GSEB scores, which are about 75% (3/4) of the maximum score, in all subgroups indicate that participants hold relatively strong self-efficacy beliefs toward graph. For example, 80% of the participants disagreed with the item "When I see graph questions, I feel that I cannot solve them." and similarly 63% of then disagreed that they would have trouble expressing the data values in graphs. Among the subgroups, seventh graders and females tend to have slightly higher GSEB scores than their peers but the differences between the subgroups seem to be minimal.

Table 2. Descriptive Statistics for the GSEB Scores by Grade Level and Gender

	Grade 7			Grade 8			General		
	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n
Male	3.11	0.50	35	2.94	0.70	19	3.05	0.58	54
Female	3.14	0.52	32	3.01	0.54	30	3.08	0.53	62
General	3.13	0.51	67	2.98	0.60	49	3.07	0.55	116

The statistical significance of the interaction effect and main effects of participants' gender and grade levels on the GSEB scores are investigated with a 2x2 factorial design ANOVA, and the findings from this analysis are reported in Table 3.

Table 3. Factorial ANOVA Statistics for the Gender and Grade Level Effects on GSEB Scores

Effect	df	*F*	*p*
Gender	1	0.24	.63
Grade Level	1	2.08	.15
Gender*Grade Level	1	0.03	.86

The factorial ANOVA results in Table 3 show that neither the interaction effect nor the main effects of the gender and grade level variables on the GSEB scores are statistically significant. Therefore, it can be concluded that participants' self-efficacy beliefs toward graphs do not change by students' gender and grade level.

Results Regarding the Second Research Question

Participants' GA factor scores from the GSEBGA scale by their gender and grade level are given in Table 4. Similar to the GSEB values, participants' mean GA scores are higher than the average scores but slightly lower GA scores indicate that participants' attitudes toward graphs are not as strong as their graph self-efficacy beliefs (GSEB scores). Also, the item frequency analysis showed that participants' graph attitudes depended on the context. For example, while 81% of the participants agreed that they would like to learn new information about graphs, only 56% agreed that they would rather see the numerical data of the questions in graph format instead of the data given in the text. It is also interesting that unlike the case in GSEB scores, the differences between the subgroups are slightly larger for the GA scores. While differences due to gender are not consistent among different grades, the seventh graders (both males and females) consistently have higher mean GA scores than the eighth graders.

Table 4. Descriptive Statistics for the GA Scores by Grade Level and Gender

	Grade 7			Grade 8			General		
	Mean	S.D.	n	Mean	S.D.	n	Mean	S.D.	n
Male	3.13	0.49	35	2.75	0.75	21	2.99	0.62	56
Female	3.01	0.69	34	2.90	0.53	29	2.96	0.62	63
General	3.07	0.60	69	2.84	0.63	50	2.97	0.62	119

The statistical significance of the interaction effect and main effects of participants' gender and grade levels on the GA scores are investigated with a 2x2 factorial design ANOVA, and the findings from this analysis are reported in Table 5.

Table 5. Factorial ANOVA Statistics for the Gender and Grade Level Effects on GA Scores

Effect	df	*F*	*p*
Gender	1	0.02	.89
Grade Level	1	4.33	.04
Gender*Grade Level	1	1.40	.24

The factorial ANOVA results in Table 5 show that while the interaction effect and the main effect of the gender are not statistically significant on the GA scores, the main effect of the grade level variable is statistically significant. Therefore, it can be concluded that participants' attitudes toward graphs are similar across both males and females; however, the GA scores significantly change by the participants' grade level, in favor of the seventh graders.

Results Regarding the Third Research Question

Participants' descriptive statistics for the GST scores by their gender and grade levels are summarized in Table 6. As seen in Table 6, while the participants' overall success is 76% (12.2/16); this promising high mean score comes from students' correct responses to elementary level GST questions. When participants' success rates were examined according to the levels of the questions, compared to a very high success rate in the elementary level questions (7.5/8=94%), participants seemed to be struggled in the intermediate level questions (4.7/8=59%). For example, while 95% of the participants were able to correctly match the bars in a bar graph according to the given information (Q10), only 49% of the students were able to correctly interpret a line graph according to a scenario (Q9). When intermediate level GST questions required students' construction of graphs, the success level decreased even more. For example, participants experienced the lowest success rate of 34% in a question where they were asked to construct a bar graph according to the data given in a pie chart (Q7).

