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Visualised Scale of Attitude Towards Mathematics: A Validity and Reliability Study

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ABSTRACT

This study was conducted to develop an instrument with good psychometric properties to measure primary school students' attitudes towards mathematics. For this purpose, the screening model was utilised in the research. The form was prepared in the form of a five-point Likert scale (Very Unhappy, Unhappy, Neither Happy nor Unhappy, Happy, Very Happy). Visuals were used to determine the students' responses on the developed scale, thus making the measurement process more fun and interesting for students. We administered the scale to two groups of primary school students and applied exploratory factor analysis (EFA) to the data obtained from the first group ($n = 576$). The results of the EFA revealed that the scale has a one-dimensional structure consisting of 14 items. The scale was then applied to the second group of elementary school students ($n = 347$) to confirm the single-factor structure through confirmatory factor analysis (CFA). The fit indices calculated during the CFA indicated an excellent model fit of the scale. Finally, Cronbach's alpha, McDonald's omega and item-total correlations were calculated for the reliability analysis of the scale, and the results yielded considerably high values. The analysis results indicate that the developed visual mathematics attitude scale is a highly valid and reliable measurement instrument.

1 | Introduction

Technological advancements impact both the current state and future trajectory of mathematics education (Kılıç 2023; Mensah and Ampadu 2024). As such, it is important to note that the demands of modern educational environments require high-quality mathematics instruction, of which instructional technology is an integral part (Corey et al. 2010; Munter 2014; Rosenquist et al. 2015).

Despite societal demands, most students perceive mathematics as difficult, abstract and uninteresting (Serin 2023). When students face mathematical problems, a lack of motivation or prior experiences often leads them to believe they are poor at mathematics before even attempting to solve them. In fact, this situation is often attributed to students' attitudes towards mathematics rather than a lack of ability (Colomeischi and Colomeischi 2015).

Mathematics is no longer regarded as a knowledge system based on absolute truths, but as a historical and cultural phenomenon that develops in a social context (Gula and Jojo 2024). This perspective makes learning processes more meaningful and inclusive by emphasising the social aspect of mathematics. Adopting this perspective in mathematics education is made possible by culturally responsive mathematics teaching (CRMT). CRMT ensures that mathematics is taught in an egalitarian framework and supports a student-centred teaching approach that is sensitive to cultural contexts (Celedón-Pattichis et al. 2018).

Culturally responsive teaching is based on sociocultural theory, which suggests that it supports the development of mathematical thinking through the use of practices, tools and symbols structured in cultural contexts (Vygotsky 1978). Vygotsky's (1978) sociocultural theory provides a powerful framework for understanding how learning and teaching processes can be related to cultural contexts, and this framework is critical for maximising students' individual and social potential.

There are different theoretical approaches to mathematics attitudes. For example, Bandura's social learning theory (Bandura 1986) suggests that students' attitudes towards mathematics are shaped by environmental influences, while Piaget's cognitive development theory (Piaget 1972) emphasises how these attitudes evolve throughout the learning process. In the light of these theoretical approaches, the present study addresses student attitudes in both a cognitive and sociocultural context.

The importance of cultural responsiveness in mathematics teaching is that it enables students to participate more effectively in the learning process and increases their learning potential. In this context, research on CRMT reveals an important necessity to meet the needs of an increasingly diverse student population (Abdulrahim and Orosco 2020).

At this point, it is important to consider cultural and individual differences when assessing mathematics attitudes in order to provide a more inclusive and effective learning environment. In addition to the cognitive and emotional components of attitudes, students' social contexts should also be taken into consideration.

1.1 | Conceptual Framework and Related Literature

Thurstone (1967) defines attitude as 'the sum total of a man's inclinations and feelings, prejudice or bias, pre-conceived notions, ideas, fears, threats, and convictions about any specified topic.' Accordingly, attitude is comprised of three components: cognitive, emotional and behavioural. (Auzmendi 1992; Gómez Chacón 2010). The cognitive component reflects concepts and beliefs related to situations or events, while the emotional component represents the positive or negative emotions they evoke. The behavioural component is related to the behaviours shown to the stimuli (as cited in León-Mantero et al. 2020). Despite varying perspectives on attitude, it is widely accepted that attitudes are learned, manifest in individuals' reactions to objects or situations, and can be evaluated as either positive or negative (Way and Relich 1993; White et al. 2006).

For example, McLeod (1992) considers the affective areas related to mathematics in three categories: emotions, attitudes and beliefs. Attitude-related frameworks have been handled in different ways over the years, such as an all-encompassing term (Poffenberger and Norton 1959) and an intermediate term (Leder and Grootenboer 2005). However, attitude has since become the focus of research on mathematics education (Ngurah and Lynch 2013). Attitude has been extensively studied as a prominent concept in both psychology and education. McLeod (1992) considered the concept of attitude as a critical part of the emotional factors of mathematics education and introduced a new perspective (Colomeischi and Colomeischi 2015; León-Mantero et al. 2020). Neale (1969) argues that attitude is crucial in learning mathematics, defining it as the inclination to like or dislike mathematics, the tendency to engage in or avoid mathematical activities, and the underlying beliefs about mathematics (as cited in Ngurah and Lynch 2013).

According to the Organisation for Economic Cooperation and Development (OECD 2003) PISA surveys, which evaluate students' knowledge and skills, more than two-thirds of 15-year-old students express negative attitudes towards mathematics (Wen and Dubé 2022). Additionally, an examination of the mathematics rankings reveals that Turkey remains below the OECD averages (OECD 2023). Assessing mathematics attitudes is crucial as it can reflect students' prior experiences and influence their participation, interest, and performance in learning processes (Ma and Kishor 1997; Ngurah and Lynch 2013; Passolunghi et al. 2016). Various measurement tools have been developed to assess students' attitudes towards mathematics, including the Mathematics Attitude Scale (Aiken 1974), the Fennema-Sherman Mathematics Attitude Scales (Fennema and Sherman 1976) and the Attitude Towards Mathematics Inventory (ATMI; Tapia and Marsh 2002).

