Journal of Pedagogical Research
Volume 10, Issue 1, 2026
https://doi.org/10.33902/JPR.202640354

Research Article

The mediating and moderating role of mathematical problem-solving skills in the relationship between primary school students' number sense and mathematics self-efficacy

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The present study analyzed the mediating and moderating role of mathematical problem-solving skills in the association between number sense and mathematics self-efficacy of primary school students. The present study employed the relational survey model, a quantitative research method, and utilized structural equation modeling for analysis. The study's sample group consisted of 307 fourth-grade primary school students. The Number Sense Test, the Mathematics Self-Efficacy Scale, and the Mathematical Problem Solving Scale were utilized as data collection instruments. The study's findings indicated a positive and significant relationship between number sense, mathematical problem solving, and mathematics self-efficacy among primary school pupils. The study indicated that students' mathematical problem-solving skills mediated between number sense and mathematics self-efficacy. The study demonstrated that number sense, mathematical self-efficacy, and problem-solving abilities are positively interrelated, highlighting the need for instructional designs and teacher training programs that integrate authentic, real-life problem-solving experiences to strengthen these interconnected skills in mathematics education. These findings suggest that integrating number sense development with structured problem-solving experiences may support students' confidence in mathematics. Such instructional approaches may contribute to strengthening interconnected mathematical competencies in primary education.

Keywords: Mathematical problem solving; Mathematics self-efficacy; Number sense; Structural equation modeling

Article History: Submitted 29 October 2025; Revised 2 March 2026; Published online 14 March 2026

1. Introduction

The capacity to solve mathematical problems is a fundamental competency that is closely related to an individual's ability to analyze and develop solutions to complex situations encountered in academic and everyday contexts. Individuals who have cultivated a proficiency in numerical analysis and can adroitly discern the relationships between numerical values can formulate more efficacious solutions to problems that demand strategic thinking and mathematical reasoning (Mohamed & Johny, 2010; Sierra, 2023; Yang & Wu, 2010). Mathematics self-efficacy refers to an individual's confidence in their ability to perform mathematical tasks successfully, and this

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How to cite: Filiz, T. & Kılıç, Z. (2026). The mediating and moderating role of mathematical problem-solving skills in the relationship between primary school students' number sense and mathematics self-efficacy. *Journal of Pedagogical Research, 10*(1), 328-348. https://doi.org/10.33902/JPR.202640354

confidence is closely associated with students' motivation, persistence, and performance during problem-solving processes (Kriegbaum et al., 2015; Zou, 2025). A comprehensive understanding of the interactions among these three components is essential for designing pedagogical interventions to support skill development in mathematics education. This research endeavor addresses this lacuna in the extant scholarship by elucidating the relationships between number sense, mathematics self-efficacy, and mathematical problem solving. To this end, the study employs structural equation modeling as a methodological framework.

Given the efficacy of cognitive and affective processes in influencing mathematics achievement, it is essential to holistically evaluate the factors that contribute to this outcome (Hannula, 2020). Although mathematics anxiety, an affective factor, has been associated with lower mathematics achievement, higher levels of motivation are positively associated with improved performance (Shimuzu, 2025). As demonstrated in the existing literature, factors such as mathematical problem-solving skills (Hilbert et al., 2019), numeracy (Jordan et al., 2010; Waldera, 2018), and mathematics self-efficacy (Parker et al., 2014; Shimizu, 2025; Zou & Mustakim, 2024) are positively associated with students' mathematics achievement. Furthermore, number sense, which has been identified as the foundation of advanced problem-solving skills (McIntosh et al., 2005), has been shown to enhance mathematical problem-solving skills (Geary, 2012). A separate study reported that mathematical problem-solving competencies are positively associated with students' mathematics self-efficacy (Ma et al., 2021).

1.1. Number Sense

Developing number sense is critical in acquiring mathematical competencies (Mazzocco et al., 2011) and attaining success in mathematics (Geary et al., 2009; Sarı & Olkun, 2021). Number sense is defined as a cognitive ability comprising several key components, such as the comprehension of numerical values, their magnitude, and the relationship between them (Yang, 2005), the ability to think flexibly and fluidly when engaging with numerical operations (Dehaene, 2020), the capacity for estimation, quantitative reasoning, and inference (Greeno, 1991). The capacity for number sense, which is posited to be an innate biological faculty (Dehaene, 2020; Testolin et al., 2020), can be influenced by environmental factors and cultivated through education (Kondapaneni & Perona, 2024; Zhou et al., 2022). Numerical competence starts to develop with the inborn Approximate Number System, which enables individuals to roughly estimate the quantity of items in a set (Wang et al., 2017). The fundamental number-related aptitudes acquired during early childhood, grounded in innate numerical abilities, are delineated as Early Number Sense. Mature Number Sense, as defined by Whitacre et al. (2020), refers to the framework that evolves from early numerical skills and continues to develop through adulthood, incorporating mental computation, strategic flexibility, and the ability to choose appropriate methods for solving problems. The present study focused on early number sense [ENS], the ability to understand and manipulate numerical concepts, which can be cultivated through instruction in number sense components with varying qualities.

Cultivating individuals' number sense is paramount to devising solutions to problems related to numbers encountered in all areas of daily life (Maghfirah & Mahmudi, 2018). Number sense is critical for individuals to comprehend mathematics (Kaminski, 2002), which is significant in their overall educational experience, fostering success in this discipline and cultivating mathematical thinking skills. The primary school period is considered a pivotal stage for students to cultivate a sense of numerical proficiency (McGuire et al., 2012). In this period, a shift from rote formulas and rule-based strategies (Huang & Yang, 2018; Yang et al., 2008) towards meaningful mathematical thinking processes (Berch, 2005) has been observed to enhance students' current performance (Zhou et al., 2022) and support their long-term mathematical achievement (Jordan et al., 2007).

Individuals who demonstrate an advanced ability in quantitative reasoning tend to excel in perceiving quantitative information and generating flexible solutions to their problems (Gersten et al., 2005; Mohamed & Johny, 2010). Furthermore, these individuals develop positive attitudes toward mathematics (Galloza, 2025). Studies in the literature suggest a connection between number sense, mathematics self-efficacy, and the ability to solve mathematical problems (Jordan et al., 2010; Zhou et al., 2022). Number sense, recognized as a vital element of mathematics education, is strongly and significantly linked to students' problem-solving skills (Gürkan, 2023; Lemonidis & Kaiafa, 2014; Mutmainnah et al., 2021). It has been posited that individuals who possess a high degree of sense tend to exhibit greater adaptability in their problem-solving approach, demonstrating a proclivity for employing diverse strategies in their cognitive process (Huang & Yang, 2018). Research has indicated that people with strong number sense tend to display high levels of mathematics self-efficacy, and a moderately significant correlation exists between these two variables (Birol & Şengül, 2025; Şengül & Gülbağcı, 2013; Takır, 2016).

