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# A Study of Developing an Achievement Test for Identifying Primary School Students at Risk of Mathematics Learning Disability*

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**Abstract**

This study aims to develop a valid and reliable achievement test to identify students with mathematics learning difficulties (dyscalculia) and at-risk students. In addition, a test to measure third-grade primary students' success in learning natural numbers and operations with natural numbers sub learning areas is aimed to be developed. Critical learning outcomes were determined for students with a risk of learning disabilities in mathematics and 47 questions were created in line with these outcomes. The questions were evaluated by presenting them, along with the expert evaluation form, to three experts from. The test was administered to 171 students attending. Then, both the item difficulty and item discrimination indices were calculated as part of the item analysis, and accordingly, 21 questions were included in the main test. The KR-20 reliability coefficient of the test was calculated as 0.93, and the Spearman-Brown value for the split halves was calculated as 0.86.

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* This study was presented as a summary paper at the 5th International Symposium of Turkish Computer and Mathematics Education (TURCOMAT-5). In addition, the test was used as a data collection tool in the first author's doctoral thesis to identify primary school students at risk of MLD.

## INTRODUCTION

The renewed Turkish national curriculum urges that the curriculum should help individuals to integrate their knowledge, skill and behavior competencies (Ministry of National Education, 2018). Students need personal, academic, social and business competencies at the national and international level. One of these competencies is mathematical competency. Mathematical competency is the individual's having a mathematical way of thinking in finding solutions to the problems s/he encounters in daily life. In order for this competency to emerge, the teaching process must comprise knowledge and activities built on a solid arithmetic skill. The mathematics education given in schools aims to raise individuals who can use mathematics in daily life, who have advanced mathematical literacy skills, who can do research and work systematically, who can find solutions to the problems they encounter, and who are aware of their own learning processes (Ministry of National Education, 2018).

Although mathematics has an important place in daily life, it also has an important place in academic and business career. However, many students struggle in learning mathematics in schools. National and international assessment reports and research have found that approximately 5% of school-age children cannot meet the basic skills in mathematics (Geary, 2017). This rate varies between 6% and 14%, depending on the country (Mutlu, 2020). When appropriate support is not provided for students who have disabilities in learning mathematics, they face problems both at school and in daily life (Koç & Korkmaz, 2020). Studies show that the disabilities experienced in the acquisition of numbers and operations with natural numbers lead to negative situations in school and professional life (Güzel-Özmen, 2019; Kucian & von Aster, 2015).

The learning outcomes related to numbers and operations with natural numbers have an important place in the Elementary Mathematics curriculum. Third-grade numbers and operations with numbers have a ratio of 46% in the third grade's national curriculum. The outcomes related to the numbers and operations with numbers constitute approximately half of all learning outcomes (Ministry of National Education, 2018). Establishing solid foundations for number perception is viewed as an important step for learning success in mathematics. In addition, individuals who cannot develop the perception of number in the early stages of their life have a risk of failing at mathematics later on (Witzel & Little, 2016). Primary school students are required to understand natural numbers and operations with natural numbers until the fourth grade (NMAP [National Mathematics Advisory Panel], 2008). However, the numbers and operations learning domain is the basis for teaching other domains (Tuna & Serin, 2019) because the subjects have a close relationship with each other and form a sequential structure (Baykul, 2015; Altun, 2015).

Learning disability is defined as a disability of neurological origin that prevents the learning and use of reading, writing, and mathematical calculations (Bender, 2016). In general, learning disability is examined under three sub-titles as reading (dyslexia), writing (dysgraphia), and mathematics learning disability (dyscalculia) (American Psychological Association [APA], 2013). Dyscalculia, known as mathematics learning disability, refers to students who have difficulties understanding numbers and mathematical calculations and have problems in mental mathematical calculations and problem solving (APA, 2013). MLD risk group students who are not diagnosed for various reasons but have a math learning disability are also regarded as having a math learning disability (Aunio, 2021). MLD risk group students refer to students who have difficulties in the concept of numbers, comparison of numbers, place value, and basic arithmetic operations (Olkun, 2015).

Students with mathematics learning disabilities have been reported to experience problems in basic arithmetic skills (Butterworth & Yeo, 2004). Further, such students are known to have disabilities in counting, calculating, learning and remembering arithmetic operations and have disabilities in rhythmic counting (Butterworth et al., 2011). Reviewing the studies on the characteristics of students with mathematics learning disabilities, reveals that students have problems in basic number skills (Morsanyi et al., 2018), fluent calculation (Estévez-Pérez et al., 2019), calculation with multi-digit numbers (Cowan & Powell, 2014), and estimation/mental processing and mathematical reasoning (Karagiannakis, 2016). Students experiencing disabilities in learning mathematics have problems particularly in basic arithmetic skills such as the concept of number, counting, comparison, digit and place value, and calculation (Eissa, 2018; Kelly, 2020).

Identifying students who have mathematics learning disabilities in early years is crucial (Nelson & Powell, 2018) because it negatively affects the student's future performance and if not intervened early, it may cause the student to lag behind his/her peers (Kelly, 2020). Students who have disabilities in learning mathematics and are at risk fall behind their peers as their grade levels progress, and the gap between them gradually widens (Bender, 2016). Early diagnosis and effective instructional interventions are needed to prevent such a negative outcome (Mutlu, 2020). If early and effective intervention programs are not implemented for students with mathematics learning disabilities, these students may encounter disabilities in the future. Effective interventions can only be created by revealing individual characteristics, strengths and weaknesses. It may be to the benefit of the students to determine the issues that students experience inadequacy through evaluations by teachers and to create intervention programs.