Most studies on mathematics attitudes are primarily designed for middle school students and adults (Dowker et al. 2012; Olivares and Ceglie 2020; Wen and Dubé 2022). Considering the importance of attitude towards mathematics, it is also critical to conduct studies related to younger students as early intervention in terms of prevention studies (Dowker et al. 2012). Although there are few studies on younger students, existing research indicates they exhibit positive attitudes (Tizard et al. 2017). However, as they enter middle school, a shift towards negative attitudes is observed (Biatchford 1996; Wigfield and Meece 1988).

Attitudes towards mathematics are a critical factor that directly affects students' academic achievement and their engagement in learning processes. However, research shows that there is a lack of preparedness to meet the needs of culturally and linguistically diverse (CLD) students (Vázquez-Montilla et al. 2014). Today, mathematical learning processes continue to provide education without taking into account the cultural aspects of students, which prevents students' learning potential from being fully realised (Celedón-Pattichis et al. 2018). This deficiency clearly demonstrates the importance of developing a sociocultural context to make mathematics education more inclusive and effective.

Learning environments that take cultural differences into account enable students to establish a more positive connection with mathematics (Crespo et al. 2018). Mathematics activities that students can associate with their cultural identities can increase both their motivation and mathematical achievement (Moschkovich 2013). In this context, the development of measurement tools that take into account students' cultural characteristics can positively affect not only their academic achievement but also their attitudes towards mathematics.

The use of images and emojis in mathematics attitude scales provides meaningful interactions, especially for younger students (Kleine et al. 2016). Visuals can trigger students' emotional reactions and make their cognitive evaluation processes more effective (Mayer and Moreno 2003). The inclusion of culturally sensitive visuals can strengthen students' social and emotional bonds and lead to more realistic assessment results. It is important that the tools developed in line with these needs are designed to be culturally sensitive.

1.2 | Objectives and Hypotheses of the Current Study

Although scales exist to examine elementary school students' attitudes towards mathematics (Gulburnu and Yildirim 2021; Olivares and Ceglie 2020; Tezer and Özcan 2015), Interactive and game-based techniques are particularly essential for engaging young students (Kellett 2011). Visual support in the scales is crucial for acknowledging that students differ from adults and for facilitating their involvement in the data collection process (Kleine et al. 2016).

Moreover, one of the key aspects that distinguishes the Mathematics Scale with Visuals from other scales is its design featuring the 'Keloğlan' visual, which aligns with children's cultural contexts. The environments in which students live differ significantly. These differences may influence students' active participation in the scale and, consequently, the quality of the scores obtained (Kleine et al. 2016).

When conducting research with younger children, it is essential to use appropriate data collection tools, specifically designing child-friendly measurement instruments that reflect their familiar surroundings and align with their interests (Punch 2002). Another important issue is the contextualisation of questions so that children can answer more easily. As such, it is recommended that visual representations be utilised as response categories to enhance students' understanding of the scale (Johnston 2008). There are different studies on the use of visual representations (Bourai et al. 1997; Loughry et al. 2005; Rossiter 1977). Accordingly, Bourai et al. (1997) employed staircase visuals, Rossiter (1977) utilised thumbs-up and thumbs-down visuals, and Loughry et al. (2005) incorporated triangles of varying sizes in their scales designed as triple Likert scales.

In recent years, researchers have utilised emojis (Alismail and Zhang 2018; Fane et al. 2018; O'Brien 2016) and animated visuals (Li et al. 2024) in the design of data collection tools. Particularly in educational research, it is noted that emojis positively influence learning outcomes (Brody and Caldwell 2019; Dunlap et al. 2016). When collecting data from younger age groups, using culturally appropriate (Kleine et al. 2016) and familiar images (McCulloch 2019) is regarded as advantageous. Massey (2022) used a scale related to emojis to examine the attitudes of 8- and 9-year-olds towards mathematics, the first stage of which was to select emojis and the second stage was to draw. Their reason for using emojis here is to obtain more valid and reliable research results in the digital age. Their research concludes that the developed tool is both valid and reliable. Li et al. (2024) advanced the use of emojis by developing a Likert-type animated scale specifically for children aged 7 to 14.

Affective factors such as students' interests, beliefs, emotions, and attitudes are important in mathematics learning processes (Ngurah and Lynch 2013). It is possible to say that cognitive factors are not the only factors that determine success in mathematics teaching and learning. Measurement tools are also necessary for a thorough examination of emotional factors (León-Mantero et al. 2020).

Attitude is a multidimensional structure consisting of cognitive, emotional and behavioural components (Thurstone 1967; Auzmendi 1992). In the context of mathematics education, attitude directly affects students' perception, learning and application of mathematics (McLeod 1992). Neale (1969) emphasised that attitude determines the tendency to enjoy or avoid mathematics. The visuals used in the scale are an effective tool to support these components. At the cognitive level, they concretise mathematical concepts; at the affective level, they increase students' interest and motivation; and at the behavioural level, they encourage students' active participation. This theoretical basis suggests that the Visualised Mathematics Attitude Scale offers an innovative approach to measuring students' attitudes.

Quality educational processes in mathematics education should not be considered independent of culture (Robertson and Graven 2020; Thomas et al. 2024). When the measurement tools developed to provide quality mathematics education environments were examined, it was determined that they varied in terms of their focus on classroom climate and mathematics teaching (Charalambous and Praetorius 2018). Moreover, each assessment tool reflects the cultural values and priorities of the region in which it was developed. For example, instruments used in Western countries may emphasise teacher–student and student–student interactions while ignoring other active participation methods and ways of generating different ideas (Gökçe et al. 2021; Xu and Clarke 2019).

