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Measuring Learning Loss Due to Disruptions from COVID-19: Perspectives from the Concept of Fractions

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Abstract. *Ineffective learning during Covid-19 can be a major cause of learning loss. Through polytomous item response theory analysis, this study seeks to identify learning loss of fractions and investigate the reliability and validity of the DINA model diagnostic test. This study involved 177 Grade 8 students from six junior high schools in Banda Aceh, Indonesia, to obtain information about the validity and reliability of the diagnostic test and learning loss of fraction due to Covid-19. The research was conducted by designing diagnostic test, expert validation, and empirical testing. Multiple choice problems with polytomous options were developed. This study produced 20 valid problems based on the level of item discriminant, item difficulty, and slip and guess, with a reliability of 0.899. This study revealed that learning loss was experienced by 62 students from low-level junior high schools (100%), 51 students from middle-level junior high schools (98%), and 54 students from high-level junior high schools (85.7%). It can be said that low-level schools have the highest percentage of students with learning loss. It is recommended that future studies evaluate the effectiveness of diagnostic tests in identifying learning weaknesses in mathematics before semester exams using the items generated in this study.*

Keywords: *diagnostic test, learning loss, fraction*

Introduction

Various circumstances can lead to learning loss, such as lack of students' engagement, ineffective use of learning strategies, social disturbances, and natural calamities, among others Pier, Hough, Chriatian, Bookman, Wilkenfeld, and Miller (2021) argued that learning loss is when students do not learn the contents nor master the learning skills that should be achieved at a certain level. Ineffective learning due to school closures (Kuhfeld, Soland, Tarasawa, Johnson, Ruzek, & Liu, 2020; Maldonado & De Witte, 2020), the circumstances where teachers are unable to provide complete learning (Haser, Doğan, & Erhan, 2022), and when students do not participate in learning can affect students' knowledge resulting in a significant learning loss.

Several studies related to learning loss have been conducted in various countries, such as Austria (Paechter, Luttenberger, Macher, Berding, Papousek, Weiss, & Fink, 2015), the United States of America (Kuhfeld et al., 2020); Belgium (Maldonado & De Witte, 2020); Pakistan (Khan & Ahmad, 2021); and the Netherlands (Engzell, Frey, & Verhagen, 2021). These studies compared the learning progress over several (to check) years, considering three different periods to analyze learning loss during the summer holidays. The current study identifies learning loss through tests without comparing student scores over several years but instead identifies learning loss after Covid-19.

Learning loss can be detected through diagnostic tests such as the DINA Cognitive Diagnosis Model (CDM). DINA stands for "determinate input, noisy, "AND" gate." The "determinate input" part describes the ability of a child to properly or incorrectly respond to an item, depending on their knowledge of the attribute measured (Rupp, Templin, & Henson, 2010). Attributes are abilities or competencies that students must have to be able to solve an item (Kusaeri, 2012). Mastery of these attributes shall be represented in the Q matrix with M rows and N columns whose elements are 0 and 1. If a student can master all of the necessary attributes for the solving one item, Q matrix element will be 1. On the other hand, if a student fails to solve one of the other required attributes, it is 0 (De La Torre, Hong, & Deng, 2010; Liu, Douglas, & Henson, 2009). The “noisy” part is related to parameter slip and guessing. A student who masters all the attributes of a particular item can slip and answer incorrectly. Conversely, students who do not master attributes can guess and answer items correctly with non-zero probability (De La Torre, 2009; De La Torre & Karelitz, 2009). The last part, "AND gate," refers to the conjunctive process of determining the correct answer to an item requiring all the abilities required by that item (De La Torre, 2009). In other words, students must master all the attributes to correctly solve an item.

According to George and Robitzsch (2015), DINA's Cognitive Diagnosis Models (CDM) show that students cannot compensate for weaknesses in one skill with strengths in another. Some components are connected to slip and guess parameters, meaning that students who master the attributes of specific items can slip and answer incorrectly. Students who do not master the attributes, on the other hand, can guess and answer correctly. The "AND" gate component refers to connecting the right response to every skill needed for the item (De La Torre & Lee, 2010; Kusaeri, 2012).

