



Examining Middle School Students' Visual Mathematics Literacy Self-Efficacy Perceptions According to Various Variables

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Abstract

In this study, we first determined the level of visual mathematics literacy self-efficacy perceptions (VMLSEPs) of middle school students. Then, we examined whether these perceptions differ significantly according to various variables such as gender, class level, mathematics achievement, receiving support, and parental educational status or not. It is a survey study. Therefore, 278 middle school students participated in the study. The data was collected with the Visual Math Literacy Self-Efficacy Perception Scale (VMLSEPS). The results of validity and reliability analyses of the data showed that the analyses could be performed. After this, it was determined whether the data distributed normal or not. According to this, all the data show normal distribution; therefore, parametric tests such as independent sample t-test and One-Way ANOVA were used to analyze the data. As a result, middle school students' VMLSEPs are at a high level. While students' VMLSEPs did not show a significant difference according to gender, receiving support, and fathers' educational status, these perceptions showed a statistically meaningful difference according to class level, mathematics achievement, and mothers' educational status.

Keywords: gender, class level, math achievement, receiving support, parental educational status

1. Introduction

In today's world where information and technology change and develop rapidly, individuals who have developed their thinking skills are needed to be productive individuals. This need has made the transfer of mathematical thinking skills to daily life widespread and the importance of learning mathematics more evident (Kabael, 2019). Transferring mathematical

knowledge and skills to daily life is associated with mathematical literacy (ML) which is defined as understanding the role of mathematics in one's inner world and the outside world, being able to reach accurate and clear judgments with existing knowledge and experience and using mathematics to produce solutions to the problems that the individual encounters in daily life (McCrone & Dossey, 2007). ML enables a person to be aware and understand the role of mathematics in the modern world and to critically analyze and solve problems in daily life situations (Özgen & Bindak, 2008). The definition of the Program for International Student Assessment (PISA) is accepted as the common definition in the literature. According to the PISA, ML is defined as an individual's capacity to formulate, use, and interpret mathematics in various contexts (Organization for Economic Co-operation and Development-OECD, 2017). In this context, mathematically literate individuals can more easily realize the need for mathematics and find solutions to the problems they encounter in daily life.

Although there are many types of literacy, today there is a need for visual information, which is also required by mathematics. Visual elements have an important contribution to the development and teaching of mathematics (Bekdemir & Duran, 2012). Visual literacy is the ability to understand, analyze, question, and discover visual information (Karaçam & Ocak, 2023). Visual mathematics literacy is defined as expressing daily life problems visually and mathematically by evaluating information based on visuals (Bekdemir & Duran, 2012). One of the concepts related to ML and visual literacy that closely affects an individual's motivation, success, and behavior is self-efficacy (Pajares, 2001). Self-efficacy is an individual's personal belief in his or her ability to plan and perform the necessary activities in the process of achieving set goals (Bandura, 1997). When individuals believe that they have the control and ability to perform a given task, they are more willing and determined to perform the task (Sharp et al., 2002). Determining individuals' self-efficacy perceptions can help explain and understand their behaviors.

Studies have examined the visual mathematics literacy self-efficacy perception (VMLSEP) level in terms of various variables (such as gender, class level, ...) in the literature (Altıntaş & İlgin, 2021; Birgün & Gülbez, 2014; Çelik, 2019; Deveci & Aldan-Karademir, 2018; İlhan & Aslaner, 2020; Kaba & Özdişci, 2018; Pişkin-Tunç, 2021; Şengül et al., 2012, 2017; Tutkun et al. 2014). There are also studies in which tools were developed to measure VMLSEPs (Bekdemir & Duran, 2012; İlhan & Çelik, 2016). According to Şengül et al. (2012), if teachers increase their students' VMLSEPs, they increase their achievement. Duran and Bekdemir (2013) revealed a moderate, positive, and significant relationship between 7th class middle school students' VMLSEPs and their visual mathematics achievement. Çilingir and Dinç-Artut (2016) examined the effect of teaching with a realistic mathematics education approach on VMLSEPs and observed that the students in the experimental group had higher VMLSEPs than the control group. Özdemir et al. (2016) focused on the relationship between VMLSEPs and problem-solving skill perceptions and determined a low-level, positive, and significant relationship between them. İlhan and Aslaner (2017) investigated the effect of using dynamic geometry software in teaching geometry subjects on the visual mathematics literacy perceptions of pre-service teachers and concluded that there was a significant difference in favor of the post-test. In their study with middle school 8th class students, Ev-Çimen and Aygüner (2018) examined the relationship between students' VMLSEPs and their actual performance. İlhan et al. (2019) investigated the relationship between visual mathematics literacy and geometry achievement of pre-service teachers. Katrancı and Şengül (2019) searched the relationship between middle school students' mathematics literacy and VMLSEPs and found a high level of positive relationship. Aksu et al. (2019) reported that VMLSEP positively and significantly predicted the metacognitive reading comprehension awareness level. İlhan and Aslaner (2021) found a moderate positive relationship between pre-service