The choice of images was justified on the basis of students' level of familiarity and relevance to local contexts (Kleine et al. 2016). The use of culturally meaningful figures such as Keloğlan strengthens students' emotional connection to the scale and increases participation. This is in line with the contribution of familiar visuals to the data collection process, which is also emphasised by McCulloch (2019). This study differs from existing tools in terms of integrating visual elements in a culturally context-sensitive manner. In addition to the digital innovations provided by animated scales (Li et al. 2024) and emoji-based scales, in this study, cultural context is considered to play an important role as it is integrated into mathematics attitude measures. In the literature, cultural relevance has been ignored in most of the scales for younger age groups. This study aims to overcome this deficiency and presents a scale enriched with cultural elements.

The importance of this study lies in the fact that it presents a Visualised Mathematics Attitude Scale developed by considering cultural sensitivity in mathematics teaching and individual differences of students. This scale aims not only to measure students' attitudes towards mathematics, but also to increase students' interest in learning by making this measurement fun and engaging. The findings will enable teachers to design a more inclusive and effective mathematics education and shed light on practices to increase student achievement. Therefore, the study aims to make significant contributions to both theoretical and applied educational literature.

In this context, this study aims to develop and validate an instrument with robust psychometric properties to measure primary school students' attitudes towards mathematics. The research questions to be addressed in the study are outlined below:

1. Is the developed 'Visualized Scale of Attitude towards Mathematics' valid to measure elementary school students' attitudes towards mathematics?
2. Is the developed 'Visualized Scale of Attitude towards Mathematics' reliable to measure elementary school students' attitudes towards mathematics?

2 | Method

This study employed a screening model to develop a valid and reliable scale for assessing elementary school students' attitudes towards mathematics. According to Karasar (2009), screening models aim to describe a situation that existed in the past or still exists, an event that is the subject of research, an individual or an object as it exists in its own conditions. The primary feature distinguishing this research from other attitude scales is its use of a visually based measurement tool with strong psychometric properties, specifically designed for elementary students to express their attitudes towards mathematics.

2.1 | Study Group

Given the impact of socioeconomic status on students' access to educational materials and study habits, it was deemed essential to include participants from diverse socioeconomic backgrounds in the study group. Due to the lack of official data on the socioeconomic levels of schools in Turkey, expert opinions are used to classify schools according to socioeconomic levels (Alan and Atalay Kabasakal 2020; Ilhan et al. 2022). In this context, we gathered input from eight teachers and four school administrators. In line with the opinions, the schools in the Aksaray provincial center are divided into three groups: low, middle and high socioeconomic levels. The study's data were collected from four schools representing three different socioeconomic levels. Additionally, a balanced sample was ensured by distributing students across four different grade levels (1st through 4th).

The characteristics of the students whose data were collected during the scale development process are presented in two separate tables: one for the EFA sample ($n = 576$) and another for the CFA sample ($n = 347$). For EFA and CFA, data were collected in two sessions, spaced 4 weeks apart, ensuring no overlap of students from the same schools across the sample groups. Table 1 presents the demographic characteristics of students included in the exploratory factor analysis (EFA).

A total of 576 students participated in the study. This sample shows diversity in terms of demographic characteristics such as school, class, gender and number of siblings. The distribution of participants across schools is as follows: School 1 had 85 students (14.8%), School 2 had 214 students (37.2%), School 3 had 161 students (28.0%) and School 4 had 116 students (20.1%). In terms of grade distribution, there were 142 students (24.7%) from 1st grade, 146 students (25.3%) from 2nd grade, 143 students (24.8%) from 3rd grade and 145 students (25.2%) from 4th grade. In terms of gender distribution, 303 girls (52.6%) and 273 boys (47.4%) were included in the study. Regarding the number of siblings, there are 30 students with no siblings (5.2%), 252 students with one sibling (43.8%), 167 students with two siblings (29.0%), 84 students with three siblings (14.6%) and 43 students with four or more siblings (7.5%). The demographic characteristics of the students included in the confirmatory factor analysis (CFA) are presented in Table 2.

TABLE 1 | Demographic characteristics of the students included in the exploratory factor analysis.

Demographics	Frequency	Percentage
School		
School (1)	85	14.8
School (2)	214	37.2
School (3)	161	28.0
School (4)	116	20.1
Class (grade)		
1st grade	142	24.7
2nd grade	146	25.3
3rd grade	143	24.8
4st grade	145	25.2
Gender		
Female	303	52.6
Male	273	47.4
Siblings		
None	30	5.2
1 sibling	252	43.8
2 siblings	167	29.0
3 siblings	84	14.6
4 siblings and above	43	7.5

A total of 347 students participated in the study. This sample shows diversity in terms of demographic characteristics such as school, class, gender and number of siblings. The distribution of participants across schools is as follows: School 1 had 55 students (15.9%), School 2 had 128 students (36.9%), School 3 had 82 students (23.6%) and School 4 had 82 students (23.6%). In terms of class distribution, there were 87 students (25.1%) from the 1st grade, 85 students (24.5%) from the 2nd grade, 87 students (25.1%) from the 3rd grade and 88 students (25.4%) from the 4th grade. Regarding gender distribution, 173 girls (49.9%) and 174 boys (50.1%) were included in the study. Considering the number of siblings, 42 students (12.1%) had no siblings, 160 students (46.1%) had one sibling, 88 students (25.4%) had two siblings, 39

TABLE 2 | Demographic characteristics of the students included in the confirmatory factor analysis.

Demographics	Frequency	Percentage
School		
School (1)	55	15.9
School (2)	128	36.9
School (3)	82	23.6
School (4)	82	23.6
Class (Grade)		
1st grade	87	25.1
2nd grade	85	24.5
3rd grade	87	25.1
4st grade	88	25.4
Gender		
Female	173	49.9
Male	174	50.1
Siblings		
None	42	12.1
1 sibling	160	46.1
2 siblings	88	25.4
3 siblings	39	11.2
4 siblings and above	18	5.2

students (11.2%) had three siblings, and 18 students (5.2%) had four or more siblings.