Table 6. GST Mean Scores by Grade Level, Gender, and Graph Question Level

	Grade 7 (n=75)			Grade 8 (n=51)			General (N=126)		
	Elem. Level	İnter. Level	Total	Elem. Level	İnter. Level	Total	Elem. Level	İnter. Level	Total
Male (n=58)	7.3	4.3	11.6	7.8	5.1	12.9	7.5	4.6	12.1
Female (n=68)	7.7	4.4	12.1	7.2	5.4	12.6	7.5	4.9	12.4
General	7.5	4.4	11.9	7.5	5.3	12.8	7.5	4.7	12.2

Table 6 data also indicates interesting differences across the subgroups. While students of both genders and grades have very similar mean scores in elementary level questions, eight graders' have scored higher in intermediate level questions than the seventh graders. A 2x2 factorial design ANOVA was run to test the effects of the gender and grade level variables on the GST scores. The results indicated that the gender main effect is not statistically significant neither on the total GST scores [$F(1,123)=0.19$; $p=.66$], nor on the elementary [$F(1,123)=0.04$; $p=.84$] and intermediate [$F(1,123)=0.22$; $p=.64$] level questions. These findings indicate that both males and females have similar GST scores in both elementary and intermediate level questions. On the other hand, while the main effect of the grade level variable was not significant on the overall GST scores [$F(1,123)=2.62$; $p=.11$] and the elementary level [$F(1,123)=0,03$; $p=.87$] questions, it has a significant effect on the intermediate level [$F(1,123)=4.76$; $p=.03$] questions. Based on these results, while students at both grade levels were found to have similar scores in the overall GST and the elementary level questions, eighth graders were found to have significantly higher scores in the intermediate level questions than the seventh graders. The partial eta-squared value ($\eta^2_{Partial}=.04$) calculated for the grade level main effect, suggests that the grade level variable has a small effect size on the intermediate level question scores.

Results Regarding the Fourth Research Question

The descriptive statistics of participants' graph literacy perception scores for line graphs (LGLP), bar graphs (BGLP), and pie charts (PCLP) by their gender and grade level are summarized in Table 7. The Table 7 data indicates that while participants' overall graph literacy perceptions are above the average levels, their BGLP scores are consistently higher than their corresponding LGLP and PCLP scores in all gender and grade level subgroups.

Table 7. LGLP, BGLP, and PCLP Mean Scores by Grade Level and Gender

	Grade 7 (n=58)			Grade 8 (n=38)			General (N=96)		
	LGLP	BGLP	PCLP	LGLP	BGLP	PCLP	LGLP	BGLP	PCLP
Male (n=43)	2.9	3.2	2.9	2.6	2.9	2.5	2.8	3.1	2.8
Female (n=53)	3.0	3.4	3.1	3.0	3.4	3.0	3.0	3.4	3.1
General	3.0	3.3	3.0	2.8	3.2	2.8	2.9	3.3	2.9

The statistical significance of the interaction effect and main effects of the independent variables (gender and grade level), and the graph type factor on the graph literacy perception scores are investigated with a three-way (2x2x3) ANOVA design for mixed measures, and the findings are reported in Table 8.

Table 8. Mixed-measures ANOVA Within-subject effect Statistics for the Graph Type, Gender and Grade Level Effects on Graph Literacy Perception Scores

Within Subject Effect	df	*F*	*p*
Graph Type	2	11.68	<.01
Graph Type * Gender	2	0.52	.59
Graph Type * Grade Level	2	0.48	.62
Graph Type * Gender * Grade Level	2	0.01	.99

The test results in Table 8 show that neither of the gender and grade level variables has a significant interaction effect with the graph type variable, which indicates that the order of the LGLP, BGLP, and PCLP scores are similar across the subgroups. The only significant effect was found for the within factor (graph type) of the model, which means that participants' graph literacy perception scores for line graphs (LGLP), bar graphs (BGLP), and pie charts (PCLP) significantly differ. Based on the partial eta-squared value ($\eta^2_{Partial}=.11$), the graph type has a medium effect size on the graph literacy perception scores. The differences between the LGLP, BGLP, and PCLP scores are investigated via a follow-up pairwise comparison test with a Bonferroni adjustment. 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 have significantly higher literacy perception scores for the bar graphs than the line graphs and pie charts.