teachers' perceptions of visual mathematics literacy and their reasoning skills regarding geometric shapes and their geometry performance. In his study examining the effects of modeling, game-based, collaborative, and traditional learning approaches on visual mathematics literacy, İlhan (2021) revealed that the collaborative learning approach was significantly more effective than other approaches. Toprak and Orman (2023) revealed that reading comprehension has a partial mediating effect on the relationship between visual mathematics literacy and mathematics achievement.

In this study, we first determined the level of VMLSEPs of middle school students. Then, we examined whether these perceptions differ significantly according to various variables such as gender, class level, mathematics achievement, receiving support, and parental educational status or not. To achieve these aims, the following research questions (RQ) were attempted to be answered.

RQ1. What is the level of VMLSEPs of middle school students?

RQ2. Do these perceptions show a significant difference according to the variables of gender, class level, mathematics achievement, receiving support, and parental educational status?

2. Method

It is a survey study. In this type of study, the process of data collection is related to the answers to questions asked to the individuals, and the data is collected from the sample (Fraenkel & Wallen, 2006). This study examined the VMLSEPs of middle school students, and the study was conducted with 278 students.

2.1.Data Collection Tools

In this research, the Demographic Information Form (DIF) and the Visual Math Literacy Self-Efficacy Perception Scale (VMLSEPS) were used as data collection instruments. Detailed information about these is given below.

DIF: This form includes six questions to learn about the participants' gender, class level, etc. These questions are independent variables.

VMLSEPS: Bekdemir and Duran (2012) developed this scale to measure VMLSEPs. The scale consists of 38 items and three sub-factors. These sub-factors are F1: Field content, F2: Process, and F3: Situations. The Cronbach's alpha internal consistency coefficient of the scale was 0.943. For the sub-factors, these values were calculated as 0.653, 0.927, and 0.839, respectively. The lowest score that can be obtained from the scale is 38, and the highest score is 190. A high score also indicates a high level of VMLSEP. The score ranges and groups according to the scores are as follows.

Between 148 and 190 points: Good or Good Group (GG)

Between 84 and 147 points: Medium or Medium Group (MG)

Between 38 and 83 points: Bad or Poor Group (PG)

In this study, the validity of the data was first tested with confirmatory factor analysis. In this context, the results are as follows. $\chi^2/df = 2.17$ (≤ 2.5 = Perfect fit (Kline, 2005)), RMSEA = 0.06 (≤ 0.06 = Good fit (Thompson, 2004)), NFI = 0.92 (≥ 0.90 = Good fit (Thompson, 2004)), NNFI = 0.96 (≥ 0.95 = Perfect fit (Sümer, 2000)), CFI = 0.96 (≥ 0.95 = Perfect fit (Sümer, 2000; Thompson, 2004)), IFI = 0.96, RMR = 0.09 (≤ 0.1 = Mediocre fit (Kline, 2005)) and SRMR = 0.06 (≤ 0.08 = Good fit (Brown, 2006)). These findings showed that the data were valid. Then,

reliability analyzes were conducted. Accordingly, the Cronbach alpha value of VMLSEPS was calculated as 0.934. These values for sub-factors were 0.610, 0.911, and 0.825, respectively. If Cronbach alpha values are between 0.60 and 0.80, it is stated that the data is reliable, and if it is between 0.80 and 1.00, the data is highly reliable (Yıldız & Uzunsakal, 2018). According to this, all data were found to be sufficiently reliable. Therefore, the data for this study was valid and reliable. For this reason, analyses were done.

2.2.Data Analysis

To address RQ1, we conducted descriptive statistics. The average of the scores from the scale and its sub-factors was calculated to determine the perception level. Because the scale is a 5-point Likert-type, the following limit values were considered when evaluating the results:

Reference values= 1.00-1.80: Very low; 1.81-2.60: Low; 2.61-3.40: Moderate; 3.41-4.20: High; 4.21-5.00: Very high

To answer RQ2, we checked whether all data showed a normal distribution. If the group is larger than 50, the Kolmogorov-Smirnov test is recommended for normality, and if the group is smaller than 50, the Shapiro-Wilks test is recommended. If the p values are greater than 0.05, the data are normally distributed (Büyüköztürk, 2020). In addition, if the kurtosis value is between ± 1.0 and ± 2.0 , it is interpreted that the data are suitable for analysis with valid tests for normal distribution (George & Mallery, 2010). However, if the skewness value is between -1 and +1, the data are normally distributed (Hair et al., 2013).