2.2 | Data Collection Tool

During the development process, the principles of scale development were adhered to, including defining the measurement tool's objectives, outlining its characteristics, creating an item pool, obtaining expert opinions, conducting pilot tests and revisions, ensuring the scale's validity and reliability and evaluating the items (see Figure 1). These principles provide a systematic approach to scale development and ensure that measurement tools are valid and reliable (DeVellis 2016).

After reviewing the literature, visuals were created to tailor the scale for the development of primary school students. In selecting the animations for the visuals, Keloğlan, a character from an ancient Turkish fairy tale, was chosen to ensure cultural relevance. The animation drawing was carried out in cooperation with a graphic designer and a field expert, and professional design software (Adobe Illustrator) was used in the animation process. An original animated drawing of Keloğlan was created for the visual representation. Animation-related adjustments were made in collaboration with field experts, and a pilot study was conducted to ensure that the facial expressions effectively represented the desired features. For example, facial expressions representing positive and negative emotional states (Very Unhappy, Unhappy, Neither Happy nor Unhappy, Happy, Very Happy) were determined, and the effects of these expressions on student responses were analysed in a pilot study. In the pilot study, students' responses to the facial expressions were observed, and necessary adjustments were made to the visuals based on these responses.

At this point, only the face image was included in the scale to enhance its usefulness and avoid distracting elements that could arise from the full image of the bald boy (see Figure 2). After the final arrangements were made regarding the visuals, the item pool was created. We gathered feedback and suggestions from three field experts and a measurement and evaluation expert regarding the 20-item pool developed. Following the feedback received, we revised and combined the items, leading to the removal of several items from the scale. In this direction, we created the first draft of the scale with a total of 14 items. After the pilot application, validity and reliability analyses were conducted. The pilot implementation process was applied to a group of 50 students from schools with different socioeconomic levels in order to evaluate the measurement tool in terms of language, content and visual adequacy. In the pilot study, the comprehensibility of the visuals given to the students and the connections established with the attitude statements were observed. According to the results of the pilot study, some statements and visual options were edited.

The Data Analysis and Findings section provides detailed information regarding the validity and reliability analyses. In the research, the 'Experiment Form for the Visualized Scale of Attitude towards Mathematics' was employed as the data collection tool to assess the mathematics attitudes of elementary school students. The 'Trial Form for the Visualized Scale of Attitude towards Mathematics' used for data collection in the study, was finalised following a thorough literature review and consultations with experts. The scale form consists of 14 items. The items are designed to gauge students' reactions by having them select visuals that they find most appropriate.

2.3 | Data Collection

Ethics Committee permissions were obtained before the data collection process started. After completing the ethical approval process, the necessary permits for data collection were obtained from the Aksaray Provincial Directorate of National Education. Following the obtaining the necessary permissions for data collection, interviews were conducted with the school administration and teachers. Before the data collection process began, a schedule was developed for data collection through interviews with the teachers. The applications were carried out in a classroom environment where students could feel more comfortable. During the scale application, no feedback was provided to prevent students from feeling that their responses were correct or incorrect. In this collective data collection process, the Experiment Form for the Visualised Scale of Attitude towards Mathematics was administered to students in each class as a group, with the researcher acting solely as an observer and providing brief explanations when necessary. The collected data was transferred to the SPSS program, and codes were used

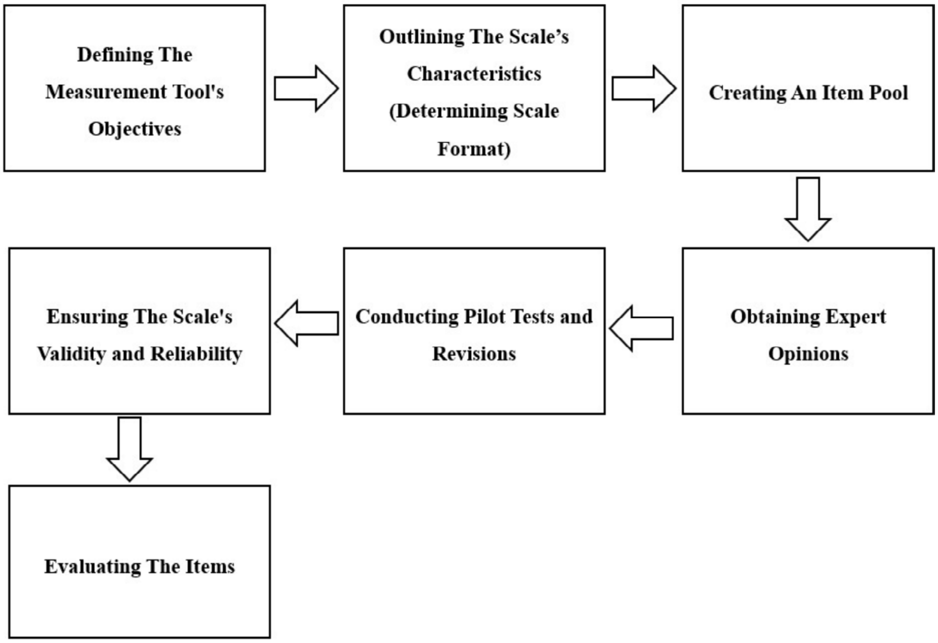

FIGURE 1 | Principles of scale development.