Demonstrating the current success status of students can be a guide for teachers in the learning and teaching activities. It can reveal the current achievement levels of the students with the standard achievement tests with proven validity and reliability. With the data to be obtained from these tests, teachers and researchers can have information about the effectiveness of the learning-teaching process and the disabilities that their students experience. These data can support teachers in their instructional planning. Achievement tests suitable for grade levels are needed to objectively reveal student progress in the learning-teaching process and to identify students who need additional intervention. Research on mathematics education reports an urgent need for measurement tools to determine students' level of success (Olkun, 2015; Taşlıbeyaz, 2021).

Assessment and evaluation, which constitutes an important dimension of the teaching process, has a critical role in both determining the current learning levels of students and forming the basis for future learning (Balcı, 2019). Evaluation, which is one of the important elements of the learning-teaching process, determines the level at which the subjects are learned and the targeted learning objectives are achieved. Measurement and evaluation is critical to define the readiness level of students, to see the learning deficiencies of low-achieving students and to decide about the effectiveness of the teaching process (Gönen et al., 2011). Identifying students' strengths and weaknesses with formal and informal assessment tools is recommended to develop effective instructional interventions for students at risk with mathematics learning disabilities (Dowker, 2016). With the standardized tests, the learning status of students who have disabilities can be revealed. By screening large groups of students with valid and reliable standardized tests, struggling students and students who need stronger support are identified (Kelly, 2020).

There is not found standard assessment tool to identify students with mathematics learning disabilities. Studies conducted to identify students who have learning disabilities report that various assessment tools have been used to identify them and multiple assessment tools should be used to do so (Uygun, 2020). Formal (achievement tests, inventories, intelligence tests, and neuropsychological tests) and informal (program-based evaluation, criterion-dependent evaluation, interview, observation, error analysis and checklist) evaluation tools are used together to identify students with mathematics learning disabilities (Uygun, 2020). In addition, there are some other diagnostic tools developed and implemented by countries and researchers. Among these tools are the inconsistency model (Durmaz, 2020; Olkun, 2015), which considers the inconsistency between the individual's ability and achievement scores, and the intervention response model, which allows early identification and support of students with disabilities (Polat & Akkaya, 2020; Witzel & Little, 2016). Finally, computer-based diagnostic tools (Butterworth, 2012), exclusive and inclusive criteria (Mutlu, 2016), Multi-Filter Model (Mutlu & Akgün, 2017), AIDEK that can be used by teachers who comply with national norms (candidate selection, examination, exclusion, elimination and decision making), and TIZ (Enriched for Turkey) models have been developed by researchers (Durmaz, 2020). There is also a checklist (ÖGBA) developed to identify students in the risk group for learning disabilities (Taşlıbeyaz, 2021).

An analysis of the test development studies on primary school students' mathematics achievement reveals that these studies have been conducted at different grade levels and learning domains, focusing on natural numbers (Hellstrand et al., 2020; Ersoy & Bayraktar, 2018; Yılmaz & Yılmaz, 2021), operations with natural numbers, fractions, and measurement. When the international literature is examined, it is stated that the studies conducted to measure the mathematics achievement of primary school students (1-4th grades) are limited (Pandra & Mardapi, 2017). These studies have focused on scale (McCarney & House, 2018; Coleman et al., 2010), checklist (Chan et al., 2004), questionnaire (Willcutt et al., 2011), inventory (Hammill & Bryant, 1998), and screening test (Geary et al., 2009). It was concluded that whereas some diagnostic tools for reading disability have been developed (Kargın et al., 2015; Melekoğlu et al., 2019), few studies have specifically focused on mathematics learning disability (Taşlıbeyaz, 2021).

While some studies report results about several assessment tools that have been developed to identify students who have learning disabilities and are at risk, further research is needed (Olkun, 2015; Taşlıbeyaz, 2021). Reviewing the achievement test development studies conducted in Turkey, it is clear that the number of studies that measure student achievement in primary school mathematics education by reporting on the validity and reliability of these measurements is limited (Balcı, 2019). The existing studies have not been updated in line with the 2018 mathematics curriculum and are not directly related to mathematics learning disabilities. The use of intelligence tests alone in diagnosing students with learning difficulties in Turkey (Olkun, 2015) may lead to misdiagnosis (Özmen, 2015). Misdiagnosis can be prevented by using achievement tests and other informal assessment tools together with IQ tests. In addition, there is no direct test development study for learning numbers and operations with numbers for students with learning disabilities in mathematics. There is a need for standard measurement tools with validity and reliability calculations to identify students at risk for math learning disabilities at an early age and to plan the necessary support education (Özmen, 2015). The lack of a validated and reliable standard achievement test considering the 2018 curriculum for students in the risk group for mathematics learning disability constitutes the problem situation of the current study.

In view of the literature and problems presented, some factors make this study important. As the first factor, this study may help identify students who are early age at risk for mathematics disabilities, thus enable offering them the necessary instructional support. With the support activities offered, it is possible to eliminate the learning gaps of the students and to continue their education without falling behind their peers. With the developed numbers and operations mathematics achievement test, the deficiencies of the at-risk students regarding the natural numbers and operations can be determined and necessary support practices can be carried out. This study can be used to determine the disabilities experienced by students who have a risk of learning disabilities in mathematics. This study is also important in that it can be used as a guide for both teachers and researchers in preparing compensation and support education programs to overcome these disabilities. In addition, it can provide accurate information to classroom teachers and school counselors in pre-diagnosis screening. Thus, students who need detailed assessment can be identified. Lastly, this study is important in that it is the first standardized achievement test developed for primary school students with a risk of mathematics learning disability, considering the 2018 mathematics educational program.