1.2. Mathematical Problem Solving

Mathematics, a field that demands rigorous problem-solving and logical reasoning, encourages students to employ an interdisciplinary approach to problem-solving (Rong & Wimuttipanya, 2025). Problem-solving is an instructional strategy that actively involves students in solving problems, thereby developing their problem-solving skills (Olivares et al., 2021). Concurrently, problem-solving capabilities are essential to effectively acquiring mathematical competencies (Schoenfeld, 1985). Problem solving encompasses not only the application of specific steps by rote but also the meticulous analysis of problems, the formulation of logical strategies, the execution of these strategies, and a critical evaluation of the solution (Arfé et al., 2020). The problem-solving process is characterized by a series of steps, beginning with comprehending the problem. It is followed by exploring various strategies, leading to the selection of the most suitable one. The preparation of a plan conducive to flexible thinking is then initiated. Implementing the aforementioned plan is followed by evaluating the process (Polya, 2014).

It has been established that problem-solving contributes to the development of critical thinking skills, which are considered to be a component of metacognitive abilities (Almasarweh & Khudairat, 2021). Furthermore, previous research has shown that self-regulation skills are positively associated with problem-solving abilities (Popham et al., 2019). Similarly, problem-solving abilities have been found to be positively related to mathematics self-efficacy (Ma et al., 2021) and academic achievement (Rong & Wimuttipanya, 2025). Problem-solving competence plays a central role in applying mathematical knowledge to novel situations and may shape how cognitive skills translate into affective outcomes such as self-efficacy (Bandura, 1997; Schoenfeld, 2007). In a study conducted by Özcan et al. (2019), motivation and mathematics anxiety were found to be indirectly associated with mathematical problem-solving performance through mathematics self-efficacy. The present study suggests that problem solving enhances motivation in the learning process, thereby mitigating anxiety and facilitating the enhancement of mathematical reasoning abilities (Supriadi et.al., 2024). As posited by scholars, utilizing student-centered constructivist methods, incorporating discussion and group work, is a pivotal factor in cultivating problem-solving skills (Çibukçiu, 2025). Incorporating real-life scenarios is further emphasized, with scholars suggesting their presentation to foster authentic problem-solving experiences (Olivares et al., 2021; Torres-Pena et al., 2025). Additionally, the integration of digital technology is proposed by researchers as a means to enhance learning and engagement, particularly in virtual learning environments (Santos-Trigo et al., 2019). The capacity for number sense has been demonstrated to facilitate the generation of diverse and adaptable solutions during the problem-solving process (Yang & Wu, 2010), enhance operational fluency, and promote the development of problem-solving skills (Sierra, 2023; Tuğrul-Kalaç, 2023). Conversely, the development of problem-solving skills has been found to contribute to mathematics self-efficacy (DiNapoli & Miller, 2022; Liu et al., 2021).

1.3. Mathematics Self-efficacy

Mathematics self-efficacy is defined as an individual's belief in their own mathematical abilities. More broadly, self-efficacy involves the belief in one's capacity to accomplish a goal, even when faced with potential challenges along the way (Bandura, 1997). Bandura, in his Social Cognitive Theory [SCT], emphasizes the influential role of self-efficacy in shaping individuals' lives, noting that it affects how people construct their thoughts, make decisions, and invest effort in pursuing their goals (Bandura, 2006). Self-efficacy is closely related to whether individuals believe they can complete a task and to the level at which they perform it (Skaalvik & Skaalvik, 2017). The correlation between self-efficacy and job performance has significantly predicted motivation in various contexts (Bandura, 1986).

Self-efficacy is an important affective characteristic associated with students' academic achievement and the quality of mathematics instruction (Usher, 2009). According to Bandura's SCT, perceived self-efficacy develops through a blend of mastery experiences, observing others' successes, social encouragement and feedback, as well as emotional and psychological factors (Bandura, 1986). Experiences are identified as a primary source associated with mathematics self-efficacy (Street et al., 2024). Mathematics self-efficacy is shaped through experiences and environmental contexts (Hendricks, 2014). Therefore, individuals' mathematics efficacy can be elevated by incorporating metacognition strategies in educational pursuits (Al-Momani, 2024). Solving a problematic issue by students is conducive to attaining mastery in problem-solving skills, thereby contributing to the development of their self-efficacy (Du et al., 2021; Liu et al., 2021). Students with high mathematical problem-solving abilities also tend to exhibit high mathematics self-efficacy (Kamalimoghaddam et al., 2016). Put simply, an individual's ability to understand and solve mathematical problems is closely related to their confidence in managing such problems, which reflects their level of self-efficacy (DiNapoli & Miller, 2022; Manzano-Sanchez et al., 2018). Current research consistently shows a strong and positive correlation between mathematics self-efficacy and mathematical achievement (Kriegbaum et al., 2015), mathematics learning motivation (Zou, 2025), academic achievement (Shimuzu, 2025; Zou, 2025), and number sense (Al-Momani, 2024; Birol & Şengül, 2025).

1.4. The Relationship between Mathematical Self-efficacy, Mathematical Problem Solving and Number Sense

Many cognitive and affective factors have been found to be associated with mathematics performance (Hannula, 2020; Schukajlow et al., 2019). The present study examines how mathematical problem-solving (Olivares et al., 2021; Rong & Wimuttipanya, 2025) and number sense (Yang et al., 2004), as cognitive factors related to mathematics performance, are associated with students' mathematics outcomes. We also examined the relationship between self-efficacy and the study variables (Kriegbaum et al., 2015; Usher, 2009), which is an affective factor, on mathematics performance. The aim of this study was to examine the theoretical relationship between these variables based on Bandura's Social Cognitive Theory. Bandura's SCT underscores the interplay between environmental factors, individual beliefs, and behaviors. This theoretical framework elucidates the phenomenon of individuals' belief in their capacity to cope with a given situation through the conceptualization of self-efficacy, underscoring its pivotal role in the learning processes of individuals (Bandura, 1986). Self-efficacy is positively associated with academic performance (Talsma, 2018; Zou & Mustakim, 2024). As posited by Street et al. (2024), individuals who grapple with challenging problems tend to allocate more effort toward problem-solving. This occurrence is likely linked to their level of mathematics self-efficacy. This heightened effort often culminates in superior problem-solving outcomes, characterized by an absence of trepidation regarding potential errors (Street et al., 2024).