Although there are numerous attributes required for each object, the DINA model is a parsimonious model that only requires two parameters. The DINA model assumes that attribute vectors belonging to the same group have equivalent likelihoods of successfully solving the problem (De La Torre, 2011). Thus, the DINA model combines the Q-matrix and an examinee's skill vector to generate a latent response vector. The DINA model examines multidimensionally binary latent abilities. Each skill pattern in the DINA model can be deemed a latent class or group since the number of skill patterns is finite. The DINA model can be incorporated into multiple categorization models, including CDMs. CDM enables researchers to re-investigate student answers underlying the concepts covered by the questions (George & Robitzsch, 2015) based on students' mastery of the attributes being measured (Rupp et al., 2010). Therefore, diagnostic tests are often used by big tuition centers or companies to diagnose their students for follow-up, whether these students need to take remedial classes in preparation for graduation and university entrance exams (Burkholder, Wang, & Wieman, 2021).

Diagnostic tests measure the attainment of particular competencies regarding knowledge and skills to provide information about students' cognitive strengths and weaknesses (Leighton & Gierl, 2007). Diagnostic tests allow the detection of learning difficulties based on established educational standards or psychological parameters (Ketterlin-Geller & Yovanoff, 2009). A well-designed test is assessed through reliability and validity analysis. Item response theory (IRT), a mathematical model that considers the possibility of respondents giving correct answers for each item, is one of the approaches to test the validity of an instrument (Huang, Lin, & Cheng, 2009). The diagnostic test developed in this study focused on measuring knowledge related to the concept of fractions refers to the Grade 8 mathematics curriculum in Indonesia.

Indonesia is currently implementing an innovative curriculum called the "Kurikulum Merdeka" (independent curriculum) that emphasizes flexibility and enables educators to tailor their teaching approaches to students' needs. The independent curriculum prioritizes the development of soft skills and character while also focusing on essential material and promoting flexible learning. According to this curriculum, education should concentrate on the crucial, relevant, and in-depth subject matter, providing ample time for building students' creativity and innovation in achieving essential competencies such as literacy and numeracy. To achieve this goal, teachers must be adept at identifying students requiring special guidance through diagnostic tests. By doing so, teachers can ensure students attain desired competencies without compromising their creativity and innovation.

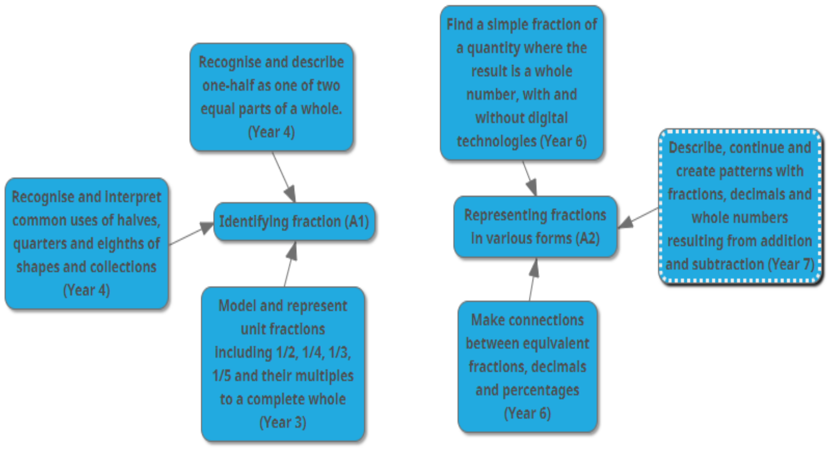
Research has clearly established that fractions are far more problematic than integers (Prasetyawan, 2016). Hariyani, Herman, Suryadi, and Prabawanto (2022) found that students made the most mistakes in comparing, adding, and subtracting fractions. Therefore, there is a need to address the difficulties that students encounter in learning fractions. The first step is to precisely diagnose where students are situated with respect to established curricular benchmarks. The unavailability of such an instrument in the Indonesian context motivated the development of the current diagnostic test, especially in post-Covid-19. It is anticipated that with such a diagnostic test to identify learning loss in fractions, teachers and educators can design programs to address the issue. This study aimed to investigate the validity and reliability of the DINA model diagnostic test and identify learning loss of fractions through polytomous item response theory (IRT) analysis.