This study aims to develop a valid and reliable achievement test to identify students with mathematics learning difficulties (dyscalculia) and at-risk students. In addition, a test to measure third-grade primary students' success in learning natural numbers and operations with natural numbers sub learning areas is aimed to be developed.

# METHOD

### RESEARCH DESIGN

This study aims to develop a valid and reliable achievement test to identify students with mathematics learning difficulties (dyscalculia) and at-risk students. For this purpose, a standard achievement test was developed in which validity and reliability calculations were made through different question types (multiple choice, matching, filling in the blanks, open-ended) considering the number and operations learning domain achievements for the third-grade primary school mathematics course.

### POPULATION AND SAMPLE

This study was approved by Trabzon University Scientific Research and Publication Ethics Committee (Social and Human Sciences) with a protocol number of 81614018-000-E.525 on December 1, 2020. The population of this research consists of third-year primary school students studying in the province of Bayburt, located in northeast Turkey. On the other hand, the study sample includes 171 students selected among the students attending the third year of primary school in Bayburt by a simple random sampling method. The sample group voluntarily participant in the research. The data were collected from in the third grade students who had achieved the outcomes in the natural numbers and operations learning domain, in the spring period of the 2020-2021 school year.

### DATA COLLECTION

The data were collected by the Numbers and Operations Mathematics Achievement Test (SIMBAT), which was developed by the researchers for natural numbers and operations gains with natural numbers. The data were obtained from the 38-item piloting of the test. Preparing the test for actual implementation is detailed below in the test development process section. There are some key points to consider in developing a valid and reliable achievement test. There are different opinions in the literature regarding test development processes (Adıgüzel, 2016; Fraenkel et al., 2018; Turgut & Baykul, 2015). The classical and modern test development approach by Crocker and Algina (2006) is used to shape the test development process steps for this study. The process steps are described in detail below.

#### *DETERMINING THE RESEARCH PURPOSE AND LITERATURE REVIEW*

The aim was to develop a reliable and valid achievement test to measure the success of elementary school third class students in the domain of natural numbers and operations with natural numbers and to support the identification of students with mathematics learning disability risk group. The review of the related literature revealed that no achievement test had been developed for which validity and reliability analyses had been performed to identify students with mathematics learning disability risk group, and that such a test was needed. Students with mathematical disabilities or in the risk group are known to have problems in basic arithmetic skills (numbers and operations with numbers) and need support (Butterworth et al., 2011; Morsanyi et al., 2018). In extension, the numbers and operations learning domain constitutes the basis for learning advanced mathematics. Based on these two reasons and the literature review, an achievement test for natural numbers and operations with natural numbers was developed. With the developed achievement test, the students at risk of learning disabilities in mathematics can be identified, a contribution to the literature can be made, and the curriculum can be shaped by taking into account the subjects that the students have difficulty with.

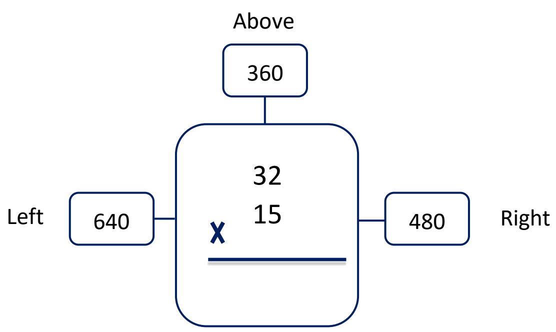
***TABLE OF SPECIFICATION***

First of all, for students who have disabilities in learning mathematics and who are at risk, critical acquisitions for the learning of natural numbers and operations with natural numbers were determined by reviewing the national curriculum and based on related literature (Ministry of National Education, 2018). Identified outcomes are the main outcomes that students with mathematics learning disabilities experience disabilities with. Then, a table of specification for critical outcomes and question items was created. Moreover, an expert who has done studies on the table of specifications, the concept of numbers, and the gains of operation with natural numbers gave an expert opinion regarding the tests developed. The creation of this table is important in ensuring the content validity of the developed achievement test.

***ITEM POOL (QUESTION FORMATION)***

In line with the determined critical outcomes, questions were formed by taking into account the symptoms of students with mathematics disabilities and those at risk. At least two different questions were prepared for each of the determined learning outcomes. The questions were composed of 47 questions in the types of open-ended, matching, short-answer and multiple-choice items. Sample question types for numbers and operation with numbers sub-learning areas are presented below.

**Table 1.** *Sample Question Types Based on Learning Outcomes*

<table>
<tr><th>Learning Outcomes</th><th>Sample Questions</th></tr>
<tr><td>“Reads and writes three-digit natural numbers.”</td><td>In the boxes below, write the pronunciation of the numbers whose spellings are given and the spellings of the numbers whose pronunciations are given in the blanks?<br>305: ................................<br>490: ................................<br>648: ................................<br>741: ................................<br>Two hundred five: ……..…..…<br>Three hundred eighty: ………..<br>Nine hundred fifty-six: ……….<br>One hundred forty-seven: ……..</td></tr>
<tr><td>“Multiplies a two-digit natural number by a two-digit natural number at most, a three-digit natural number by a one-digit natural number at most.”</td><td>
<br>In which direction box should Aysen write the result of the multiplication operation?<br>A) Above B) Right C) Left</td></tr>
</table>

The test was supported with other question types, considering the probability that multiple-choice tests could be answered by chance (Atılgan, 2009). In addition, the subjects that students who have disabilities in learning mathematics and who are at risk have disabilities can be revealed with different types of questions. The questions, together with the table of specification, were presented to the experts.