Discussion

This study investigated a group of Turkish middle students' graph skills and affective states about graphs. As key variables indicating students' affective states about graphs, participants' self-efficacy beliefs about graphs (GSEB), graph attitudes (GA), and graph literacy perceptions (GLP) are measured. The GSEB and GA scores were examined as the scope of the first and second research questions. Based on the findings for these two questions, the participants were found to hold positive attitudes towards graphs in general and also hold fairly high self-efficacy beliefs about graphs. The GSEB and GA factor scores of the GSEBGA scale did not significantly differ among the gender subgroups, which imply that these fairly high graph self-efficacy beliefs and the positive attitudes toward graphs are common among both males and females. For the grade level variable, on the other hand, while the GSEB scores were similar among the seventh and eighth graders, seventh graders had higher GA scores than the eighth graders.

The affective states of students about graphs were not adequately studied in the related literature before, thus there is not enough data to compare the conclusions drawn for the GSEB and GA scores. However, these findings are mostly consistent with relevant previous studies. It is frequently cited in the literature (Fry, 1981; Gan et al., 2010; Ludewig, 2018; Shah & Hoeffner, 2002; Wainer, 1992) that presenting information in a visual form, such as graphs, is more understood and usually preferred by the people. Also, after a study with a large secondary school student sample, Yinkang and Yoong (2007) reported that students held neutral to positive views about the statistical graphs. Therefore, it is not surprising to find the middle school participants of this study to hold positive attitudes toward graphs and high graph-self efficacy beliefs. Also, it is heartening to find that these positive affective states are common among both male and female students. However, the surprising finding is that the seventh graders have significantly higher positive graph attitudes (GA scores) than their eighth-grade peers. It is interesting that the eighth-graders, who are expected to have more graph experience, do not have higher GSEB or GA scores, but on the contrary, have significantly lower GA scores than the seventh graders. These findings indicate that although the graph comprehension is reported to be related to prior graph experiences (Glazer, 2011), middle school students' affective states necessarily do not improve by getting more graph experience. Furthermore, the findings of this study recommend that students tend to have more positive views on graphs when they have limited graph experience and getting more graph experience, more likely the unsatisfactory ones, may result in students' low affective states about graphs. These conclusions are also consistent with the conclusions from the past studies, where younger students were found to comfortably stick to incorrect graph solutions unknowingly (Asp, Dowsey, & Hollingsworth, 1994; Capraro et al., 2005), which would mask their negative affective states about graphs.

The third research question of this study investigated the graph skills of participants with the GST. While participants were found to perform well in the elementary (reading the data) level graph skills questions (94% success), they were found to struggle in the intermediate (reading between the data) level graph skills questions (59% success). Students failed most (34% success) in a question, requiring transforming a graph to another type of graph. These findings are parallel to several previous studies (Asp et al., 1994; Capraro et al., 2005; Friel & Bright, 1995; Koparan & Güven, 2013; Lai et al., 2016; Ozmen, et al., 2020), which concluded that middle school students were successful in simple graph skills, such as reading data from the graphs but they fail in more advanced graph skills, such as graph interpretation and construction.

The difference between the average scores in the elementary and intermediate level graph skills questions obtained in this study, also shows similarity to the previous research data. For example, after a study on fourth and sixth-grade students' performance on twelve different graphs, Pereira-Mendoza and Mellor (1990) reported the average success levels of sixth graders as 98% for graph reading tasks and 78% for graph interpretation tasks. Based on their findings from 46 Turkish eight graders, Ozmen et al. (2020) concluded that although 92% of their participants succeeded on reading the data level questions, their participants' overall success levels were lower than 50% in reading between the data or reading beyond the data level questions. The differences between middle school students' achievement levels in elementary and intermediate level graph skills questions are also parallel to the TIMSS results. Among the international eighth-graders, compared to 60% success in reading data value of a line graph, only 29% of the eighth graders were able to determine the average of a graph (Ludewig et al., 2020). Similarly, Boote and Boote (2017) concluded that middle school students are challenged when interpreting science graphs. Based on these findings, this study joins a large body of studies reporting the lack of advanced graph skills of middle school students in Turkey (Beler, 2009; Koparan & Güven, 2013; Ozmen, et al., 2020; Tortop, 2011), as well as middle school students around the world (Asp et al., 1994; Berg & Boote, 2017; Boote, 2014; Boote & Boote, 2017; Capraro et al., 2005; Kramarski, 2004).