Method

The participants were 177 Year 8 students from six junior high schools in Banda Aceh City, Indonesia, to obtain data on the validity, reliability, and learning loss about fractions due to Covid-19. The schools were selected by considering the student ability level at the high, medium, and low-level schools, represented in the average of studnets' score of National Examination computer-based (*Ujian Nasional Berbasis Komputer*/UNBK) at 2019, School examination computer-based (*Ujian Sekolah Berbasis Komputer*/USBK) at 2021, and USBK at 2022. The consistency of the school level each year was employed to identify the representation of students' abilities at each school level. The number of students in low, medium, and high-level schools was 62, 52, and 63.

The test was developed in the middle of 2022. The development of a diagnostic test in this study was done through seven stages: identifying basic competencies and formulating indicators, designing a learning continuum, designing a material hierarchy, formulating attributes, constructing questions, validation by experts, and empirical testing (Kusaeri, 2012; Tatsuoka, Corter, and Tatsuoka, 2004).

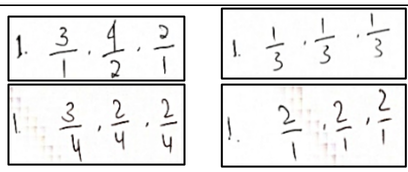
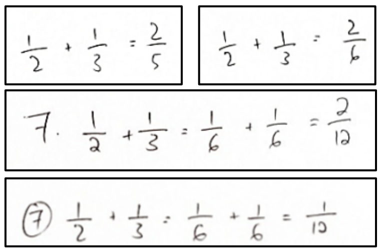
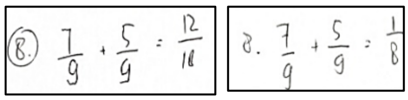
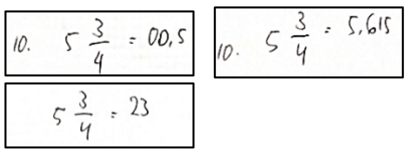
Table 1. Stages of the Diagnostic Test

No	Stages of the diagnostic test	The stages of testing
1	Identifying basic competencies and formulating indicators	Identify learning materials based on the 2013 curriculum for Junior High School in grade 8, including Numbers, Sets, Algebraic Forms, and Linear Equations and Inequalities with One Variable. Fraction is considered a fundamental topic with many errors demonstrated by students; thus, it is chosen for this study.
2	Designing a learning continuum	The learning continuum corresponding to the Australian Curriculum, Assessment and Reporting Authority (ACARA) (2015) and the Year 2013 Curriculum (Indonesian curriculum), with fractional sub matter confined to ordinary fractions, decimals, and percents, is used to analyze attributes on fractional content.
3	Designing a material hierarchy	
4	Formulating attributes	(A1) Introduction fraction (A2) Representing fractions in various forms (A3) Sorting and comparing fractions (A4) Adding and subtracting fractions (A5) Multiplying and dividing fractions
5	Constructing questions	There are 97 multiple-choice questions with four options created.
6	Validation by experts	The item was validated by the validator based on content, construction, and linguistic aspects
7	Empirical test trial	Providing e-learning-based diagnostic test questions for grade 8 students

The development began with identifying attributes based on the basic competencies to be tested. Attributes are abilities or competencies required to complete an item (Kusaeri, 2012: Tatsuoka et al., 2004). In designing attributes, it is necessary to pay attention to the learning continuum of the material. This study referred to ACARA (2015) and the Year 2013 Indonesian Curriculum (K-13) in compiling attributes. Furthermore, a Q matrix was developed based on the attributes identified. Test items were designed by paying attention to the level of options (D0, D1, D2, and D3), followed by selecting the subjects and diagnosing and classifying students related to the materials. The problems used in this study can be seen in the appendix.

To ensure the provision of realistic and effective distractors (options), problems were initially structured according to the subject matter's learning continuum, and attributes were subsequently compiled. Grade 7 students took the test consisting of long-answer problems. The most frequent errors committed by students were identified, and only those answers that made logical sense were selected as options. These options were then categorized into levels D0 (the most severe errors), D1 (minor errors), D2 (insignificant errors), and D3 (the correct option). Attributes were compiled by considering the material hierarchy and constructing questions per the Q matrix, following an analysis of student errors. Table 2 provides a comprehensive overview of the student's queries and responses.