***OBTAINING EXPERT OPINIONS AND CONTENT VALIDITY ANALYSIS***

In light of the expert opinions, it was determined whether the items were qualified to measure the behavior to be measured, whether they were intelligible, and whether the items were suitable to the developmental characteristics of the students. The created items were evaluated by presenting them to an expert from the fields of primary education, mathematics education, and assessment, together with the expert evaluation form prepared by the researcher. The internal consistency was calculated using the Miles and Huberman formula, in line with the expert opinions. The reliability coefficient obtained by dividing the number of experts who reached a consensus to the number of experts who gave their opinions was calculated as 0.92. In the coding check, which gives internal consistency, the inter-coder (inter-rater) agreement is expected to be above 0.80 (Patton, 2014). Since this value is quite high, it can be argued that the expert evaluation is reliable. Obtaining expert opinions is considered important in ensuring the content validity of the test. Based on the expert evaluations, the test was finalized to include 38 items and was ready for the piloting. After expert opinion, five items were removed, and it did not affect the content validity of the test. Within the scope of the test, there are questions about all the measured gains.

***PILOTING***

The piloting was carried out in three separate elementary schools in the center of Bayburt in the spring term of the 2020-2021 school year. The piloting application was administered to the students attending the third year by the researcher in four days. It was carried out in two stages as numbers (19 questions) and operations with numbers (19 questions). After the first test was distributed, students were given sufficient time to answer and the students took a break before the second test. As in the first test, students were expected to answer all of the questions in the second test. The minutes of completion of the test were determined for all students who took the test. In order to identify students with mathematics learning disability risk group, a time was determined (40 minutes) by considering the completion time of the majority (mode) test. In addition, there are findings that the processing speed of students with mathematics learning disabilities is slow (Kelly, 2020). Having a time limit on the test can make it easier to identify students with mathematics learning disability risk group. As the schools continued with fewer students in classes (by splitting a regular classroom to reduce size), the tests were administered to half of the class in one day and the other half in one day, in two days, which was repeated for the other classes. The exams were held under the supervision of the researcher. The expert opinions were used for the implementation of the test. The high number of questions and the pandemic necessitated such an action. The mathematics achievement test was administered to 171 students in total. The views on the number of students to be selected for the piloting vary. When there are 30 or more items in the test, it may be sufficient to reach a sample of two or three times the number of items (Seçer, 2018). Thus, the number of students who were to take the test was kept as high as possible. After the pilot study, no changes were made to the items. Since, in the item analysis, the difficulty and discrimination indexes were among the desired values, the items were left as they were.

***ITEM ANALYSIS***

The item analyses of the test were carried out in accordance with the answers given to the questions in the test. In this sense, the item discrimination index (r) and item difficulty index (p) of each item were determined. First, answer papers belonging to 171 students were scored. Then the answer sheets are sorted from the highest score to the lowest. Later, the most successful and least successful 27% upper (n=46) and lower (n=46) groups were identified. As part of the item analysis, the item discrimination indices were examined first. For each of the questions in the pilot application, those with distinctiveness indices greater than 0.30 and, if any, greater than 0.40 were determined. The item discrimination index, which is expressed as the power to distinguish between students who know the answer to the item and those who do not, takes a value between -1 and +1. The related literature states that this value should be 0.30 and above (Atılgan, 2009).

When there is more than one item with sufficient discrimination index for a behavior, in the second stage, items with high discrimination index are selected, taking into account the mathematics learning disability risk group students, and items of medium and easy difficulty are selected. The item difficulty index is the rate at which an item is answered correctly or the rate of those who answer the item correctly. It indicates whether the item is an easy or difficult item and takes a value between 0 and +1. It is recommended that this ratio be between 0.20 and 0.80 for achievement tests (Christensen et al., 2014) and that the questions be of medium difficulty (0.40-0.60). In this study, the classification by Hasançebi, Terzi, and Küçük (2020) was used in the item difficulty indices classification. In this sense, the items are classified as follows: 0.29 and below are "difficult"; between 0.30 and 0.49 are "moderate difficulty; between 0.50 and 0.69 are "easy"; and above 0.70 are "very easy".

Considering that students with mathematics learning disabilities have disabilities in performing even simple arithmetic operations, the items with easy difficulty is thought to be effective in determining the students at risk. In fact, those students have difficulty performing basic arithmetic operations and cannot perform simple arithmetic operations (Witzel & Little, 2016). In addition, using a few easy items as the first questions is expected to increase the motivation of the students in taking the test. Based on the item analysis, an achievement test consisting of 21 questions was developed for the natural numbers and operations with natural numbers sub-learning domains. For each acquisition to be measured, more than one question was written. The questions with the most appropriate discrimination and difficulty index were used in the test. To include one question for each gain in the test is considered; therefore, content validity was ensured.

### DATA ANALYSIS

In the analysis of the data, SPSS 22 program was used. For each question in the test, the coding was performed so that the correct answer was one (1) and an incorrect answer was zero (0). For all question types in the test, correct ones were coded as one (1), and incorrect ones were coded as zero (0). The total number of questions prepared for the piloting is 38. Therefore, the highest score a student can get from the test is 38, and the lowest score is zero. First of all, the item analyses, and then the reliability analyses were performed by using the SPSS. During the item analysis, the scores the students got from the test were arranged from high score to low score. Then, the lower and upper groups of 27% were formed. Item discrimination and difficulty indexes of the questions were calculated. Finally, the reliability analysis of the test was performed by calculating the KR-20 reliability coefficient and split-half reliability.