The statistical comparisons of the GST subgroup scores yielded that the gender variable has no significant effect on elementary or intermediate graph skills; however, the grade level variable has a significant impact on intermediate graph skills. These findings are consistent with the literature since various researchers found no difference due to gender in middle school students' graph skills (Curcio, 1987; Lai et al., 2016; Ludewig et al., 2020; Oruç & Akgün, 2010) and students in upper grades almost always were found to achieve better than the students in earlier grades (Berg & Smith, 1994; Curcio, 1987; Koparan & Güven, 2013; Maggioni, 1953; Wainer, 1980). These results are consistent with the conclusion that graph comprehension is related to previous graph experiences (Asp et al., 1994; Capraro et al., 2005; Glazer, 2011).

The fourth research question of this study required a comparison of the middle school students' perceived graph literacy levels according to three graph types by using the GLPGT scale. Participants were found to have significantly higher graph literacy perceptions for the bar graphs (BGLP) than the line graphs (LGLP) and pie charts (PCLP). No significant difference was found between the LGLP and PCLP scores. These findings are consistent with the previous studies (Beler, 2009; Bell & Janvier, 1981; Friel & Bright, 1995; Johnson, 1971; Kranda & Akpınar, 2018), where middle school students were found to be more successful at bar graphs compared to other graph types. Based on the analyses of the within-subject effects for the fourth research question, the order of the graph literacy perception scores was similar among the grade level and gender subgroups. This finding indicates that middle school students in all subgroups favored the bar graphs over other graph types.

Conclusion

Based on the findings from the four research problems investigated in this study, it can be concluded that the Turkish middle school participants of this study hold positive attitudes toward graphs and have high self-efficacy beliefs about graph-related tasks. Participants also had above the average perceived graph literacy scores for all graph types; however, they were found to significantly favor the bar graphs over the line graphs and pie charts. The graph questions requiring elementary (reading the data) graph skills were mostly correctly done but the intermediate level questions requiring more advanced graph skills, such as graph interpretation and construction, were challenging for the participants. The main reason for the lower success level of students in intermediate graph skills can be explained as students' tendency to focus on explicit information rather than the implicit information on graphs (Postigo & Pozo, 2004). Students usually limit themselves with the directly presented information in graphs and consider the more advanced tasks as "It is not on the graph" (Pereira-Mendoza & Mellor, 1990). Thus, it can be concluded that middle school students are usually good at reading data from the graphs, which seem apparent for them, but a significant amount of them fail to see connections between the graph data and variables since they believe that those are not presented to them in graphs.

Participants' having low scores in GST may seem to contradict with their holding high self-efficacy and positive attitudes toward graphs. Compared to their low performance in intermediate level questions, seventh-graders' having high GA and GSEB scores need more attention. Although eighth-graders performed significantly better than the seventh graders at intermediate level GST questions, the differences between their affective states were not consistent with the GST scores. One possible explanation would be encountering less with graphs during the school courses would have resulted in an overrating impact on seventh graders' attitudinal states. Therefore, the high GA and GSEB scores of students in earlier grades would not guarantee that these students have sufficient graph literacy. Since previous literature agrees on that graph literacy can be increased by providing more graph experiences, the findings of this study signal that these experiences should be designed in effective ways that students will benefit from these experiences not only by enhancing cognitive graph skills but also by improving their affective states toward graphs. As a solution, it is emphasized in various studies (Aldrich & Sheppard, 2000; Boote & Boote, 2017; Uk et al., 2016) that graph literacy should be a dedicated part of the school curriculum, instead of graphs being covered as an ordinary curriculum topic.