According to all of these, we checked whether the data were normally distributed for each independent variable. Accordingly, independent samples t-test was used in the analyses regarding the variables of gender and receiving support, and One-Way ANOVA calculations were used for other variables. If there was a difference because of the analyses, the effect sizes were calculated. To evaluate the effect sizes, cut-off points of 0.14= Large effect, 0.06= Moderate effect, and 0.01= Small effect (Cohen, 1988; cited in Pallant, 2007) were considered.

3. Results

RQ1: What is the level of VMLSEPs of middle school students? Table 1 shows the results of this question.

Table 1: Results of VMLSEPS and its sub-factors

VMLSEPS and its subfactors	N	Min.	Max.	Mean	sd
F1	278	1.57	5.00	3.78	.69
F2	278	1.38	5.00	3.76	.71
F3	278	1.60	5.00	4.09	.69
VMLSEPS	278	1.61	5.00	3.84	.64

According to Table 1, F1's mean score is 3.78, F2's mean score is 3.76, and F3's mean score is 4.09. The mean score of VMLSEP of the students is 3.84. In addition, 0.72% (N= 2) of these students are in the BG, 48.28% (N= 134) of them are in the MG, and 51.08% (N= 142) of them are in the GG.

RQ2: Do these perceptions show a significant difference according to the variables of gender, class level, mathematics achievement, receiving support, and parental educational status? Accordingly, Table 2 shows the results regarding gender and these perceptions.

Table 2: Relationship between VMLSEPS and gender

Gender	N	Mean	sd	df	t	p
Female	136	150.23	23.08	276	2.815	.760
Male	142	142.15	24.67			

According to Table 2, middle school students' VMLSEPs did not show a significant difference according to their gender ($t_{276} = 2.815$; $p > 0.05$). The findings regarding the class level variable are presented in Table 3.

Table 3: Relationship between VMLSEPS and the class level

Class level	Sum of squares	df	Mean square	F	p
Between groups	6432.253	3	2144.084	3.770	.011
Within groups	155811.722	274	568.656		
Total	162243.975	277			

Table 3 shows that middle school students' VMLSEPs show a significant difference according to their class levels ($F_{(3, 274)} = 3.770$, $p < .05$, $\mu^2 = 0.04$). The VMLSEPs of 5th (Mean= 141.33) and 8th (Mean= 142.77) classes students are lower than the perceptions of 7th (Mean= 153.70) class students and are statistically significant. Findings regarding mathematics achievement are presented in Table 4.

Table 4: Relationship between VMLSEPS and mathematics achievement

Mathematics achievement	Sum of squares	df	Mean square	F	p
Between groups	30136.396	3	10045.465	20.835	.000
Within groups	132107.579	274	482.144		
Total	162243.975	277			

According to Table 4, middle school students' VMLSEPs show a significant difference according to their mathematics achievement ($F_{(3, 274)} = 20.835$, $p < .05$, $\mu^2 = 0.19$). The perceptions of students with a mathematics achievement score of two (Mean= 118.29) were the lowest, while the perceptions of students with a mathematics achievement score of five (Mean= 153.51) were the highest. As mathematics achievement increases, the average score also increases. The findings of the analysis regarding whether students should receive support in mathematics lessons are shown in Table 5.

Table 5: Relationship between VMLSEPS and receiving support

Receiving support	N	Mean	sd	df	t	p
Yes	146	148.88	23.71	276	2.025	.757
No	132	143.03	24.45			

According to Table 5, middle school students' VMLSEPs do not show any difference depending on whether they receive support for mathematics lessons ($t_{276} = 2.025$; $p > 0.05$). The findings regarding mothers' educational status are presented in Table 6.

Table 6: Relationship between VMLSEPS and mothers' educational status

Mother's educational status	Sum of squares	df	Mean square	F	p
Between groups	10559.532	5	2111.906	3.787	.002
Within groups	1511684.443	272	557.663		
Total	162243.975	277			

According to Table 6, middle school students' VMLSEPs show a significant difference according to their mothers' educational status ($F_{(5, 272)} = 3.787$, $p < .05$, $\mu^2 = 0.07$). The VMLSEPs of students whose mothers are illiterate are lowest (Mean= 125.00), while students whose mothers are postgraduates have the highest perceptions (Mean= 150.92). The findings regarding the father's educational status are presented in Table 7.