Table 2. Student error analysis

Question	student answers
In the figure below, fill in the dots that reflect the fractional value of each gray area. 	
Find the solution of $\frac{1}{2}+\frac{1}{3}$!	
Find the solution of $\frac{7}{9}+\frac{5}{9}$!	
Convert $5\frac{3}{4}$ to decimal form!	

To obtain quick and reliable data, the diagnostic test for fractions was implemented through the e-learning platform called Getmath. Getmath is a mathematics website specifically constructed to support students' learning. It can be used outside school to help students learn mathematics more creatively and innovatively. Getmath has been developed by the Research Center of Realistic Mathematics Education at Universitas Syiah Kuala since 2021 (http://prp-pmri.unsyiah.ac.id/getmath).

Analysis of the DINA model Diagnostic Test was undertaken through the IRT model 4PL approach using the R Program. 4PL consists of discriminating power test (parameter a), level of difficulty (parameter b), guessing (parameter g), and slip (parameter u) (Antara, 2020). The R program was used because it provided an expectation maximization (EM) algorithm, the default estimation method in the R program to estimate the same item parameters as the DINA model in calculating slips and guessing (Köhn & Chiu, 2016; Kalkan & Çuhadar, 2020).

Item response theory (IRT) provides error estimates for individual respondents and items (Hambleton, Swaminathan, & Rongers, 1991). Also, the item parameters do not depend on the group of people used to calibrate the test items, and the ability parameters do not depend on the sample test items used to calibrate people's abilities; item difficulty and people's abilities are related to the interval scale. Conveyed by Hamdi at the diagnostic test workshop, Syiah Kuala University of Banda Aceh on wednesday, 5 october 2022.

IRT consists of two test models: the dichotomous, where the scores consist of two categories (0 and 1), and the polytomous model, which consists of more than two categories (Lee, Kolen, Frisbie, & Ankenmann, 2001). The multiple-choice and long-answer questions have different advantages and disadvantages. Long-answer questions can provide more extensive information on student abilities. On the other hand, multiple-choice questions are more objective and easily reach many students (Sutiarso, Rosidin, & Sulistiawan, 2022).

IRT has four kinds of logistic models: (1PL) one-parameter logistic model, (2PL) two-parameter logistic model, (3PL) three-parameter logistic model, and (4PL) four-parameter logistic model. 1PL is a dichotomous model with a difficulty level parameter (parameter b) only. 2PL is a dichotomous model with two parameters, namely the discriminating power (parameter a) and level of difficulty (parameter b). 3PL is a dichotomous model with parameters of discriminating power (parameter a), level of difficulty (parameter b), and guessing (parameter g). Furthermore, 4PL is a dichotomous model with discriminating power (parameter a), level of difficulty (parameter b), guessing (parameter g), and slip (parameter u) (Antara, 2020; Rauch & Hartig, 2020).

The first parameter, item discrimination (a), describes the ability of an object to differentiate between people, or more especially, the slope of the item characteristic curve at the point of inflection. The second parameter, item difficulty (b), refers to the theta (θ) value at the moment of inflection. Theta values are estimations of a person's aptitude; they are comparable to a z-score or standard score and often range from -3 to 3. The third component, pseudo-guessing (g), refers to the lower asymptotes or y-intercept of the item's characteristic curve in order to categorize individuals with lower talents (or theta values) who successfully answer an item as guessing functions. Typically, probabilities for parameter estimates should be smaller than 0.20. The item characteristic curve's top asymptote is referred to by the fourth component, the slip or carelessness parameter (u). A person with the better ability (or theta value) should accurately answer an item; yet, when this person fails to do so, it is regarded as negligence or a slip (Barnard-Brak, Lan, & Yang, 2018).

The slip parameter output and guessing from the R program determined the discriminating power index. The biserial correlation index (pbis) was used, symbolized by P(1)-P(0). The discriminating power also calculates the item validity level (Fatkhudin, Surarso, & Subagio, 2014). The criteria for determining the quality of an item (Crocker & Algina, 1986) are as follows: (a) a good item (more than or equal to 0.40); (b) adequate items (0.30 and 0.39); (c) poor items (0.20 and 0.29); and (d) very poot items (less than equal to 0.19). The parameter level of slip and guessing were developed based on the modification of De La Torre and Lee (2010), with the following criteria: (a) low (0.00 and 0.15); (b) medium (0.16 to 0.25; (c) high (0.26 to 0.40); and (d) very high (0.41 and 1).