Another variable that has been examined in the study is number sense. This capacity for number sense transcends mere formulas and rules, where numerical operations are mechanically executed. Instead, it encompasses a high degree of flexible thinking in numerical contexts (Dehaene, 2020). This ability is a fundamental foundation for developing numerous mathematical competencies (Mazzocco et al., 2011). Studies have identified a connection between strong numerical skills and higher achievement in mathematics (Yang et al., 2008). The possession of a developed number sense by individuals is conducive to producing more rational and adaptive resolutions to the challenges they confront, thereby fostering the enhancement of their problem-solving abilities. Furthermore, it is hypothesized that the successful experiences obtained will positively affect the individual's self-efficacy perception. In this context, number sense is directly related to an individual's ability to process numbers in mathematics. Mathematics self-efficacy, in contrast, is related to an individual's motivation to use his or her existing knowledge. While number sense fosters students' capacity for problem-solving by encouraging the development of flexible and varied strategies, self-efficacy enhances the efficacy of this process and ensures its sustainability. In conclusion, the findings suggest that both variables are directly and indirectly related to mathematical problem-solving skills. In this study, structural equation modeling was used to examine the direct and indirect relationships among number sense, mathematical problem solving, and mathematics self-efficacy. This approach allows for the examination of the pathways through which number sense and problem-solving skills are associated with mathematical self-efficacy. It also enables the testing of the hypothesized relationships among these variables and provides a statistical assessment of the strength of these associations.

H1: The correlation between elementary school students' number sense and their self-efficacy about mathematics is positive and statistically significant.

Individuals who possess number sense are capable of formulating numerous solutions to a given dilemma, obviating the need for a rigid formulaic approach or a process that necessitates the adherence to a sequence of operations, and these individuals can employ these solutions with a high degree of flexibility (Gersten et al., 2005; Gülbağcı-Dede & Şengül, 2016). As individuals with high number sense demonstrate superior aptitude in mathematics (Akyar, 2023; Gökçe et al., 2023; Yakut, 2020), their self-efficacy is often bolstered by these experiences. The strong positive correlation between mathematics achievement and number sense, coupled with the understanding that mathematics self-efficacy significantly predicts number sense, highlights a potential relationship between these constructs that merits investigation in this study. In the contemporary international mathematics curriculum landscape, a marked emphasis is placed on cultivating 21st-century competencies, including problem-solving and numerical aptitude skills.

H2: Mathematical problem-solving skills were found to play a significant mediating role in the relationship between number sense and mathematics self-efficacy among primary school students.

In addition to its mediating role, mathematical problem-solving competence may function as a conditional factor influencing how numerical understanding is translated into students' confidence in mathematics. From a self-efficacy perspective (Bandura, 1997), students develop confidence through successful task engagement and cognitive mastery experiences. Students with stronger problem-solving competence may be better able to utilize their number sense in complex situations, potentially strengthening the relationship between numerical understanding and self-efficacy beliefs. Conversely, limited problem-solving competence may constrain students' ability to apply numerical knowledge effectively, weakening this relationship. Given that problem-solving skills are still developing during the primary school years, examining their potential moderating role may help clarify boundary conditions under which number sense relates to mathematics self-efficacy.

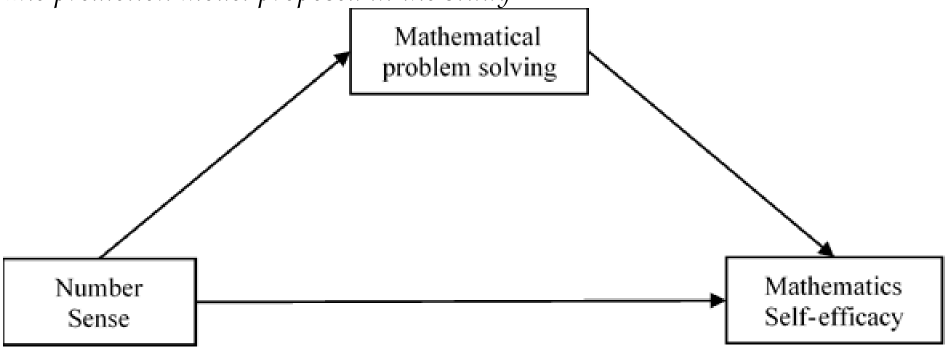
H3: Mathematical problem-solving skills were found to significantly moderate the association between number sense and mathematics self-efficacy among primary school students.

Primary school, recognized as a pivotal stage in education (McGuire et al., 2012), is a crucial period for identifying the factors influencing students' number sense, mathematics self-efficacy, and problem-solving abilities. By elucidating these relationships, we can enhance the effectiveness and efficiency of educational processes, thereby ensuring the optimal development of students' mathematical abilities. Accordingly, it is hypothesized that examining the mediating and moderating roles of mathematical problem-solving skills in the relationship between number sense and mathematics self-efficacy among primary school students will contribute to a better understanding of their mathematical competencies and help address an important gap in the literature. Moreover, the research study's findings are expected to offer significant insights to inform the development of effective educational processes and environments. These novel approaches are anticipated to foster the growth of students' number sense, problem-solving abilities in mathematics, and confidence in their mathematical abilities within the context of teaching mathematics.

1.5. Hypotheses Tested in the Study

This study aimed to investigate the mediating and moderating roles of mathematical problem-solving skills in the relationship between number sense and mathematics self-efficacy among primary school students. Within this framework, the model illustrated in Figure 1 was thoroughly tested.

Figure 1
The prediction model proposed in the study



2. Method

2.1. Research Design

This study was designed using a relational survey model, a quantitative research method. Such models offer the opportunity to reveal the relationship between two or more variables, determining the direction and strength of this relationship (Fraenkel et al., 2014). The significance of such studies lies in their capacity to facilitate future-oriented predictions. However, due to their relational nature, they do not reveal direct causal relationships. It should therefore be noted that advanced analytical methods, such as structural equation modelling [SEM], allow researchers to examine theoretically hypothesized relationships among variables (Kline, 2023). SEM is a comprehensive analytical method used to investigate structural relationships among variables within a proposed theoretical model. It is also used to test hypothesized relationships and to examine the strength and direction of associations among variables. SEM is widely used in social sciences because of several advantages, including its ability to evaluate different model structures, examine multiple relationships simultaneously, and assess the consistency of a theoretical model with the observed data (Kline, 2023). This study employed a relational survey model and used SEM to examine the mediating and moderating roles of mathematical problem-solving skills in the relationship between number sense and mathematics self-efficacy among fourth-grade primary school students.