Recommendations

Based on the analyses for the four research questions investigated in this study, as well as the findings from the related literature, it can be concluded that middle school students' affective states about graphs are at satisfactory levels but these affective states are not true indicators of their graph skills. These results emphasize that graph literacy should be an important part of the school curriculum and the objectives of the graph experiences at school courses should be multidimensional. Graph related school activities should not only improve the cognitive graph skills of students but also should maintain the positive affective states of students that they have in earlier grades. Therefore, teachers and educators are required to explore effective graph instruction methods to enhance students' both cognitive and affective states about graphs.

This study was conducted with a group of Turkish middle school students but the related literature emphasizes that graph-related problems are common in all countries and all educational levels. Therefore, new studies in different contexts are needed to investigate how students feel about different types of graphs and how their cognitive graph skills are related to their affectional states about graphs.

Limitations

The results and conclusions of this study are limited with the data from a group of Turkish middle school students, thus new studies in different countries are needed to understand the affective states of students about graphs. This study has employed a quantitative paradigm by using scales for measuring the affective states of students; so qualitative method studies are also needed to explore and explain the positive and negative impacts on students' affective states about graphs.

References

Åberg-Bengtsson, L., & Ottosson, T. (2006). What lies behind graphicacy? Relating students' results on a test of graphically represented quantitative information to formal academic achievement. *Journal of Research in Science Teaching, 43*(1), 43-62.

Aldrich, F., & Sheppard, L. (2000). Graphicacy-the fourth'R'?. *Primary Science Review, 64*, 8-11.

Arteaga, P., Batanero, C., Contreras, J. M., & Cañadas, G. R. (2015). Statistical graphs complexity and reading levels: a study with prospective teachers. *Statistique et enseignement, 6*(1), 3-23.

Asp, G., Dowsey, J., & Hollingsworth, H. (1994). *Students' understandings of pictographs and bar graphs. In challenges in mathematics education: Constraints on construction* (Proceedings of the 17th Annual Conference of the Mathematics Education Research Group of Australasia), MERGA, Lismore, NSW.

Beichner, R. J. (1994). Testing student interpretation of kinematics graphs. *American Journal of Physics, 62*(8), 750–762.

Beler, Ş. (2009). *Determining 8th grade students' difficulties in reading and interpreting graphs of photosynthesis subject*. Master Thesis, Blacksea Technical University, Trabzon.

Bell, A., & Janvier, C. (1981). The interpretation of graphs representing situations. *For the Learning of Mathematics, 2*(1), 34-42.

Berg, C., & Boote, S. (2017). Format effects of empirically derived multiple-choice versus free-response instruments when assessing graphing abilities. *International Journal of Science and Mathematics Education, 15*(1), 19-38.

Berg, C. A., & Smith, P. (1994). Assessing students' abilities to construct and interpret line graphs: Disparities between multiple- choice and free- response instruments. *Science Education, 78*(6), 527-554.

Boote, S. K. (2014). Assessing and understanding line graph interpretations using a scoring rubric of organized cited factors. *Journal of Science Teacher Education, 25*, 333–354.

Boote, S. K., & Boote, D. N. (2017). Leaping from discrete to continuous independent variables: Sixth graders' science line graph interpretations. *The Elementary School Journal, 117*(3), 455-484.

Bursal, M. (2019). Scales development study to measure the affective states of middle school students toward graphs used in science classes. *Online Science Education Journal, 4*(1), 20-43.

Capraro, M. M., Kulm, G., & Capraro, R. M. (2005). Middle grades: Misconceptions in statistical thinking. *School Science and Mathematics, 105*(4), 165–174.

Carpenter, P. A., & Shah, P. (1998). A model of the perceptual and conceptual processes in graph comprehension. *Journal of Experimental Psychology: Applied, 4*(2), 75–100.

Culbertson, H. M., & Powers, R. D. (1959). A study of graph comprehension difficulties. *Audio-Visual Communication Review, 7*(1), 97–110.

Curcio, F. R. (1987). Comprehension of mathematical relationships expressed in graphs. *Journal for Research in Mathematics Education, 18*(5), 382-393.

Çelik, D., & Sağlam-Arslan, A. (2012). The analysis of teacher candidates' translating skills in multiple representations. *Elementary Education Online, 11*(1), 239-250.