Table 7: Relationship between VMLSEPS and fathers' educational status

Father's educational status	Sum of squares	df	Mean square	F	p
Between groups	3738.379	4	934.595	1.610	.172
Within groups	158505.596	273	580.607		
Total	162243.975	277			

Table 7 shows that middle school students' VMLSEPs do not show a significant difference according to their father's educational status ($F_{(4, 273)} = 1.610$; $p > 0.05$).

4. Discussion

In this study, we found that the level of VMLSEPs of middle school students was at high level. There are studies (Çelik, 2019; Kaba & Özdişci, 2018; Katrancı & Şengül, 2019; Tutkun et al., 2014) reaching similar conclusion. Another study Ev-Çimen and Aygüner (2018) found that students consider themselves highly proficient in visual mathematics literacy. On the other hand, there are also studies (Birgin & Gülbez, 2014; Deveci & Aldan-Karademir, 2018; Şengül et al., 2017) revealing that the level of visual mathematics literacy of middle school students is moderate or below moderate. In this context, middle school students' VMLSEPs are at medium or slightly above the medium level. This may be due to not using enough manipulative to explain geometry subjects. For this reason, it is thought that students' perceptions can be increased by making the subjects as concrete as possible.

When the relationship between middle school students' VMLSEPs and gender was examined, no significant difference was found between the perceptions of male and female students. In many studies (Altıntaş & İlgin, 2021; Birgün & Gülbez, 2014; Çelik, 2019; İlhan & Aslaner, 2020; Kaba & Özdişci, 2018; Pişkin-Tunç, 2021; Şengül et al., 2017), similar result was found. However, in this study, it was determined that the perception scores of female students were higher than those of male students. In this context, female students have higher VMLSEPs. This result is parallel to previous studies (Deveci & Aldan-Karademir, 2018; Özdemir et al., 2016; Tutkun et al., 2014), which revealed that VMLSEPs differ in favor of girls. Also, Şengül et al. (2012) found that these perceptions vary significantly according to gender. Technological devices such as smartphones and tablets have entered the lives of students. Boys are more inclined to play games on digital devices; therefore, their responsibilities for studying and doing homework decrease, their attention is more distracted, and they experience focusing problems. All these factors may have caused their visual mathematics literacy to be lower than that of the girls.

It was determined that middle school students' VMLSEPs differ significantly according to their class levels. Class level has a small effect on these perceptions. Similarly, there are studies (Altıntaş & İlgin, 2021; Birgin & Gülbez, 2014; Deveci & Aldan-Karademir, 2018; İlhan & Aslaner, 2020; Pişkin-Tunç, 2021) that show a significant difference according to class level. On the other hand, there are also studies (Kaba & Özdişci, 2018; Şengül et al., 2017; Tutkun et al., 2014) that concluded that students' VMLSEPs do not differ significantly according to class level. In this study, it was concluded that the VMLSEP scores of 5th and 8th classes students were lower than the perception scores of 7th class students. Since it is thought that 5th class students do not have enough geometry knowledge to increase their perception and that it may increase in later class levels, it is reasonable that their perception score averages are lower than those of other classes. The fact that the perception score averages of 8th class students are close to the 5th class perception scores and lower than the 7th class perception scores is thought-provoking and an issue that needs to be investigated. However, considering the COVID-19 pandemic, 8th class students were subjected to online education when they started learning the basics of geometry. The fact that students had to learn difficult and complex geometry subjects

in online education while they were in active education may have caused the students to develop a negative perception and their perceptions to decrease.

It was determined that middle school students' VMLSEPs differed significantly according to their mathematics achievements, which had a large effect on these perceptions. Students with low mathematics achievement had low perception scores, whereas those with high mathematics achievement had high perception scores. This result overlaps with the results obtained from studies in the literature (Birgün & Gülbez, 2014; Çelik, 2019; Deveci & Aldan-Karademir, 2018; Kaba & Özdişci, 2018; Şengül *et al.*, 2012, 2017; Tutkun *et al.*, 2014). Based on the studies conducted, students with high VMLSEPs can be expected to be successful in national and international exams (such as High School Entrance Exam-HSEE, PISA, Trends in International Mathematics and Science Study-TIMSS). The VMLSEPs are a significant predictor of visual mathematics success (Duran & Bekdemir, 2013), and there is a significant and positive relationship between geometry achievements and visual mathematics literacy perception (İlhan *et al.*, 2019). In addition, mathematics achievement can be increased by increasing students' VMLSEPs (Şengül *et al.*, 2012). A moderate, positive, and significant relationship exists between self-efficacy perception, visual-spatial intelligence score, and mathematics achievement (Birgin & Gülbez, 2014).