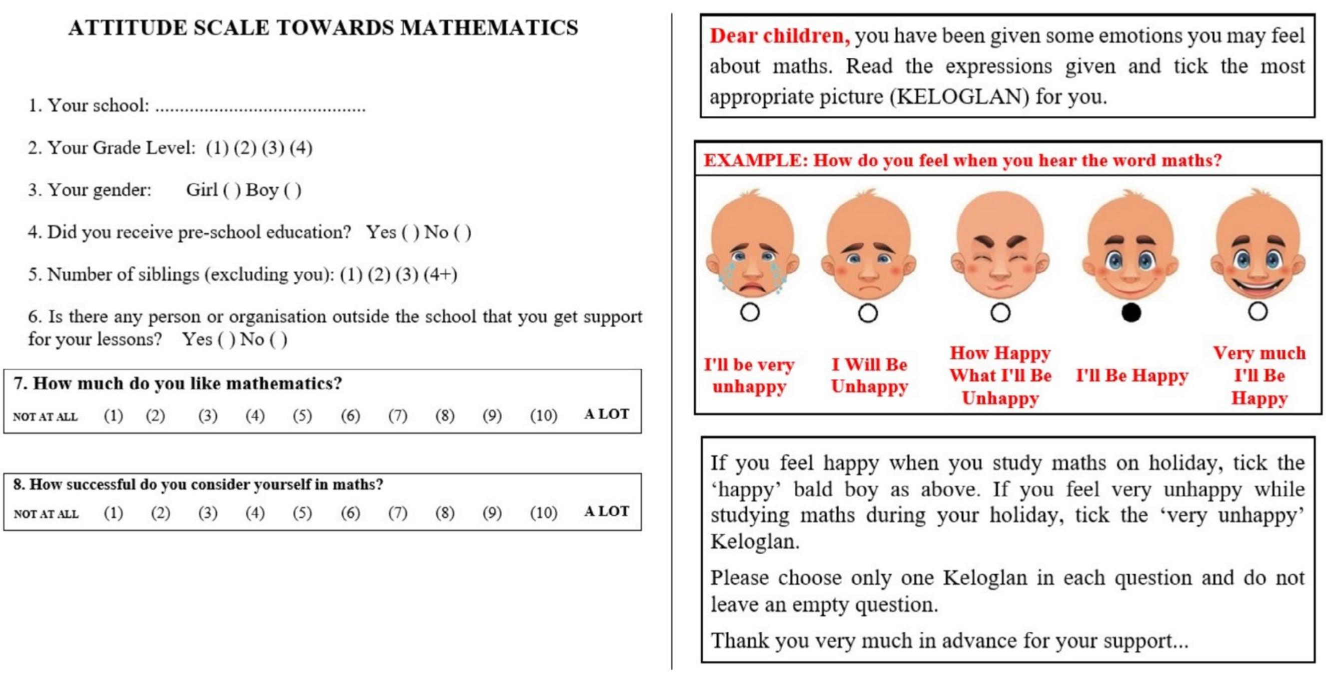

FIGURE 2 | Item and image sample of the Visualised Scale of Attitude towards Mathematics.

instead of names in order to protect the confidentiality of the students.

2.4 | Data Analysis

In analysing the data obtained from the research, EFA was conducted first, followed by CFA. To assess the suitability of both data sets for analysis, loss data analysis was initially conducted using Little's MCAR test in SPSS. The results showed that there was no bias in missing data for both the EFA sample ($X^2 = 230.842$; SD = 217; $p = 0.247$) and the CFA sample ($X^2 = 74.055$; SD = 87; $p = 0.837$). As the data loss rate in both data sets was below 5%, missing data were excluded from the analysis. Outlier analysis was performed for both data sets, and it was determined that the standardised z scores ranged between +/− 3. In addition, skewness (EFA = 1.068, CFA = −1.137) and kurtosis (EFA = 0.861, CFA = 0.499) coefficients were calculated for both data groups. These findings indicate that the total scores for both data sets follow a normal distribution. Additionally, detailed analyses for each item in both groups were conducted, showing that item averages generally fluctuate just below and above 4. For example, for the EFA sample, the mean and median of the T1 item were calculated as 4.014 and 4.00, respectively; the skewness value was −0.992 and the kurtosis value was 0.105. When the factor loadings were analysed, the items with the highest factor loadings were T2 (0.820), T7 (0.799) and T1 (0.798), while the lowest factor loading was observed in item T13 (0.661). Tabachnick and Fidell (2007) stated that the factor loadings of the items with factor loadings of 0.32 and above are poor, 0.45 and above are moderate, 0.55 and above are good, 0.63 and above are very good, and the factor loadings of the items above 0.071 are excellent. It can be said that the item factor loadings of the items of the scale are good and can be evidence for construct validity.

Similar detailed analyses for each item in both groups revealed generally negative skewness values, indicating that scores were skewed towards higher values. Kurtosis values are low, which indicates that the scores show a flatter distribution than the normal distribution. While skewness and kurtosis coefficients are zero in a perfectly symmetric normal distribution, values between ±2 for both skewness and kurtosis are generally interpreted as indicating no significant deviation from normality (Bachman 2004).

The KMO value, obtained prior to the EFA, was found to be 0.949, indicating sampling adequacy. The minimum acceptable KMO value for factor analysis is 0.60 (Kaiser 1974). Accordingly, the data set has a sufficient sample size for EFA (Kaiser and Rice 1974). Bartlett's test of sphericity result is meaningful. This means that the inter-item correlations are appropriate for EFA (Tabachnick and Fidell 2007: 614). Based on the results, the scale items underwent rotation, factor loadings were examined, and the principal components analysis of the scale was conducted.

In the second part of the study, CFA was conducted through the AMOS software to test and verify the factor structures obtained from the EFA. CFA is a highly developed technique that is based on testing theories about latent variables and is preferred for use in advanced research (Tabachnick and Fidell 2001). The validity of the obtained factor structures was tested using this method (Özdamar 2016). Additionally, for criterion validity, correlations were examined between the scale data and students' responses to the items 'How much do you like mathematics?' and 'How successful do you find yourself in mathematics?' rated on a scale from 0 (not at all) to 10 (very much) in the personal information form. Finally, reliability analyses of the structures obtained after both exploratory and CFA were performed. In this direction, Cronbachs' Alpha, Mc Donalds Omega and item total correlations were calculated.