DeVellis, R. F. (2016). *Scale development: Theory and applications* (4th Edition). Sage Publications.

Field, A. (2018). *Discovering statistics using SPSS* (5th Edition), Sage Publications.

Freedman, E. G., & Shah, P. (2002). *Toward a model of knowledge-based graph comprehension*. In: Hegarty M., Meyer B., Narayanan N.H. (Ed) Diagrammatic representation and inference. Diagrams 2002. Lecture notes in computer science, 2317. Springer, Berlin, Heidelberg.

Friel, S. N., & Bright, G. W. (1995). *Graph knowledge: Understanding how students interpret data using graphs*. (ERIC Document No: 391 661). Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, Columbus, Ohio.

Friel, S. N., & Bright, G. W. (1996). *Building a theory of graphicacy: How do students read graphs?* (ERIC Document No: 395 277). Annual Meeting of the American Educational Research Association (AERA), New York.

Friel, S. N., Curcio, F. R., & Bright, G. W. (2001). Making sense of graphs: Critical factors influencing comprehension and instructional implications. *Journal for Research in Mathematics Education, 32*(2), 124–158.

Fry, E. (1981). Graphical literacy. *Journal of Reading, 24*(5), 383–389.

Gan, Y., Scardamalia, M., Hong, H.Y., & Zhang, J. (2010). Early development of graphical literacy through knowledge building. *Canadian Journal of Learning and Technology, 36*(1).

Gioka, O. (2007). Assessment for learning in teaching and assessing graphs in science investigation lessons. *Science Education International, 18(*3), 189–208.

Glazer, N. (2011). Challenges with graph interpretation: A review of the literature. *Studies in Science Education, 47*(2), 183-210.

Greenberg, R. A. (2014). *Graph comprehension: Difficulties, individual differences, and instruction*. (Doctoral Dissertation), University of Michigan, Ann Arbor.

Johnson, T. G. (1971). *Influence of selected factors on the ability of fourth, fifth, and sixth graders to read graphs*. (Doctoral Dissertation), University of Southern California.

Koparan, T., & Güven, B. (2013). A study on the differentiation levels of middle school students' statistical thinking. *Elementary Education Online, 12*(1), 158-178.

Kramarski, B. (2004). Making sense of graphs: Does metacognitive instruction make a difference on students' mathematical conceptions and alternative conceptions? *Learning and Instruction, 14*, 593–619.

Kranda, S., & Akpınar, M. (2018). Defining of graphical literacy levels of 7th grade students' in social studies course. *Journal of Kırşehir Education Faculty, 19*(3), 2459-2472.

Lai, K., Cabrera, J., Vitale, J. M., Madhok, J., Tinker, R., & Linn, M. C. (2016). Measuring graph comprehension, critique, and construction in science. *Journal of Science Education and Technology, 25*(4), 665–681.

Leinhardt, G., Zaslavsky, O., & Stein, M. K. (1990). Functions, graphs, and graphing: Tasks, learning, and teaching. *Review of Educational Research, 60*(1), 1–64.

Lowrie, T., & Diezmann, C. M. (2011). Solving graphics tasks: Gender differences in middle-school students. *Learning and Instruction, 21*, 109–125.

Ludewig (2018). *Understanding graphs: Modeling processes, prerequisites and influencing factors of graphicacy*. Doctoral Dissertation, Tübingen University, Tübingen.

Ludewig, U., Lambert, K., Dackermann, T., Scheiter, K., & Möller, K. (2020). Influences of basic numerical abilities on graph reading performance. *Psychological Research, 84*, 1198–1210.

Maggioni, E. L. (1953). *The construction and evaluation of a test of ability to read and interpret graphs for grades six, seven and eight*. Doctoral Dissertation, Boston University, Boston.

Malter, M. S. (1952). Studies of the effectiveness of graphic materials. *The Journal of Educational Research, 46*(4), 263–273.

Martin, M. O., Mullis, I. V. S., Foy, P., & Stanco, G. M. (2012). *TIMSS 2011 international results in science*. International Study Center, Boston College, MA, USA.

MEB (2005). *Science and technology course instructional program and guide (Grades 6–7–8)*. Ankara: Ministry of Turkish National Education.