Zhang (2006) grouped the difficulty level of the items as follows: (a) items with a high/very high level of guessing parameters and low slip have low difficulty levels, (b) items with low/very high level guessing parameters have high difficulty level, while (c) items with low guessing and slip parameters have a moderate difficulty level.

As modified from De La Torre (2010), the guessing and slip parameter levels are stated as follows.

Table 3. The level of guessing and slip parameter

Interval	The level of slip and guessing parameter
$0.00 - 0.15$	Low
$0.16 - 0.25$	Moderate
$0.26 - 0.40$	High

The reliability test was done based on the output of the R program for each attribute. The reliability index ranges from 0-1, with the higher (close to 1) reliability coefficient of a test, the higher the accuracy (Aiken, 1985). On the other hand, validity is evaluated based on the discriminating power of the items (Fatkhudin et al., 2014).

In this study, the items developed were multiple choice polytomous models by placing a level on each distractor (option). Thus, the learning loss analysis refers to the option level, consisting of levels D0 (the most serious errors), D1 (mild errors), D2 (the lightest errors), and D3 (the correct option). This study includes the 4PL model's item response theory (IRT) analysis for detecting learning loss.

A student is classified as experiencing learning loss if he/she chooses the correct option less than 74%. These criteria are based on mathematical performance item maps initiated by the National Assessment of Educational Progress (NAEP) (2022), that student performance for each question represents a probability of ability with a percentage of 65% for constructed response questions, 74% for four-option multiple choice questions, and 72% for five-option multiple choice questions. The learning loss identification through a diagnostic test is not based on a total score; hence, the proportion of domain items the students answer correctly is used (Leighton & Gierl, 2007). This study identified learning loss based on three categories: latent class (groups of students who master the material or groups of students who do not master the material), individuals, and school level (high, medium, and low).

Results and Discussion

Validity and Reliability

Diagnostic test questions developed based on five attributes were used for 23 items. The number of attributes should not be more than items in the Q matrix (De La Torre, 2009). The attributes developed can be seen in Table 4.

Table 4. Attributes of fractions

No	Attributes	Example
A1	Introduction Fractions	 $\frac{1}{2}$
A2	Representing fractions in various forms	Converts the fraction $\frac{37}{5}$ to a decimal solution: $5\sqrt{37} = 7{,}4$; 35; 20; 20; 0
A3	Sorting and comparing fractions	$0{,}25 > \frac{23}{10}$
A4	Adding and subtracting fractions	$\frac{3}{2}+\frac{2}{3}=\frac{(3)3+2(2)}{6}=\frac{9+4}{6}=\frac{13}{6}$
A5	Multiplying and dividing fractions	$\frac{2}{3}\times\frac{7}{5}=\frac{14}{15}$

These five attributes were tested on several items designed based on the Q matrix. The Q matrix is a cognitive model for the performance of test items hypothesized by cognitive researchers, teachers, or other experts, by determining which attributes are needed to respond to items correctly (Köhn and Yi Chiu, 2016; Tatsuoka, 1990). Table 5 displays the developed Q matrix.

CDM aims to conclude that students have a skill related to the attributes tested (George & Robitzsch, 2015). The five attributes tested on 177 students showed the following reliability values: 0.9928, 0.9856, 0.9822, 0.9339, and 0.9689 for attributes A1 to A5, respectively. It shows that the five attributes have a good consistency with an overall reliability of 0.899.

Table 5. Q matrix

Item number	A1	A2	A3	A4	A5	Item number	A1	A2	A3	A4	A5
	Attribute number						Attribute number				
1	1	0	0	0	0	13	1	1	0	1	0
2	1	1	0	0	0	14	1	1	0	1	0
3	1	1	0	0	0	15	1	1	0	1	0
4	1	1	0	0	0	16	1	1	0	1	1
5	1	1	1	0	0	17	1	0	0	0	1
6	1	1	1	0	0	18	1	0	0	0	1
7	1	1	1	0	0	19	1	0	0	0	1
8	1	1	1	0	0	20	1	0	0	0	1
9	1	1	0	1	0	21	1	0	0	1	1
10	1	1	0	1	0	22	1	0	0	0	1
11	1	1	0	1	0	23	1	1	0	0	1
12	1	1	0	1	0						

Through the 4PL IRT model approach, the validity analysis consists of a test of discriminating power (parameter a), level of difficulty (parameter b), guess (parameter g), and slip (parameter u). Based on the slip and guessing value on each item, it produces a difficulty index and difficulty level of the questions. Tables 6 and 7 present the difficulty index and item difficulty level.