3 | Findings

This section presents the results of the exploratory and confirmatory factor analyses for the Attitude towards Visual Mathematics Scale, along with the findings for criterion validity and reliability analyses.

3.1 | Findings for the EFA

To determine the construct validity of the scale, EFA was initially conducted, resulting in a single-factor structure. Table 3 presents the factor loadings of the obtained single-factor structure and the explained variance.

TABLE 3 | The structure of the sub-dimension of the Visualised Scale of Attitude towards Mathematics and the results of the EFA.

	Items	Factor ladings	Explained variance (%)
Attitude	T2	0.820	56.806
	T7	0.799	
	T1	0.798	
	T6	0.785	
	T5	0.778	
	T11	0.770	
	T4	0.768	
	T9	0.740	
	T3	0.733	
	T8	0.727	
	T12	0.726	
	T14	0.719	
	T10	0.713	
	T13	0.661	

Table 3 reveals that the scale, consisting of 14 items, exhibits a one-dimensional structure. Analysis of the factor loadings indicated that they ranged from 0.661 to 0.820. Furthermore, the 14-item one-dimensional structure was found to explain 56.806% of the total variance. Since the total variance explained is more than 50% and the factor loadings of the items are greater than 0.45, it can be said that the Visualised Scale of Attitude towards Mathematics meets the appropriate conditions for EFA (Büyüköztürk 2011). In addition, the scree plot graph given in Figure 3 also confirms the single-factor structure of the scale.

3.2 | Confirmatory Factor Analysis Results

CFA was performed for the validity of the Visualised Scale of Attitude towards Mathematics. The findings obtained as a result of the analysis are presented in detail below (Figure 4).

Upon examining the model, it was found that all standardised path coefficients were statistically significant, ranging from 0.63 to 0.85, with all path coefficients exceeding 0.40. Hair et al. (2014) reported that when item factor loadings were between 0.30 and 0.40, they met the minimum level for interpretation, when they were 0.50 or greater, they were considered significant in practice, and when they exceeded 0.70, they were indicative of a well-defined structure. Under these conditions, all factor loadings are well above the acceptable cut-off value. Upon examining the model fit indices (χ^2/df = 1.744; $p < 0.001$; RMSEA = 0.046; CFI = 0.98; TLI = 0.98; GFI = 0.95; AGFI = 0.93; NFI = 0.96; RMR = 0.031; SRMR = 0.027; IFI = 0.98), it was determined that the values indicated an excellent fit (Brown 2015; Hooper et al. 2008; Kline 2011; Schermelleh-Engel et al. 2003), leading to the conclusion that the proposed model was validated.

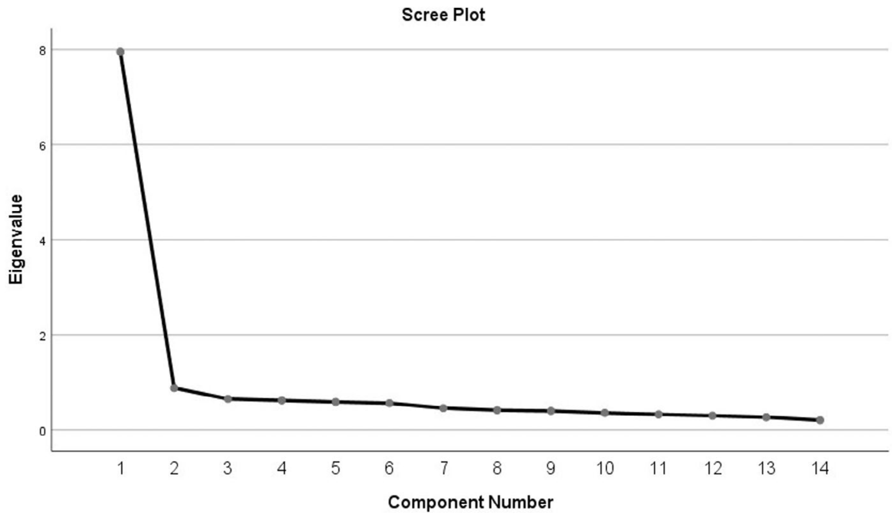

FIGURE 3 | The screeplot graph.

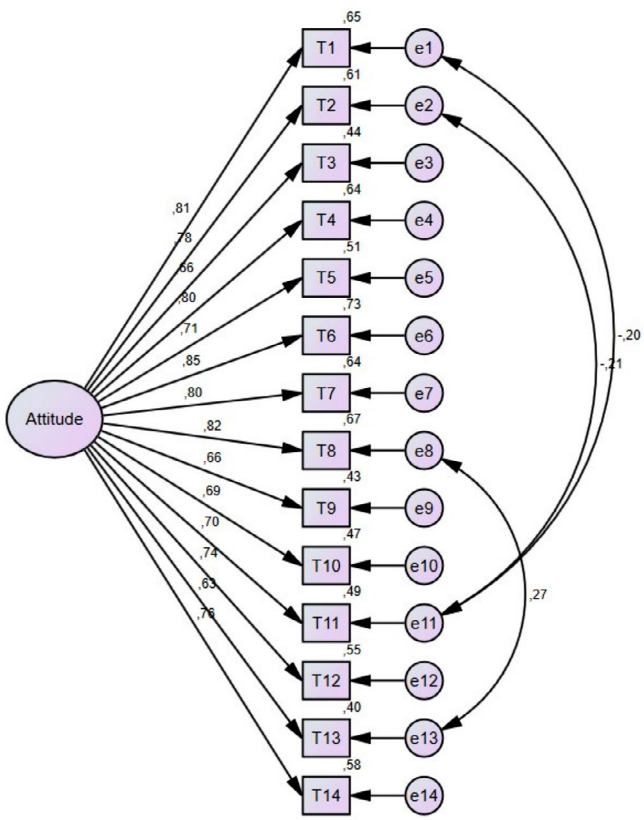

FIGURE 4 | Confirmatory factor analysis diagram for the Visualised Scale of Attitude towards Mathematics.