## FINDINGS

In this section, the findings related to the achievement test developed to measure the success of primary school third-grade students in learning natural numbers and operations with natural numbers and to support the identification of students who are in the risk group for learning disabilities in mathematics are presented. Below, the critical outcomes, item and reliability analyses determined respectively for the validity and reliability of the test are presented in detail.

### RESULTS REGARDING THE VALIDITY OF THE TEST

The results on the content and construct validity of the test are presented. First, the data respecting the table of specification for content validity are shared. The results related to the determined critical outcomes, the sub-learning domain to which they belong, and the distribution of these outcomes to the questions are presented in Table 2.

**Table 2**. *Distribution of Learning Outcomes to Items*

| *Sub-learning Areas* | *Learning Outcomes* | *Item no.* |
|---|---|---|
| Natural Numbers | "Reads and writes three-digit natural numbers." | 1, 2.1, 2.2 |
| | "Beginning with any number within 1000, it counts forward rhythmically by ones, tens, and hundreds." "Counts forward by sixes, sevens, eights, and nines within 100 rhythmically. | 3, 4, 5 |
| | "Determines the digit names of three-digit natural numbers and the digit values of the numbers in their digits." | 6, 7 |
| | "Rounds the natural numbers with the three-digits to the nearest ten or hundred." | 8.1, 8.2, 9, 10 |
| | "Compares a maximum of five natural numbers less than 1000 and orders them using symbols." | 11.1, 11.2, 11.3 |
| | "Expands and forms a pattern of numbers whose difference is constant." | 12, 13 |
| | "Comprehend odd and even natural numbers." "Examines the sums of odd and even natural numbers on the model, expresses whether their sum is odd or even." | 14, 15 |
| Addition with Natural Numbers | "At most three-digit numbers, he/she does the addition with and without carry." "Solves problems that require addition with natural numbers." | 16, 17 |
| | "In doing addition with three natural numbers, changing the order in which numbers are added to each other indicates that it did not change the result." | **18*, 19*** |
| | "In an addition problem, he/she finds the addend that is not given." | 20, 21, 22 |
| Subtraction with Natural Numbers | "Performs subtraction that requires decimal and does not require decimal." | 23, 24 |
| | "Mentally can subtract two digits of multiples of 10's from two-digit numbers, and two-digits natural numbers of multiples of 10's from three-digits of 100's." | **25*, 26*** |
| | "Solves problems that require addition and subtraction with natural numbers." | 27, 28 |
| Multiplication with Natural Numbers | "Explains the fold meaning of multiplication." | **29*, 30*** |
| | "Creates the multiplication table." | 31, 32 |
| | "Multiplies a two-digit natural number by a two-digit natural number at most, a three-digit natural number by a one-digit natural number at most." | 33, 34 |
| | "Can Use short-cut for multiplication by 10 and 100." | **35*, 36*** |
| | "Solves problems that require two operations, one of which is multiplication." | 37, 38 |
| Division with Natural Numbers | "Divides two-digit natural numbers by one-digit natural numbers." "Recognizes the relationship between the divider, the divisor, the quotient, and the remainder in division." | 39, 40 |
| | "Can use short-cut to divide a two-digit natural number with the first digit is 0, to a two-digit numbers of 10s." | **41*** |
| | "Solves problems that require two operations, one of which is division." | 42, 43 |

Note: The test, which consisted of 47 items with its sub-items before expert opinion, was reduced to 38 items after expert opinion. Items written in bold and marked with (*) were excluded from the test.

Table 2 shows the key learning outcomes, sub-learning areas and the number of questions prepared for mathematics learning disability risk group students. The critical outcomes were determined in light of the expert opinions. 47 items prepared in line with critical outcomes were prepared for the piloting with 38 items after expert opinions. Experts stated that five gains and nine questions related to these gains could be given through other gains and their questions. Therefore, five gains and nine questions were removed from the test. Thus, the gains and questions marked in bold were removed from the test. At least two questions were prepared for each learning outcome. Some questions are observed to consist of sub-items. The questions in the sub-items were also considered as a separate question, and analyzed. With the item analyses conducted after the piloting, a total of 21 questions, 11 questions from the natural numbers test and 10 questions from the natural numbers operations test, were included in the original test.

Secondly, both the item discrimination index and item difficulty index were calculated as part of the item analysis. While the item difficulty index takes a value between 0 and 1, if the calculated value is close to zero, the problem can be interpreted as difficult, and if it is close to one, the problem can be interpreted as easy. The item discrimination index can be expressed as the degree to which the item distinguishes students who know the answer from those who do not. The item discrimination index ranges from -1 to +1. As the calculated value approaches zero, the discriminative power of the item of the students in the upper and lower groups is low, and as it approaches one, the discrimination of the students in the upper and lower groups is considered high. Discrimination values higher than 0.40 demonstrate a highly distinctive test. The data on item difficulty index and discrimination indices are presented in Table 3.