2.2. Participants

This study employed a cluster sampling method to select the sample. This methodology involves randomly selecting a sample from one or more units and assigning participants from these units (Creswell, 2018). Within this design, schools were defined as the primary sampling clusters and fourth-grade classrooms within those schools constituted the secondary units. The cluster sampling method was deemed appropriate for reaching geographically dispersed participants and improving feasibility within the study's logistical constraints. The sampling frame consisted of public primary schools listed by provincial directorates of the Ministry of National Education.

Seven provinces representing different geographic regions of Türkiye were included to increase contextual diversity. From each province, five public primary schools were randomly selected from the accessible school list, and all fourth-grade students in the selected classrooms were invited to participate. This approach was intended to capture variability in educational contexts rather than to produce a nationally representative sample. The investigators visited the designated schools and administered the instruments face-to-face. Data collection was completed over three consecutive school days, and the instruments were administered in separate sessions to reduce response fatigue. Participation was voluntary, and students could opt in or out of the study. The final sample consisted of 307 fourth-grade students enrolled in public primary schools in Türkiye. The sample size (N = 307) meets commonly recommended thresholds for structural equation modeling and is considered adequate for reliable parameter estimation and model testing (Kline, 2023; Wolf et al., 2013). The demographic composition of the sample was as follows: 184 participants (58.5%) were female and 123 (41.5%) were male. The participating schools included urban and semi-urban settings and served students from varied socio-economic backgrounds, thereby providing contextual diversity. However, because the number of participants per province was modest, the sample should not be considered regionally representative. As students were nested within schools, responses may reflect shared contextual influences. Although clustering effects were not modeled analytically, this potential dependency should be considered when interpreting the findings.

The researchers informed potential participants about the duration of the study, its purpose, how confidentiality would be ensured, and that participation was voluntary. Participants were assured that they could withdraw from the study at any time and that their decision to participate in the research would not affect their academic status. Written informed consent was obtained from all participants before the start of the study. In addition, parental or legal guardian consent was obtained for participants under 18. Every stage of the research was completed with priority given to ethical principles. The research protocol has been approved by the ethics committee of which the corresponding author is a member. All participant data was coded with identity information concealed, stored securely, and used solely for this research.

2.3. Instruments and Data Collection

The present study employed three distinct instruments to gather the empirical data: the Number Sense Test [NST], the Mathematical Problem Solving Scale [MPSS] and the Mathematics Self-Efficacy Scale [MSS]. This section introduces the scales employed and the findings of each scale's validity and reliability analyses. To reduce the risk of common method bias, participants were assured of anonymity and confidentiality and were informed that there were no right or wrong answers.

2.3.1. Number Sense Test

The Number Sense Test, developed by Palabıyık and Işık-Tertemiz (2021), will be used to evaluate the number sense abilities of Year 4 primary school students. The NST for fourth-grade students comprises 24 items, with a KR-20 reliability coefficient of 0.817. The test had a mean discrimination index of 0.45, and a mean item difficulty index of 0.66. Therefore, the test appears to have an acceptable/average level of difficulty and excellent discrimination (Kumar et al., 2021). The NST content includes questions related to components of number sense, such as number and operation skills, understanding numbers, flexible calculation, counting strategies and measurement references. In the context of this study, a re-examination of the scale's reliability was undertaken. As a result of this analysis, the KR-20 coefficient indicating internal consistency for the entire scale was found to be .80. This reliability coefficient indicates that the scale is a valid and reliable measurement tool.

2.3.2. Mathematical Problem Solving Scale

Mathematics Problem-Solving Scale is a standardized instrument designed to assess the mathematical problem-solving skills of fourth-grade primary school students. The scale in question consists of 16 items and three factors developed for primary school students (Değirmenci & Deringöl, 2024). The scale is composed of three factors: The following topics will be examined: first, self-evaluation in problem-solving, second, problem-solving knowledge, and third, metacognition in problem-solving. The scale items are meticulously arranged into a 5-point Likert scale, encompassing categories such as "Always," "Frequently," "Occasionally," "Rarely," and "Never." The item factor loadings of the scale, which is comprised of three factors, range from 0.39 to 0.75. The maximum attainable score on the scale is 80, while the minimum is 16. The scale is not designed to accommodate reverse coding. However, the confirmatory factor analysis [CFA] conducted to assess the scale's model fit revealed the scale's three-factor structure to be substantiated. Additionally, the fit indices obtained were reported to be satisfactory (χ^2/df=2.225, RMR=0.077, CFI=0.923, RMSEA=0.080, GFI=0.913, and AGFI=0.914). The researchers calculated the Cronbach Alpha coefficient for each scale sub-dimension as .85, .84, and .75, respectively. The scale includes items such as "I plan how I can solve the problem after reading the problem" and "I think about how I solved previous problems while solving problems." The scale's reliability analyses were conducted again in this study's context. According to the results obtained, the Cronbach Alpha internal consistency coefficient for the entire scale was determined to be .86, and the Guttman Split Half coefficient was found to be .81. These analyses substantiate the validity and reliability of the scale.