3.3 | The Criterion Validity Study of the Visualised Scale of Attitude Towards Mathematics

To assess the criterion validity of the scale, students were asked the questions 'How much do you like mathematics?' and 'How successful do you find yourself in mathematics?' on a scale from 0 (not at all) to 10 (very much), and the correlations between their responses and the scale scores were analysed. Positive and high correlations were found between the Visual Mathematics Attitude Scale and students' enjoyment of mathematics ($r=0.74$; $p=0.000$) as well as their self-perceived success in mathematics ($r=0.66$; $p=0.000$). Based on these results, it can be concluded that the criterion validity of the Attitude towards Visual Mathematics Scale is at a relatively high level.

3.4 | Findings Regarding the Reliability of the Scale

As part of the reliability analyses, the Cronbach's alpha value and adjusted item-total correlation values were calculated to assess the internal consistency of the scale. In addition to calculating the Cronbach's alpha value for construct reliability, it is also recommended to calculate the composite reliability (CR) value and for convergent validity, it is recommended to calculate the average variance explained (AVE) value as well as determining the factor loadings with CFA (Hair et al. 2009). Cronbach's Alpha and CR are expected to be ≥ 0.70 and AVE is expected to be ≥ 0.50 (Fornell and Larcker 1981, 39–50). The calculated internal consistency reliability values, CR value and AVE value are presented in Table 4.

According to Table 4, the Cronbach's alpha (α) value was calculated to be 0.94, while McDonald's omega value was determined to be 0.95. Since these values are greater than the acceptable value of 0.70, the scale is found to be highly reliable (Altunışık et al. 2012, 124.). Additionally, the corrected item-total correlations ranged from a low of 0.637 to a high of 0.821, significantly exceeding the minimum threshold of 0.30 (Brown 2015). Moreover, with a CR value of 0.95 and an AVE value of 0.56, it can be concluded that both internal consistency reliability and convergent validity were achieved. These results, along with others obtained thus far, demonstrate that the one-dimensional structure of the Attitude towards Visual Mathematics Scale, comprising 14 items, is a highly valid and reliable instrument.

4 | Discussion

While technological developments were initially slow in the 21st century, there is currently a rapid pace of change. There is no doubt that interest, predisposition and investment in

TABLE 4 | Reliability analysis results forVisualised Scale of Attitude towards Mathematics (after CFA).

Item	Corrected item-total correlation	Cronbach's alpha	McDonald's omega	CR	AVE
T1	0.767	0.94	0.95	0.95	0.56
T2	0.740				
T3	0.637				
T4	0.784				
T5	0.681				
T6	0.821				
T7	0.772				
T8	0.812				
T9	0.643				
T10	0.672				
T11	0.660				
T12	0.722				
T13	0.638				
T14	0.742				

mathematics play a crucial role at the core of rapid technological change. Although developed countries are keeping up with this change process more easily, developing countries have started to show more interest in mathematics-related research (Engelbrecht and Borba 2024; Leoste et al. 2022). From the perspective of sustainable development goals, early mastery of mathematics and positive student attitudes effectively combine the social, psychological and educational dimensions of mathematics, fostering a multidimensional mathematical culture. When students internalise mathematics, they can evaluate the social, ecological and economic dimensions of global development and critically address political problems (Said et al. 2024). All of these underline the importance of detecting students' attitudes about mathematics at an early age and taking precautions. Technological developments have begun to influence evaluation methods alongside their impact on mathematics education. Accordingly, Likert-type scales are reliable and practical, and in recent years, the use of emojis, visuals, or animated scales has increased in response to needs arising from digitalisation (Kılıç et al. 2021).

In this context, the primary aim of the research is to design a valid and reliable measurement tool to assess children's attitudes towards mathematics. In this study, the 'unified validity model' (Messick 1995, 1998) was employed to develop a valid and reliable measurement tool. In this model, validity is defined as 'data and information that allows us to make meaningful comments on scores or findings for a specific purpose and at a specific time' (Downing 2003, 836). Especially in measurement tools where abstract characteristics such as 'attitude' are evaluated, it is necessary to collect a large amount of evidence to ensure structural validity, that is, to interpret the scores (Cronbach 1988; Messick 1998).

Content, result, meaning, structural and factorial validity analyses were performed to ensure the structural validity and reliability of the scale. To put it another way, this study was conducted to develop a psychometrically powerful measurement tool to measure elementary school students' attitudes about mathematics and to verify this through item creation, expert evaluations, pilot studies and analyses. The validity and reliability of the scale were explained by these processes together with the results of the analysis.

The analysis process began by assessing the data's suitability for factor analysis, revealing that the missing data were not significant and followed a normal distribution. The results of the Little MCAR test showed that the lost data were random and minimal, allowing these cases to be removed from the data set. Moreover, both data sets (EFA and CFA) exhibited a normal distribution with skewness and kurtosis values within the acceptable range (±2) (Bachman 2004). This situation supports that advanced-level analyses such as EFACFA can be performed with reliable data.

The EFA results show that the scale has a robust factor structure. The KMO value of 0.949 and a significant Bartlett's test of sphericity indicated that the data set was appropriate for factor analysis (Kaiser 1974; Tabachnick and Fidell 2007). High factor loadings, ranging from 0.661 to 0.820, were identified, accounting for 56% of the total variance explained. As stated by Büyüköztürk (2011), the explanation of variance of more than 50% indicates a solid factor structure.

The CFA results confirmed the factor structure obtained from the EFA. All fit indices (X^2/SD = 1.744, RMSEA = 0.046, CFI = 0.98, TLI = 0.98, GFI = 0.95) indicate an excellent model fit (Brown 2015; Hooper et al. 2008; Kline 2011; Schermelleh-Engel et al. 2003). These results strongly support the construct validity of the scale and show that the factor structure is valid across different samples.