Table 6. Item difficulty index

No	Category	Item number	
		Guessing	*Slip*
1	Low	1,4,9,10,11,12,14,19,20,22	2,4,5,6,7,8,9,11,12,14,15,16,17,18,19
2	Moderate	5,8,13,15,17	21
3	High	2,3,7,16,18,21,	10,20,22
4	Very High	6,23	1,3,13,23

Table 7. Item difficulty distribution

Item number	Guessing	Slip	difficulty index
Item 1	0.088	0.689	High
Item 2	0.297	0	Low
Item 3	0.308	0.923	High
Item 4	0.044	0	Moderate
Item 5	0.239	0	Moderate
Item 6	0.999	0	Low
Item 7	0.322	0	Low
Item 8	0.205	0	Low
Item 9	0.111	0	Low
Item 10	0.036	0.333	High
Item 11	0	0	Moderate
Item 12	0	0.111	Moderate
Item 13	0.193	0.999	High
Item 14	0.144	0	Moderate
Item 15	0.186	0	Moderate
Item 16	0.336	0	Low
Item 17	0.167	0.150	Moderate
Item 18	0.263	0.070	Low
Item 19	0	0.076	Moderate
Item 20	0.152	0.359	High
Item 21	0.292	0.250	Low
Item 22	0	0.371	High
Item 23	0.482	0.750	High

The distribution in Table 7 shows the difficulty index for each item and the average of students who master the attributes of each item that can slip (slip happens when students who understand the material provide incorrect answers), or those who do not master the attributes can guess and answer correctly with varying non-zero probabilities (De La Torre, 2009). Questions that have low guessing scores and high slips are categorized as difficult questions, while questions with high guessing scores and low slips are classified as easy questions. In other words, items that have low slip indicate that students rarely answer this question incorrectly. While a high slip indicates that students who master the attribute have a high chance of answering the question incorrectly. Table 8 presents the discriminant of each item.

Table 8. Item discriminant

Item number	P(1)-P(0)
Item 1	0.21156
Item 2	0.701997
Item 3	-0.23195
Item 4	0.955237
Item 5	0.760909
Item 6	0
Item 7	0.677816
Item 8	0.794532
Item 9	0.8889
Item 10	0.630159
Item 11	0.9998
Item 12	0.21156

Item number	P(1)-P(0)
Item 13	-0.19334
Item 14	0.85534
Item 15	0.813634
Item 16	0.663816
Item 17	0.682048
Item 18	0.665992
Item 19	0.923095
Item 20	0.488723
Item 21	0.457463
Item 22	0.628278
Item 23	-0.23251

The distribution of the discriminating power of each item is described in Table 9. Table 9 shows that four items had poor discriminating power, with 3 out of the four items having a discriminant of less than 0, indicating that mostly these items were answered correctly by the groups of students who did not master the material.

Table 9. Distribution of discriminating power

No	Level of discriminating power	Item
1	Good	2, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22.
2	Fair	-
3	Poor	1
4	Very Poor	3, 6, 13, 23.

Items with a discriminant of less than 0 were items 3, 13, and 23. The average student working time on those items was 3 minutes 9 seconds, 2 minutes 27 seconds, and 3 minutes 4 seconds, respectively. These three items were difficult questions, as shown by the difficulty level in Tables 6 and 7. Ideally, students require a longer time to understand and solve the hard questions (Tambychik & Meerah, 2010). Based on the 4PL analysis: item discriminating power (parameter a), item difficulty level (parameter b), guessing (parameter g), and slip (parameter u), three items (3, 13, and 23) had poor discriminating power and high difficulty index. Thus, they were removed, and the remaining 20 items were declared valid.