**Table 3.** *Data on Item Difficulty and Discrimination Indexes*

| *Natural Numbers* | | | | | *Operations with Natural Numbers* | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Item* | | | | | *Item* | | | | |
| Item no. | Difficulty index ($p_j$) | | *Discrimination index ($r_{jx}$)* | | *Item no.* | *Difficulty index ($p_j$)* | | *Discrimination index ($r_{jx}$)* | |
| 1 | 0.77 | Very easy | 0.45 | Very good | 16 | 0.85 | Very easy | 0.28 | Can be used with correction |
| 2.1. | 0.69 | Easy | 0.50 | Very good | 17 | 0.82 | Very easy | 0.26 | Can be used with correction |
| 2.2. | 0.72 | Very easy | 0.54 | Very good | 20 | 0.79 | Very easy | 0.36 | Can be included in the test |
| 3 | 0.91 | Very easy | 0.17 | Not included in the test | 21 | 0.79 | Very easy | 0.41 | Very good |
| 4 | 0.70 | Easy | 0.58 | Very good | 22 | 0.52 | Easy | 0.82 | Very good |
| 5 | 0.76 | Very easy | 0.47 | Very good | 23 | 0.61 | Easy | 0.76 | Very good |
| 6 | 0.57 | Easy | 0.80 | Very good | 24 | 0.76 | Very easy | 0.39 | Can be included in the test |
| 7 | 0.72 | Very easy | 0.54 | Very good | 27 | 0.72 | Very easy | 0.54 | Very good |
| 8.1. | 0.53 | Easy | 0.89 | Very good | 28 | 0.63 | Easy | 0.73 | Very good |
| 8.2. | 0.50 | Easy | 0.95 | Very good | 31 | 0.64 | Easy | 0.63 | Very good |
| 9 | 0.61 | Easy | 0.63 | Very good | 32 | 0.67 | Easy | 0.65 | Very good |
| 10 | 0.69 | Easy | 0.56 | Very good | 33 | 0.58 | Easy | 0.82 | Very good |
| 11.1. | 0.70 | Easy | 0.50 | Very good | 34 | 0.65 | Easy | 0.65 | Very good |
| 11.2. | 0.69 | Easy | 0.47 | Very good | 37 | 0.54 | Easy | 0.86 | Very good |
| 11.3. | 0.36 | Medium difficulty | 0.65 | Very good | 38 | 0.58 | Easy | 0.78 | Very good |
| 12 | 0.61 | Easy | 0.71 | Very good | 39 | 0.56 | Easy | 0.69 | Very good |
| 13 | 0.67 | Easy | 0.60 | Very good | 40 | 0.58 | Easy | 0.82 | Very good |
| 14 | 0.47 | Medium difficulty | 0.82 | Very good | 42 | 0.58 | Easy | 0.73 | Very good |
| 15 | 0.60 | Easy | 0.73 | Very good | 43 | 0.61 | Easy | 0.76 | Very good |

Looking at Table 3, the distribution of the item difficulty and discrimination indexes related to the numbers and operations with numbers test and the questions included in the main test can be observed. When the item discrimination indexes are examined, it can be stated that the discrimination of the questions is generally very good. In addition, there are 2 items that can be included in the test with correction, 2 items that can be included in the test with no corrections or minor corrections, and 1 item that should not be included in the test. The distinctiveness index of the test ranges from 0.17 to 0.95. While the average item discrimination index of the numbers test was 0.60, the average of the operations with numbers test was 0.62.

When the item difficulty indexes of the questions in the test are examined, the questions are generally observed to consist of easy (f=27) and very easy (f=11) questions. Item difficulty indexes in achievement tests are expected to be around 0.50. The item difficulty index of the test ranges from 0.26 to 0.91. The mean item difficulty was calculated as 0.65 in both the numbers test and the operations with numbers test. Considering these calculations and ideal values, the questions that were easy and highly distinctive were included in the test for students in the risk group for learning disabilities in mathematics.

Considering the characteristics of students in the risk group for learning disabilities in mathematics, the questions to be included in the test were determined according to the item analysis. Then, the test statistics of the items included in the test were calculated. The test statistics of the items selected for the final test are presented in Table 4.

**Table 4**. *Item Statistics for Items Included in the Final Test*

| *Pilot Test* | *Final Test* | *Difficulty Index* | *Item Variance* | *Item Standard Deviation* | *Discrimination Index* | *Item Reliability Coefficient* |
|---|---|---|---|---|---|---|
| *Item no.* | *Item no.* | ($p_j$) | $s_j^2 = p_j.q_j$ | $s_j = \sqrt{p_j.q_j}$ | ($r_{jx}$) | $r_j = s_j.r_{jx}$ |
| 2.1. | 1 | 0.70 | 0.21 | 0.45 | 0.50 | 0.22 |
| 2.2. | 2 | 0.72 | 0.20 | 0.44 | 0.54 | 0.23 |
| 4 | 3 | 0.70 | 0.21 | 0.45 | 0.58 | 0.26 |
| 6 | 4 | 0.57 | 0.24 | 0.48 | 0.80 | 0.38 |
| 8.1. | 5 | 0.53 | 0.24 | 0.48 | 0.89 | 0.42 |
| 8.2. | 6 | 0.50 | 0.25 | 0.50 | 0.95 | 0.47 |
| 11.1. | 7 | 0.70 | 0.21 | 0.45 | 0.50 | 0.22 |
| 11.2. | 8 | 0.69 | 0.21 | 0.45 | 0.47 | 0.21 |
| 11.3. | 9 | 0.36 | 0.23 | 0.47 | 0.65 | 0.30 |
| 12 | 10 | 0.61 | 0.23 | 0.47 | 0.71 | 0.33 |
| 15 | 11 | 0.60 | 0.24 | 0.48 | 0.73 | 0.35 |
| 17 | 12 | 0.82 | 0.14 | 0.37 | 0.26 | 0.09 |
| 20 | 13 | 0.79 | 0.16 | 0.40 | 0.36 | 0.14 |
| 22 | 14 | 0.52 | 0.24 | 0.48 | 0.82 | 0.39 |
| 23 | 15 | 0.61 | 0.23 | 0.47 | 0.76 | 0.35 |
| 27 | 16 | 0.72 | 0.20 | 0.44 | 0.54 | 0.23 |
| 32 | 17 | 0.67 | 0.22 | 0.46 | 0.65 | 0.29 |
| 34 | 18 | 0.65 | 0.22 | 0.46 | 0.65 | 0.29 |
| 37 | 19 | 0.54 | 0.24 | 0.48 | 0.86 | 0.41 |
| 39 | 20 | 0.56 | 0.24 | 0.48 | 0.69 | 0.33 |
| 42 | 21 | 0.58 | 0.24 | 0.48 | 0.73 | 0.35 |
| Total | | 13.14 | 4.60 | 9.64 | 13.64 | 6.26 |