2.3.3. Mathematics Self-efficacy Scale

Mathematics Self-efficacy Scale evaluated the self-perceived mathematical abilities of Year 4 primary school students. The MSS, a multifaceted construct encompassing three factors (attitude, practice, and motivation) and 13 items, was developed by Karalı and Coşanay (2022). It can be argued that this scale is a valid and reliable instrument for measuring elementary school students' levels of self-efficacy in mathematics. The scale items are organized as "Never," "Sometimes," and "Always" on a three-point Likert scale—the calculated item factor loadings of the scale range from 0.58 to 0.82. Conversely, confirmatory factor analysis revealed the scale's model fit. The results of the analyses yielded the following values, which indicate excellent fit: χ^2/df=1.33, NFI=0.95, NNFI=0.98, IFI=0.99, CFI=0.99, GFI=0.95, AGFI=0.93, RMR=0.016, RMSEA=0.036. The RFI=0.94 and SRMR=0.046 values were reported to be at an acceptable fit level. The researchers subsequently calculated the Cronbach Alpha coefficient for each scale sub-dimension (attitude, practice, and motivation) as .79, .71, and .63, respectively. Although the Cronbach's alpha coefficient for the motivation sub-dimension was slightly below the conventional .70 threshold (α = .63), reliability coefficients between .60 and .70 may be considered acceptable in exploratory research and in scales with a limited number of items (Hair et al., 2014). In addition to Cronbach's alpha, McDonald's omega (ω) coefficient was calculated to provide a more comprehensive estimate of internal consistency. The omega value for the motivation sub-dimension was found to be 0.72, which exceeds the recommended threshold of 0.70 and indicates acceptable reliability. Taken together, these results suggest that the motivation sub-dimension demonstrates adequate internal consistency for the purposes of the present study. To further evaluate measurement quality, confirmatory factor analysis results supported the factorial structure of the scale, indicating that the items adequately represented the intended construct. Because lower reliability can attenuate observed relationships, measurement error was accounted for within the SEM framework through the use of latent variables, which partition true score variance from measurement error (Kline, 2023). The reliability coefficient for the entire scale was documented as 0.84. In the course of this study, the reliability analysis of the scale was conducted once more. The results obtained from this analysis indicated that the Cronbach Alpha internal consistency coefficient for the entire scale was .76, and the Guttman Split-Half coefficient was .75. These results provide evidence supporting the scale's validity and reliability.

2.3.4. Procedure

Prior to the collection of data, the requisite permissions were obtained from the relevant school principals and classroom teachers. The students participating in the study were included voluntarily. Participants completed the Problem-Solving and Mathematics Self-Efficacy Scales in the initial data collection phase. Subsequently, the NST was administered to the students to assess their number sense performance. The researchers administered the data collection tools to the students over three class hours (120 minutes), which were held on separate days. The number of sense performances of the students was collected by two independent researchers who analyzed their answers to the NST, coding correct answers as one and incorrect answers as 0. Inter-rater reliability was determined by calculating Cohen's Kappa coefficient. In this specific context, the reliability was calculated to be .93.

2.3.5. Data Analysis

Because the data in the present study were collected using self-report instruments, the potential influence of common method bias [CMB] was carefully considered. Following the recommendations of Podsakoff et al. (2003), several procedural remedies were implemented during the data collection process to reduce the likelihood of method bias. Participants were assured of the anonymity and confidentiality of their responses and were informed that there were no right or wrong answers. These precautions were intended to minimize evaluation apprehension and social desirability bias. In addition to these procedural measures, statistical techniques were employed to assess potential common method variance. As a preliminary diagnostic, Harman's single-factor test was conducted. Furthermore, to provide a more robust examination of potential method bias, a Common Latent Factor [CLF] approach was applied within the structural equation modeling framework (Podsakoff et al., 2012). In this procedure, a latent factor representing potential method variance was incorporated into the measurement model, allowing all observed indicators to load on both their theoretical constructs and the common latent factor.

The data analysis began with the calculation of Cronbach's alpha coefficients to assess the internal consistency of each scale. The results indicated satisfactory reliability levels, suggesting that the scales were appropriate for use in the study. Following reliability assessment, normality was examined. Skewness and kurtosis values were inspected to assess univariate normality, and the obtained values fell within acceptable ranges (Hair et al., 2014). Kolmogorov–Smirnov test results also indicated conformity with univariate normal distribution assumptions. Multivariate normality was evaluated using Mahalanobis distance and Mardia's skewness and kurtosis statistics, and the results supported the assumption of multivariate normality. Pearson correlation coefficients were computed to examine the relationships among number sense, mathematical problem solving, and mathematics self-efficacy. The magnitudes of the correlations were interpreted according to Cohen's (1988) criteria, which classify effect sizes as small (r = .10), medium (r = .30), and large ($r \geq$ .50). Internal consistency reliability was further evaluated using Cronbach's α coefficients. In accordance with the recommendations of Kline (1999) and Nunnally and Bernstein (1994), coefficients of .70 and above were considered acceptable.

Confirmatory Factor Analysis [CFA] was conducted to evaluate the factorial structure of the scales. The DWLS estimation method was preferred because the instruments consisted of Likert-type ordinal items and the sample size was moderate (n = 307) (Flora & Curran, 2004; Li, 2016). Model fit was evaluated using multiple indices, including CFI, TLI, RMSEA, and SRMR. Based on the criteria suggested by Hu and Bentler (1999), model fit was considered acceptable when CFI and TLI values exceeded .90 and RMSEA and SRMR values were .08 or lower. Additionally, the χ^2/df ratio was examined, with values below 3 indicating acceptable fit.

In the structural model of this study, mathematical problem solving was proposed to be the mediating variable (M) of the relationship between number sense (X) and mathematics self-efficacy (Y) (see Figure 1). In this context, Hayes' Process Macro was used to test parallel mediation models, and Model 4 was preferred in the analyses. In order to examine the extent to which the relationship between number sense and mathematics self-efficacy is mediated by mathematical problem solving, a bootstrap method with 5,000 samples was applied (Hayes & Preacher, 2014). Additionally, the Kappa square (K^2) with a 95% bootstrap confidence interval was calculated to estimate the magnitude of the indirect effect.

3. Findings

3.1. Common Method Bias

The results of Harman's single-factor test indicated that the first unrotated factor accounted for 16.20% of the total variance, which is well below the commonly suggested threshold of 50%. This finding suggests that common method bias is unlikely to represent a serious threat to the validity of the results. In addition, the comparison between the standardized factor loadings of the original measurement model and those of the model including the common latent factor revealed minimal differences, all remaining below the recommended threshold of 0.20. Moreover, the model fit indices of the CLF model were comparable to those of the original model. These findings indicate that common method variance did not substantially influence the parameter estimates or the relationships examined in the study.

3.2. The Correlations between Number Sense, Mathematical Problem Solving, and Mathematics Self-efficacy

The relationships among primary school students' number sense, mathematical problem-solving skills, and mathematics self-efficacy were analyzed using the Pearson product-moment correlation coefficient. An examination of the relevant literature reveals analogous findings outlined in Table 1.

Table 1
Pearson Product-Moment Correlation Coefficients between the Variables.