The criterion validity of the scale was examined by correlations between students' scale scores and their 'liking mathematics' and 'finding themselves successful in mathematics'. The obtained high and significant correlations ($r = 0.74$ and $r = 0.66$) show that the scale effectively measures students' attitudes to mathematics. These results reinforce that the scale offers significant and valid measurements.

A Cronbach's alpha value of 0.94 and a McDonald's omega value of 0.95 indicate excellent internal consistency; these values are well above the accepted limit of 0.70 (Altunışık et al. 2012). In addition, item-total correlations ranged between 0.637 and 0.821, indicating that all items contributed positively to the scale. The CR value was calculated as 0.95, and the AVE value was calculated as 0.56; these values indicate that the internal consistency reliability and convergent validity of the scale are achieved (Fornell and Larcker 1981).

In the process of developing the scale, all the items included in one dimension were examined in detail and no item was removed from the scale. Analysis of the correlations of the developed 14-item scale demonstrated that it is a suitable tool for measuring students' attitudes towards mathematics. When we look at the first studies on attitudes towards mathematics, we can see that mathematics attitude is defined by the dimensions of 'enjoyment', 'self-efficacy' and 'anxiety' (Neale 1969), 'enjoyment', 'self-efficacy', 'self-worth', 'intrinsic motivation', 'anxiety' and 'moral judgement' (Aiken 1970, 1972) and 'enjoyment', 'self-efficacy', 'intrinsic motivation' and 'anxiety' (Blackweir 2016; Fennema and Sherman 1976).

In studies examining attitudes towards mathematics, the fact that measurement tools are not organised according to the contexts, age groups, interests and cultures to be measured prevents accurate results. When evaluating attitudes towards mathematics, it is necessary to proceed meticulously in accordance with the principles of scale development (Blackweir 2016). To assess the mathematical attitudes of elementary school students, the GMTAS scale is a measurement tool with good psychometric properties that has been designed with visuals in accordance with the interests of students (McCulloch 2019), their culture (Kleine et al. 2016) and the requirements of the age (Kılıç et al. 2021) and has been developed by collecting a large number of pieces of evidence for construct validity (Cronbach 1988; Messick 1998).

The scale developed in this study fills the gaps left by existing instruments in several ways. Firstly, the visual structure can better direct the perception and attention of young students. Secondly, the design of the scale builds a bridge between mathematics education and cultural elements, allowing students to evaluate mathematics in a more meaningful context. This approach is in line with Robertson and Graven (2020) and Thomas et al. (2024) who suggest that quality mathematics education cannot be considered independent of cultural contexts.

The developed Visualised Mathematics Attitude Scale is a unique tool that assesses both students' attitudes towards mathematics and their interaction with cultural context. The appropriateness of the scale to cultural contexts not only increases the interest of students but also provides more valid and reliable data for educational research. In this context, the enriched structure of the scale with cultural elements contributes to a more inclusive mathematics education.

The Visualised Mathematics Attitude Scale is not only limited to measuring students' attitudes towards mathematics, but also has the potential to be adapted for use in different contexts and cultures. Since the visual elements of the scale were designed with cultural appropriateness and familiarity in mind, reconfiguring these elements in different geographical and cultural contexts can increase the validity of the scale. For example, replacing local figures such as 'Keloğlan' with figures recognised and loved in other cultures may increase students' interest and connectivity to the scale.

In this study, the survey model was preferred; however, with the use of longitudinal methods or mixed designs, students' attitude changes over time can be examined more comprehensively. Longitudinal studies can also be conducted to understand the long-term effects of students' cultural differences.

In addition, integrating the scale with educational technologies can support its applicability in digital learning environments. For example, the use of animated visuals and digital response systems can make the measurement process more interactive and accessible. This will allow the scale to be used effectively not only in traditional classroom settings but also in online education processes.

In order to apply this scale effectively, a short orientation training for the researchers who will apply the scale before the application can ensure the correct and effective use of visual elements. In order to minimise the effect of students' perceptual and cultural differences on the research results, it is recommended to conduct a pilot study before the application. These recommendations will support the effective and comprehensive application of the scale and will enable more inclusive and meaningful results to be obtained in mathematics education.

One of the biggest obstacles encountered in the dissemination of culturally responsive practices in mathematics stems from the political structure of education (Sleeter 2012). Therefore, implementing a mathematics teaching approach that takes into account cultural contexts and is sensitive to the different learning needs of students should be one of the main goals of mathematics education (Abdulrahim and Orosco 2020).

Educational policy makers, teacher educators, professional development specialists and researchers should focus on training teachers who are equipped to effectively integrate cultural contexts into the mathematics learning process. Such an approach not only increases academic achievement but also transforms mathematics education into a more inclusive and meaningful structure by including students' individual and social identities in the learning process.

4.1 | Limitations

The results of the study show that the developed attitude scale is usable, reliable and quite acceptable. Construct validity was provided by the mutual correlations of the scale items, item-total correlations, EFA and CFA. However, our sample consisted primarily of elementary school students selected from a specific geographical region and institution, which potentially limits the generalisability of our findings to a more diverse population. In addition, since primary school education in our country is 4 years and these years cover the age range of 7–10 years, the possibility of conducting the research in higher age groups is presented as another limitation.

In this study, although the diversity of the socioeconomic groups from which the data were collected was ensured, the fact that the participants were only from a certain city is a limitation in terms of generalisability. In addition, the differences in the understanding of the visuals by the students were taken into consideration during the application process of the scale. Therefore, it was accepted as a limitation that the meaning of the visuals and expressions should be tested on larger groups in a cultural context.

Ethics Statement

Necessary permissions were obtained in accordance with the letter of Aksaray University Ethics Committee dated 27.05.2024 and numbered E-57528460-755.02.01-00000948828 and the letter of Aksaray Provincial Directorate of National Education numbered E-76490249-605.01-103391839.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The datasets analyzed during the current study are available from the corresponding author upon reasonable request.

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