MEB (2013). *Elementary science course instructional program (Grades 3, 4, 5, 6, 7 and 8)*. Ankara: Ministry of Turkish National Education.

MEB (2018). *Elementary science course instructional program (Grades 3, 4, 5, 6, 7 and 8)*. Ankara: Ministry of Turkish National Education.

Mullis, I. V. S., Martin, M. O., Foy, P., & Arora, A. (2012). *TIMSS 2011 International results in mathematics*. International Study Center, Boston College, MA, USA.

OECD (2013). *PISA 2012 results in focus.* OECD Publications.

Oruç, Ş., & Akgün, İ. H. (2010). The acquisition level of graphic reading skills of elementary social studies 7th grades students. *International Journal of Eurasia Social Sciences, 1*(1), 51-58.

Ozmen, Z. M., Guven, B., & Kurak, Y. (2020). Determining the graphical literacy levels of 8th grade students. *Eurasian Journal of Educational Research, 86*, 269-292.

Patahuddin, S. M., & Lowrie, T. (2019). Examining teachers' knowledge of line graph task: A case of travel task. *International Journal of Science and Mathematics Education, 17*(4), 781-800.

Pereira-Mendoza, L., & Mellor, J. (1990). *Students' concepts of bar graphs: Some preliminary findings*. Proceedings of the Third International Conference on Teaching Statistics, Newfoundland, Canada.

Phillips, R. J. (1997). Can juniors read graphs? A review and analysis of some computer-based activities. *Journal of Information Technology for Teacher Education, 6*(1), 49–58.

Postigo, Y., & Pozo, J. I. (2004). On the road to graphicacy: The learning of graphical representation systems. *Educational Psychology, 24*(5), 623-644.

Shah, P., & Freedman, E. G. (2011). Bar and line graph comprehension: An interaction of top- down and bottom- up processes. *Topics in Cognitive Science, 3*(3), 560-578.

Shah, P., Freedman, E., & Vekiri, I. (2005). The comprehension of quantitative information in graphical displays. In P. Shah & A. Miyake (Eds.), *The Cambridge Handbook of Visuospatial Thinking* (Cambridge Handbooks in Psychology, 426-476). Cambridge University Press.

Shah, P., & Hoeffner, J. (2002). Review of graph comprehension research: Implications for instruction. *Educational Psychology Review, 14*(1), 47–69.

Simkin, D., & Hastie, R. (1987). An information-processing analysis of graph perception. *Journal of the American Statistical Association, 82*(398), 454–465.

Tairab, H. H., & Al-Naqbi, A. K. K. (2004). How do secondary school science students interpret and construct scientific graphs? *Journal of Biological Education, 38*(3), 127–132.

Tiefenbruck, B. F. (2007). *Elementary teachers' conceptions of graphical representations of categorical data*. (Doctoral Dissertation), University of Minnesota, Minneapolis.

Tortop, T. (2011). *7th- grade students' typical errors and possible misconceptions in graphs concept before and after the regular mathematics instruction*. (Master Thesis), Middle East Technical University, Ankara.

Uk, I., Matuk, C., & Linn, M. C. (2016). *Students using graphs to understand the process of cancer treatment*. International Conference of the Learning Sciences, Singapore.

Wainer, H. (1980). A test of graphicacy in children. *Applied Psychological Measurement, 4*(3), 331–340.

Wainer, H. (1992). Understanding graphs and tables. *Educational Researcher, 21*(1), 14–23.

Woolfolk, A. (2004). *Educational psychology* (9th Edition). Pearson Education.

Yabanlı, H., Yıldırım, B., & Günaydın, Ö. (2013). Translating from map to line graph. *Journal of Inquiry Based Activities, 3*(1), 12-19.

Yingkang, W., & Yoong, W. K. (2007). Exploring attitude toward statistical graphs among Singapore secondary school students. *The Mathematics Educator, 10*(1), 39–58.

Zacks, J., & Tversky, B. (1999). Bars and lines: A study of graphic communication. *Memory & Cognition, 27*(6), 1073-1079.

Zhang, D. C. (2016). *Using icon array as a visual aid for communicating validity information*. Doctoral Dissertation, Bowling Green State University, Ohio.

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