Variable	*Bivariate Correlation*			*Descriptive Statistics*			
	1	*2*	*3*	*Mean*	*SD*	*Skewness*	*Kurtosis*
1. Number sense	-	0.28**	0.41**	16.61	4.44	−0.95	0.85
2. Mathematical problem solving		-	0.61**	59.63	11.22	−0.19	−0.64
3. Mathematics self-efficacy			-	30.65	4.23	−0.84	1.05

Note. **$p < .01$

Upon examination of Table 1, it becomes evident that the skewness (range = −0.19 and −0.95) and kurtosis (range = -0.64 and 1.05) values are found to fall within the "good" range of the normal distribution (Hair et al., 2014). The findings of the correlation analysis indicate a statistically significant positive relationship between number sense and mathematical problem-solving skills in primary school students ($r = .28$, $p < .01$). Additionally, a positive and significant relationship was identified between students' number sense skills and their mathematics self-efficacy ($r = .41$, $p < .01$). Furthermore, a substantial and positive correlation was identified between students' mathematical problem-solving abilities and their mathematics self-efficacy ($r = .61$, $p < .01$). By these findings, it can be posited that there exist statistically significant and moderate correlations between all variables in the study (Cohen, 1988).

3.3. The Mediating Role of Mathematical Problem-solving Skills in the relationship between Number Sense and Mathematics Self-efficacy

The findings concerning the analysis of the direct relationship between elementary school students' number sense and mathematics self-efficacy, as well as the indirect relationships observed through mediating variables, are presented in Table 2.

Table 2
The role of problem-solving skills in the relationship between number sense and mathematics self-efficacy

Variable		*Outcome variable*					
		M (MPSS)					
		Coeff.	*SE*	*t*	*p*	*95% Confidence Interval*	
						Lower	Upper
Constant	i_{M1}	47.90	2.39	20.06	< .001	43.20	52.60
X (NST)	*A*	0.71	0.14	5.09	< .001	0.43	0.98
		$R^2 = 0.08$ $F = 25.83$; p <.001					
		Y (MSS)					
Constant	i_y	14.55	1.08	13.46	< .001	12.42	16.67
X (NST)	*c*'	0.25	0.04	5.82	< .001	0.17	0.33
M (MPSS)	*B*	0.20	0.01	11.78	< .001	0.17	0.23
		$R^2 = 0.42$ $F = 114.45$; p <.001					

Note: The bootstrap sample size was set to 5000. The coefficients labeled as a, b, c, c′, and i represent unstandardized regression estimates. SE denotes the standard error, and Coeff refers to the unstandardized coefficient. Here, X indicates the independent variable, M the mediator variable, and Y the dependent variable.

The data presented in Table 2 indicate a substantial and positive relationship between numerical literacy and elementary school students' proficiency in mathematical problem-solving (β = 0.71, 95% CI [0.43, 0.98], t = 5.09, p < .001). This finding suggests that enhancing students' numerical abilities may significantly contribute to their mathematical problem-solving capabilities. The correlation coefficient (R^2) indicated that number sense accounted for approximately 8% (R^2 = 0.08) of the observed changes in mathematical problem-solving skills. The findings indicate that elementary school students’ mathematical problem-solving skills are positively associated with their mathematics self-efficacy (b path; β = 0.20, 95% CI [0.17, 0.23], t = 11.78, p < .001). The correlation between number sense and mathematical problem-solving skills and the change in mathematics self-efficacy was significant, with approximately 42% of the variance explained. Furthermore, a substantial positive relationship was identified between number sense and mathematics self-efficacy (c' path; β = 0.25, 95% CI [0.17, 0.33], t = 5.82, p < .001). When mathematical problem-solving skills were not included in the model, number sense was significantly associated with mathematics self-efficacy (c' path; β = 0.39, 95% CI [0.29, 0.49], t = 7.88, p < .001). In summary, the overall indirect relationship in the mediation model was found to be statistically significant. In the final model, the indirect association between number sense and mathematics self-efficacy among elementary school students was examined. The confidence intervals in the fully standardized effect size values were found to be significant because they did not include the value of 0 (zero). The fully standardized effect size (K^2) is 0.15. The value of K^2 determines the interpretation of effect sizes. When K^2 is set to .01, the effect is classified as low; when K^2 is set to .09, the effect is classified as medium; and when K^2 is set to .25, the effect is classified as high. Consequently, it can be posited that the mediation effect in the evaluated model approximates the medium value. As shown in Figure 2, the model presents the total association between number sense and mathematics self-efficacy. Figure 2 depicts the model in which this relationship is mediated by mathematical problem-solving skills.

3.4. The Moderating Role of Mathematical Problem-solving Skills in the relationship between Number Sense and Mathematics Self-efficacy

The findings regarding the moderating role of mathematical problem-solving skills in the relationship between elementary school students’ number sense and mathematics self-efficacy are presented in Table 3.

Figure 2
The moderating role of mathematical problem-solving skills in the relationship between number sense and mathematics self-efficacy

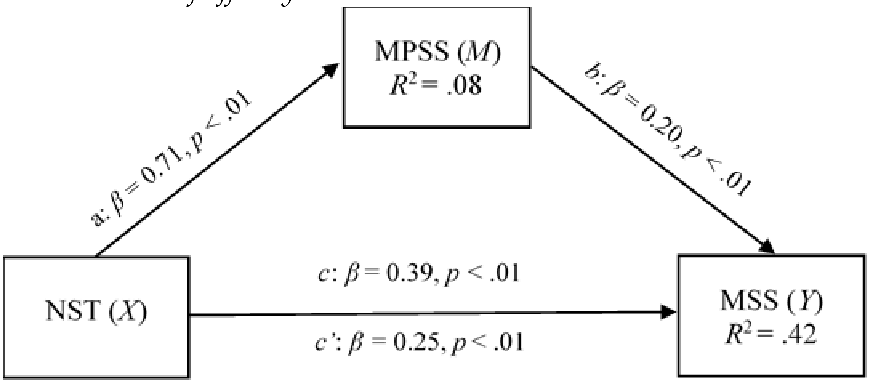


Table 3
Regression analysis results for the moderating role

Variable	*b*	*SE*	*t*	*p*
Constant	13.70*** [6.68, 20.71]	3.57	3.84	<.001
Number sense (*X*)	0.30 [−0.11, 0.71]	0.21	1.43	.15
Mathematical problem solving (*W*)	0.22* [0.09, 0.33]	0.01	3.48	.01
X.W	−0.001 [−0.008, 0.006]	0.004	−0.25	.80

Note: $R = .66$, $R^2 = .43$; ***$p < .001$, **$p < .01$, *$p < .05$; SE: Standard Error; values in parentheses are confidence intervals. Non-standardized beta coefficients (*b*) are reported.