When Table 4 is examined, the item statistics of each item included in the test are seen. When the data of the item difficulty index, which shows the difficulty or ease of the problem, are examined, it can be seen that it ranges between 0.36 and 0.82, and is close to medium difficulty in general. The average item difficulty index of the items selected for the main test was calculated as 0.62. The items are expected to distinguish between students who know the answer and those who do not know it in terms of the construct measured. The discrimination values of the items selected for the test are observed to vary between 0.26 and 0.95. The mean item discrimination value was calculated as 0.64.

The variance and standard deviation values calculated depending on the item difficulty index can be expressed as the power to distinguish between individuals in terms of the construct measured. Items with large variance and standard deviation values were selected for the test to distinguish students in the risk group for learning disabilities in mathematics from their peers with normal development in terms of the measured outcome. In other words, relatively easy items with an item difficulty value between 0.40 and 0.70 were preferred. It is observed that the item variance values vary between 0.14 and 0.24, and the total variance value is 4.60. The standard deviation values are between 0.37 and 0.50. Item reliability coefficient calculated according to item discrimination and standard deviation values is expected to be high. The higher the item reliability, the higher the reliability of the test. The reliability coefficients of the items vary between 0.09 and 0.47.

**RESULTS REGARDING THE RELIABILITY OF THE TEST**

The reliability of the measurement tool is obtained by calculating the consistency between the scores obtained in different time periods on the same test and the consistency between the answers received (Büyüköztürk, 2015), and thus, the reliability coefficient, also known as the correlation coefficient, is calculated. The correlation coefficient, which provides knowledge about the degree and direction of the relationship between two variables, takes values between -1 and +1. The desired value for the reliability coefficient is positive and quite high (Özçelik, 2013). Cronbach's Alpha (α) and Kuder Richardson-20 (KR-20) methods are frequently used to calculate the internal consistency coefficient between test scores (Turgut & Baykul, 2015). The KR-20 method is used when the test items consist of two options as "yes-no" and "true-false". KR-20 was calculated as the reliability coefficient because the difficulty levels of the questions in the test showed a heterogeneous distribution and were coded with two options (true (1) – false (0)). The fact that the calculated KR-20 internal consistency coefficient is above 0.70 indicates that the measurement tool is reliable (Büyüköztürk, 2015). The reliability coefficient for the test (KR-20) was calculated as 0.93. If the reliability coefficient obtained from the measurement tool is between 0.60 and 0.80, the measurement tool can be interpreted as reliable, and if it is between 0.80 and 1.0. the measurement tool is highly reliable (Kayış, 2018). Considering the calculated reliability coefficient, it can be stated that the developed SIMBAT is a highly reliable measurement tool.

In addition, the split-half reliability of the test was calculated. The consistency between test scores is revealed with the reliability of the two halves, also known as split-half (Büyüköztürk, 2015). The reliability of the test is calculated by the correlation coefficient between the two halves. The Spearman-Brown coefficient is presented as the reliability coefficient (Kayış, 2018). The test was divided into two halves and split-half reliability was calculated. The internal consistency coefficient (KR-20) of the test and the split-half reliability analysis are presented in Table 5.

**Table 5**. *Reliability Analysis of the Test*

| *Reliability Statistics* | | | |
|---|---|---|---|
| KR-20 ( Internal consistency coefficient ) | | | 0.93 |
| | First Half | Value | .899 |
| | | Items (N) | 19[a] |
| | Second Half | Value | .895 |
| | | Items (N) | 19[b] |
| | Total Items (N) | | 38 |
| Correlation Between Forms | | | .757 |
| Spearman-Brown Coefficient | | | .862 |

a. Items: 1, 2.1, 2.2, 3, 4, 5, 6, 7, 8.1, 8.2, 9, 10, 11.1, 11.2, 11.3, 12, 13, 14, 15.

b. Items : 16, 17, 20, 21, 22, 23, 24, 27, 28, 31, 32, 33, 34, 37, 38, 39, 40, 42, 43.

In Table 5, both the KR-20 internal consistency coefficient and the correlation coefficient values for the two halves are presented. The KR-20 internal consistency coefficient was calculated as 0.93. When the reliability analysis results of the two halves were examined, the correlation coefficient between the forms was calculated as 0.75 and the Spearman-Brown Coefficient as 0.86. The correlation coefficient between forms indicates that the forms belonging to the two halves of the test are compatible. Therefore, it can be stated that the reliability coefficient is high and the test is quite reliable. As a result of the reliability analysis, both the KR-20 internal consistency coefficient and the correlation coefficients related to the split-half reliability show that the test is very reliable.

## DISCUSSION, CONCLUSION AND IMPLICATIONS

In this study, an achievement test was developed that can be used to measure the success of primary school third grade students in the natural numbers and operations with natural numbers learning domain, and to determine the students in the risk group for learning disabilities in mathematics for the stated domains. The validity and reliability study of the developed achievement test was carried out by taking into account the characteristics of students at risk for math learning and the critical outcomes they had difficulty with. As a result, it was determined that the numbers and operations mathematics achievement test (SIMBAT) is a reliable and valid measurement tool. By examining the content and construct validity of the test, it was concluded that the test is valid. In addition, based on the KR-20 and split-half reliability calculations, it was concluded that the test is reliable. The prepared table of specifications, the item analyses performed, the calculated item statistics, the calculated internal consistency coefficient and the split-half reliability reveal that the test is valid and reliable.