Middle school students' VMLSEPs do not show a significant difference depending on whether they receive support outside of school or not. Out-of-school support is for completing missing mathematics subjects or preparing for exams. Therefore, it may not have affected VMLSEPs.

While middle school students' VMLSEPs differ significantly according to their mother's educational status, there is no significant difference according to their father's educational status. It was determined that the perception scores of mothers whose education level was illiterate were the lowest and those of mothers whose education level was postgraduate were the highest. Mothers' educational status has a moderate effect on these perceptions. Since it is generally mothers who follow the course progress of students in Türkiye and provide support, when necessary, the significant difference can be considered an expected result. However, these perceptions create significant differences according to the educational status of both mothers and fathers (Kaba & Özdişci, 2018; Şengül *et al.*, 2017). In contrast, students' VMLSEPs differ significantly according to the father's education level, but not according to the mother's education level (Tutkun *et al.*, 2014). In this context, it does not seem possible to provide a clear result as to whether students' perceptions differ significantly according to the educational status of their parents.

5. Suggestions

Considering these results, new studies can be conducted to investigate the reasons for low or high VMLSEPs. By adding qualitative data to quantitative studies, the factors affecting students' VMLSEPs and the reasons for these perceptions can be investigated in depth. Since it is thought that success in both mathematics and geometry courses can be increased by increasing these perceptions, teachers should support their lessons with activities that increase students' perceptions. In addition, it is thought that students' perceptions can be increased by making the subjects as concrete as possible.

Conducting new studies in which the level of VMLSEPs of students studying at primary school, high school, and undergraduate level is determined and the relationship is examined according to various variables (gender, class level, mathematics achievement, whether they receive external support, etc.) will be useful in terms of contributing to the literature. In

addition, detailed information can be obtained using different scales or by conducting experimental studies on the subject in a larger sample.

Since questions requiring visual mathematics literacy are included more in national and international exams (HSEE, PISA, TIMSS), this should be given importance in the processes of learning and teaching mathematics. In this context, students should be given the opportunity to use, develop, and interpret transformations such as graphics, tables, figures, and modeling in solving the questions. It is also recommended that students be compared with problems involving real-life situations that will improve their visual mathematics literacy.

Questions, activities, or studies created with visuals, diagrams, graphs, tables, and modeling help students to concretize their abstract thoughts. Therefore, visual elements should be included in the curriculum and textbooks to be developed. It is also recommended to support the lessons with manipulative using different teaching-learning methods and to concretize the subjects with dynamic geometry software.

6. Implications

Within the framework of the results of the study, teachers should include activities in their lessons. More focus should be placed on concretizations during the lecture process. For example, when two-dimensional views of an object are desired to be drawn from different directions, a concrete version of that object should be brought to the class.

It does not seem possible to obtain a definitive result as to whether students' VMLSEPs show a significant difference according to gender. Therefore, it is important to conduct new studies that examine students' VMLSEPs to gender and investigate the reasons for this.

In PISA 2022, the predominant field was ML, and ML proficiency levels were created. These proficiency levels are scales that show what students have achieved and what they have not achieved according to their scores to provide clearer information about student success in PISA. Of the eight proficiency levels (1a, 1b, 1c, 2, 3, 4, 5, and 6) created within the scope of ML, the lower score limit of the fifth proficiency level was determined to be 607. One of the competencies required by the fifth competency level is explained as "Students at this level can develop models for complex situations and work with these models by determining existing constraints or introducing new constraints and defining assumptions" (Ministry of National Education-MoNE, 2022). Considering that the proficiency required by the fifth level is related to visual mathematics literacy and that a minimum score of 607 is required to reach this level, students' VMLSEP scores are an important condition for improving mathematics success. In addition, middle school students' mathematics success has a wide-ranging impact on their VMLSEPs, and their success in mathematics also improves their perceptions. Therefore, visual elements should be used in the course content and books.

For out-of-school support to positively affect visual mathematics literacy, an exam-oriented approach should be avoided. Instead, manipulative that support visual perception should be used. Although there is no clear result according to the educational status of the parents, a high level of education is a desirable condition. Therefore, it is recommended that the education level should be increased. This can be achieved through open or distance education.

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