As demonstrated in Table 3, it is evident that incorporating all prediction variables in the regression analysis explains approximately 43% of the change observed in the outcome variable. The table presents the unstandardized regression coefficients (*b*) for each predictor variable in relation to the outcome variable. In addition, *p*-values and confidence intervals are provided to indicate the statistical significance of these coefficients. The presence of moderation was evaluated based on the statistical significance of the interaction term (X.W). The findings demonstrated that mathematical problem solving did not exhibit a moderating effect ($b = -0.001$, 95% CI [−0.008, 0.006], $t = -0.25$, $p > .05$).

4. Discussion and Conclusion

The study's findings demonstrate a positive and significant relationship between elementary school students' number sense, mathematical problem-solving skills, and mathematics self-efficacy. These findings contribute to the literature by clarifying how numerical understanding may be translated into students' confidence in mathematics through engagement in problem-solving processes. In order to excel in problem solving, it is essential to develop a comprehension of numerical data, establish relationships between numerical values, and ascertain the most effective methods to arrive at solutions. This ability is supported by the adoption of flexible thinking processes (Kyaw & Thein, 2018). Individuals with number sense possess the capacity to comprehend numerical data and establish relationships between them (Yang, 2005). They are adept at producing flexible and multifaceted solutions to problems (Çekirdekçi et al., 2018; Huang & Yang, 2018; Yang & Wu, 2010) and can perform problem-solving operations with fluency (Sierra, 2023; Tuğrul-Kalaç, 2023). Studies examining the relationship between number sense and problem-solving skills have reported a direct and positive correlation between these domains among preschool (Yaşar-Yusumut, 2023), primary (Gürkan, 2023; Roxburgh, 2016), and secondary (Kyaw

& Thein, 2018; Mutmainnah et al., 2021) school students. Consistent with this body of research, the present findings reinforce the view that number sense provides a cognitive foundation that supports students’ engagement in problem-solving tasks. According to the National Council of Teachers of Mathematics [NCTM] (1989), numerical aptitude and problem-solving abilities represent two of the most critical components of effective mathematics curricula. From a conceptual perspective, number sense supports flexible reasoning and strategy selection, which are essential for successful problem-solving performance. In this context, it has been observed that the development of number sense and mathematical problem-solving skills occurs in primary school (Roxburgh, 2016) through various educational interventions. The emphasis in the literature on number sense as a factor associated with mathematical problem-solving skills (Geary, 2012) and as a foundational component of advanced problem-solving abilities (McIntosh et al., 2005) highlights the strong relationship between number sense and problem-solving competence. Research has shown a positive relationship between number sense and problem-solving skills (Alkaş-Ulusoy, 2020; Gürkan, 2023). Additionally, problem-solving skills have been found to be associated with self-efficacy (DiNapoli & Miller, 2022). These associations suggest that successful problem-solving experiences may reinforce students’ beliefs in their mathematical capabilities, thereby supporting mathematics self-efficacy. Therefore, it can be concluded that cognitive number sense also significantly affects self-efficacy (Birol & Şengül, 2025). However, given the relational nature of the present study, the findings should be interpreted as associations among variables rather than evidence of causal relationships.

Although number sense significantly predicted mathematical problem-solving skills, the explained variance was modest. This finding suggests that mathematical problem solving is a multidimensional competency influenced by a wide range of cognitive, instructional, and contextual factors. Prior research indicates that variables such as reading comprehension, executive functions, metacognitive regulation, instructional quality, prior achievement, and classroom climate contribute substantially to students’ problem-solving performance (Almasarweh & Khudairat, 2021; Ma et al., 2021; Popham et al., 2019). Therefore, while number sense represents an important foundational component, the mediation pathway identified in this study should be interpreted as statistically detectable yet practically modest. Future research incorporating additional mediating variables may provide a more comprehensive explanation of how numerical understanding contributes to problem-solving competence.

Another finding of the study is that there is a significant positive relationship between students' mathematical problem-solving skills and their self-efficacy in mathematics. Self-efficacy is an individual's evaluation of their ability to perform a task successfully (Waddington, 2023). If an individual confronted with a problematic situation is uncertain of their competencies, they may allocate minimal effort toward problem resolution, or even ultimately relinquish the attempt at resolution (Toptaş & Gözel, 2017). In this case, individuals' capacity to understand and solve mathematical problems affects their confidence in their ability to cope with the problem, that is, self-efficacy (DiNapoli & Miller, 2022; Kayapinar, 2015; Manzano-Sanchez et al., 2018). From a self-efficacy perspective, successful problem-solving experiences provide mastery experiences that reinforce students’ beliefs in their mathematical competence. Indeed, studies have demonstrated that enhancing problem-solving skills is associated with increased mathematics self-efficacy (Ma et al., 2021). In this regard, the significance of fostering students' problem-solving abilities becomes evident, as it contributes to enhancing their mathematics self-efficacy. A substantial and favorable correlation has been demonstrated between mathematical problem solving and mathematics self-efficacy (Du et al., 2021; Kamalimoghaddam et al., 2016; Liu et al., 2021). Taken together, these findings suggest that engagement in meaningful problem-solving processes may support the development of students’ confidence in mathematics by enabling successful task experiences. Therefore, it can be posited that improving students' mathematical problem-solving skills is concomitant with enhancing their self-efficacy. However, given the correlational design of the present study, this relationship should be interpreted as associative rather than causal.

The findings of this study indicate that elementary school students' number sense is positively associated with their mathematics self-efficacy. This association suggests that students who can flexibly interpret numerical information and judge the reasonableness of results may feel more confident when engaging in mathematical tasks. Research has demonstrated a positive correlation between a high number sense and success in mathematics (Gökçe et al., 2023; Jordan et al., 2010). Because successful task engagement is a key source of self-efficacy beliefs, students who effectively use number sense in mathematical situations may develop stronger confidence in their capabilities. This suggests that individuals with a high number sense may possess a heightened sense of confidence, contributing to their success. This notion is supported by the theory of self-efficacy, which posits that successful experiences lead to increased efficacy (Bandura, 1997; Galloza, 2025). The extant literature suggests the existence of a moderate positive significant relationship between number sense and mathematics self-efficacy of primary school students (Birol & Şengül, 2025), secondary school students (Veloo, 2010), and preschool teachers (Tsao, 2004). These findings collectively suggest that number sense may support confidence in mathematics across developmental levels by enabling successful engagement with numerical tasks. In a similar study, Kılıç-Gerz (2024) reported a low but significant positive relationship between number sense and mathematics self-efficacy among classroom teachers, indicating that this association may vary in strength depending on experience level and contextual factors.