SIMBAT was developed by taking into account the natural numbers and operations with natural numbers learning outcomes in the third grade primary school mathematics course. The developed test is an easy-to-apply and easy-to-grade test that can be used by teachers and researchers to identify and support students in the risk group for learning disabilities in mathematics. Early detection of mathematics learning disabilities and providing necessary support education are important to ensure that students at risk of having disabilities in learning mathematics are not left behind and continue their education (Kelly, 2020; Nelson & Powell, 2018). Considering that students in the risk group for learning disabilities in mathematics have problems in basic arithmetic skills (Butterworth & Yeo, 2004; Kelly, 2020), first of all, their learning disabilities for natural numbers and operations with natural numbers can be identified and addressed. In addition, considering that the learning domain of numbers and operations is the basis for other domains, students who have disabilities should be supported in the domain of numbers and operations learning.

It was determined that the numbers and operations mathematics achievement test (SIMBAT) is a reliable and valid achievement test that can be used to identify students in the risk group for learning disabilities in mathematics. Standardized tests can be used to identify students in the risk group for learning disabilities in mathematics, but they are not sufficient on their own (Kelly, 2020; Khalik, 2014; Olkun, 2015). Normally developing students may also score low on basic arithmetic skills (Butterworth, 2016). Therefore, the scores obtained on the achievement test alone are not sufficient to determine mathematics learning disabilities. Academic success of students cannot be measured and evaluated using a single method (Ministry of National Education, 2018). In the evaluation of students with learning disabilities, formal assessment tools should be combined with informal assessment tools, and thus, multiple tools should be used (Kelly, 2020). Because students with learning disabilities show different characteristics, they are a difficult group to diagnose. The research literature confirms that a detailed and accurate diagnosis is a tool used for an effective instructional intervention (Ashlock, 2015).

By screening large-scale student groups with standardized achievement tests, students who fail and need comprehensive support are identified (Kelly, 2020). Students can be determined by taking expert opinions on the results of the administered standard achievement test and determining a standard with statistical calculations. Students at risk of learning disabilities in mathematics can be identified through the cut-off scores determined. The related literature reports that standard-setting studies are carried out either in test-centered or student-centered way. In the test-centered method, experts determine the level that corresponds to a performance standard by reviewing test items. In the student-centered method, some statistical calculations (median, arithmetic mean, regression) are performed, and expert opinions are taken into account. In the current study, a cut-off score was created by using the test-centered approach and taking expert opinions in accordance with the purpose and context. The students in the lower 25% are at risk of learning disabilities in mathematics. Parallel findings have been reported in different other research (Lewis & Fisher, 2016; Dennis et al., 2015). In addition, the rate of students with mathematics learning disabilities among all students has been reported to vary between 3% and 8% (Geary, 2017). In studies conducted to determine the prevalence of mathematics learning disability in different countries, this rate varies between 6% and 14% (Mutlu, 2020). The result found in the current study is similar to the studies conducted to identify students at risk. In addition, considering that formal evaluation will be supported by informal evaluation, the number of students to be included in the formal evaluation can be kept large. Also, students with normal development can also get low scores in achievement tests. Therefore, keeping the cut-off score lower can provide an accurate identification of students at risk of learning disabilities in mathematics. Since different cut-off points are used in different studies, a standard can be determined in line with the opinions of experts and teachers depending on the research purpose.

The third grade is considered as the critical year for students in the risk group for learning disabilities in mathematics (Fletcher et al., 2006) because arithmetic skills become more complex for students in this period. Identifying the disabilities experienced by third graders forms the basis for the support activities to be carried out. With the developed mathematics achievement test, it will be possible to identify the subjects that students have difficulty with and to carry out necessary support activities. The developed SIMBAT can be used by researchers to identify students in the risk group for learning disabilities in mathematics as participants, as well as for follow-up after effective instructional interventions. Furthermore, the developed mathematics achievement test can be given to a higher grade to identify students at risk who fall behind. In addition, teachers play an active role in monitoring and evaluating students' progress and the effectiveness of teaching (Kelly, 2020). It can also be used by primary school teachers in the monitoring and evaluation of third-grade students. By monitoring and evaluation, the disabilities experienced by these students can be determined and the necessary support activities can be carried out. Considering the results of the research, the following suggestions are made to researchers and practitioners.

SIMBAT is a standard achievement test that can be used in the evaluation of third-grade students, which includes only the outcomes of the third grade of primary school. Given the importance of early diagnosis, a test can be developed that can be used in the evaluation of all primary school students. This study is limited to 171 students in three primary schools located in the center of Bayburt. For more generalizable results, a similar study can be conducted by including a higher number of students from other regions and schools. By using the test (SIMBAT), the relationship between the academic achievement of students at risk of learning disabilities in mathematics and various variables can be examined.

Primary school teachers can make a multiple assessment by using informal assessment tools (in-class assessment) together with standard achievement tests while identifying students at risk of learning disabilities in mathematics. By using SIMBAT to screen students with a risk of learning disabilities in mathematics, effective instructional interventions can be developed especially for the subjects they experience difficulty with.

**AUTHOR CONTRIBUTION**

First author has been involved in drafting the manuscript, and have made substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data. The second author has been involved in drafting the manuscript or revising it critically for important intellectual content. He was also involved in the process of analyzing and interpreting the data.

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