Additionally, students' mathematical problem-solving abilities were found to play a mediating role in the relationship between number sense and mathematics self-efficacy. In other words, students' number sense and mathematical problem-solving skills are closely associated with their mathematics self-efficacy. This relationship may be explained by the role of mathematical problem-solving skills in the effective use of knowledge (Bimbim et al., 2026; Kassa et al., 2025). Mathematical problem solving is linked both to number sense (Geary, 2012), which is considered an important foundational competency, and to mathematics self-efficacy. Similar to the research finding, it is emphasized that mathematical problem-solving skills have an important mediating role for many variables. One such study (Supriadi et al., 2024) found that mathematical problem solving is important in increasing learning motivation, reducing anxiety, and improving mathematical reasoning.

Mathematics self-efficacy, a variable of interest in the study, was found to significantly mediate between achievement, anxiety, and motivation (Zou, 2025). Similarly, number sense was found to significantly mediate between self-regulation and problem solving (Yaşar-Yusumut, 2023) and nonverbal intelligence and children's mathematics performance (Zhou et al., 2022). In line with the present findings, previous studies have similarly reported that these variables may function as mediators or are associated with common outcomes such as achievement, motivation, and anxiety. These findings are believed to offer a more nuanced understanding of the correlations between the variables discussed in the present study.

The study's findings demonstrate that students' mathematical problem-solving skills do not moderate the relationship between number sense skills and mathematics self-efficacy. In summary, the correlation between numerical aptitude and self-efficacy remains constant irrespective of the extent of problem-solving capabilities. The non-significant moderation finding suggests that mathematical problem-solving skills may not function as a boundary condition in the relationship between number sense and mathematics self-efficacy at the primary school level. One possible explanation relates to developmental factors; because students' problem-solving competencies are still emerging during middle childhood, they may not yet differentiate how numerical understanding translates into self-efficacy beliefs (Best & Miller, 2010). Another explanation may involve restricted variability in performance levels or alignment between measured constructs, which can attenuate interaction effects in moderation analyses (Hayes, 2018). The relatively modest reliability of the motivation sub-dimension of the mathematics self-efficacy scale may have attenuated the strength of the observed relationships. Lower internal consistency can reduce correlation magnitudes and parameter estimates in structural models; therefore, findings related to this sub-dimension should be interpreted with caution. It is also plausible that problem-solving skills operate primarily as a mediating mechanism rather than a moderating condition, as cognitive competencies often support self-efficacy through mastery experiences (Bandura, 1997; Pajares & Miller, 1994). Future research using longitudinal designs and alternative conditional models may provide further insight into these relationships.

5. Practical Implications and Future Research

The present study revealed a significant positive correlation between number sense, mathematical self-efficacy, and problem-solving abilities. These findings suggest that educational environments could be designed to cultivate these skills during the mathematics education process. Rather than broad instructional changes, the findings indicate the value of integrating number sense development with structured problem-solving experiences. Moreover, given the role of problem solving in elucidating the relationship between number sense and mathematics self-efficacy, instructional practices that engage students in reasoning about numerical magnitude, flexible calculation strategies, and number relationships within authentic problem contexts may support their confidence in mathematics. In this vein, educational materials that facilitate the utilization of diverse problem-solving methodologies and present authentic, real-life problem scenarios can be developed. Classroom activities that encourage multiple solution strategies, reflection on solution processes, and discussion of reasoning may help students connect numerical understanding with successful problem-solving experiences. Given the established link between number sense, mathematics self-efficacy, and problem-solving skills, implementing targeted instructional designs can support these variables. However, given the modest variance explained in problem-solving skills, such instructional efforts should be considered one component of a broader approach that also supports metacognitive regulation, motivation, and supportive classroom environments. The efficacy of these designs can then be assessed through subsequent evaluation. Professional development initiatives may therefore focus on helping teachers integrate number sense tasks with problem-solving discussions rather than addressing these competencies in isolation. Given the current study's focus on fourth-grade primary school students, investigating the relationship between number sense, mathematics self-efficacy, and problem solving can be further explored using different sample groups. The relatively low explained variance in mathematical problem-solving skills indicates that additional cognitive, instructional, and contextual factors not included in the model may play a substantial role. Future research should incorporate a broader set of predictors to enhance explanatory power. Because the present study is constrained to quantitative data, the relationship between number sense, mathematics self-efficacy, and problem-solving skills can be corroborated by acquiring qualitative data in a subsequent study. These recommendations should be interpreted cautiously, as the correlational design does not permit causal conclusions.

One important limitation of this study is that the data were collected using a cross-sectional and relational design. Therefore, although structural equation modeling enabled the testing of theoretically specified relationships among number sense, mathematical problem-solving skills, and mathematics self-efficacy, the findings should be interpreted as associational rather than causal. Because temporal precedence cannot be established, causal inferences cannot be drawn from the present results. In addition, because the data were collected from a single source at one time point using self-report measures, common method bias cannot be entirely ruled out. Future research may reduce this risk by incorporating multi-source data, temporal separation of measurements, or marker-variable techniques. Future research employing longitudinal or experimental designs may provide stronger evidence regarding the direction and nature of the relationships among these variables. Although the sample included students from multiple provinces, the modest number of participants per province and the cluster-based sampling approach limit the generalizability of the findings. Future studies employing stratified or multistage sampling designs with larger regional representation may strengthen external validity.

Author Contributions: Both authors contributed equally to this study and approved the final version of the manuscript for publication.

Declaration of interest: The authors declare no conflicts of interest.

Data Availability: The datasets supporting the conclusions of this article are included within the article or contact the corresponding author of this article to obtain the original data.

Ethical Statement: This study was carried out in accordance with the principles of the Declaration of Helsinki. Ethical approval for the research was obtained from the Ethics Committee of Social and Human Sciences at Bayburt University (Decision No: 196, Meeting No: 5, Date of Approval: May 7, 2025). Throughout the research process, participants received comprehensive information regarding the study's objectives, procedures, and possible risks, after which informed consent was obtained. They were also clearly informed that their participation was entirely voluntary.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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