Learning Loss Results

Learning loss was analyzed based on the attribute and level of options, considering slip and guessing parameters. Based on the individual analysis, 167 (94.3%) students were identified as experiencing learning loss. The remaining ten students were not classified as learning loss because their average for D3 (the correct option) was higher than option level D0 (the most serious errors), D1 (mild error), and D2 (lightest error). For example, 10 students did not experience learning loss because they chose 18 items for D3, 0 for D0, 3 for D1, and 2 for D2, making the average of 78.3%, 0%, 13%, and 8.7%, respectively for D3, D0, D1, and D2.

Based on school level, this study revealed that 62 students from low-level junior high schools experienced learning loss (100%) students, 51 students from middle-level junior high schools experienced learning loss (98%), and 54 students from high-level junior high schools had learning loss (85.7%). Thus, it can be concluded that the highest proportion of students with learning loss was at low-level schools.

In group analysis (latent class), identification leads to students' mastery of the attributes in the items tested, namely: groups of students who master the material (mastery) and groups of students who do not master the material (non-mastery). For example, Figure 1 illustrates the latent class of item 7.

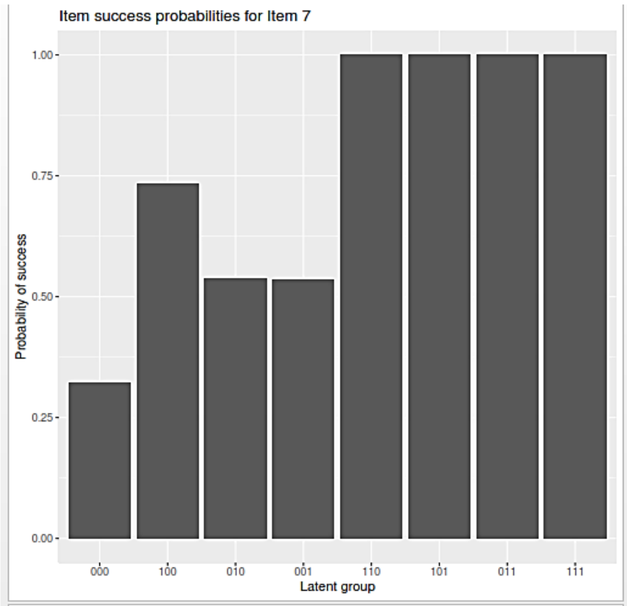


Figure 1. *Latent class* of item 7

Item 7 has three attributes: (A1) Identifying fractions, (A2) representing fractions in various forms, and (A3) sorting and comparing fractions. Concerning the option level, 15.3% of students chose the D0, 16.9% chose the D1, 8.5% chose the D2, and 58.8% chose the D3. In addition, students have low slip scores on item 7, indicating that students rarely answer questions incorrectly. The high proportion of students choosing D3 indicated that, in general, students could master item 7. However, the percentage of student performance for the four-option multiple-choice items was 74%, meaning no students mastered item 7. Figure 2 displays Item 7.

Yusuf gets $\frac{3}{10}$ of the pizza and Rara gets $\frac{5}{8}$ of the same pizza.

The number indicating which statements are true from the table below is....

No	Statement
1	Yusuf gets a bigger pizza than Rara
2	Yusuf gets a smaller pizza than Rara
3	Rara gets a bigger pizza than Yusuf
4	Yusuf and Rara got the same size pizza

Figure 2. Item 7

Several items are measured by attribute 2 (A2): items 2, 3, and 4, and they had a very low percentage for option D3 (the correct option). Some items were measured on attribute 3 (A3): items 5, 6, 7, and 8, with only item 7 having the highest percentage of D3, while other items had very low percentages but did not reach the limit of student performance. Several items measured attribute 4 (A4): items 9, 10, 11, 12, 13, 14, and 15 had a very low percentage for option D3. Several items measured attribute 5 (A5): items 16, 17, 18, 19, 20, 21, 22, and 23, with the highest percentage for the D3 option being on item 18 (65.5%) but did not reach the limit of student performance. Hence, of the five attributes tested, no item was mastered by students, as shown in Table 10.

Table 10. Percentage of option level of items

Item Number	Difficulty index	Attribute	Average Option level				Conclusion
			D0	D1	D2	D3	
1	High	A1	53.7%	29.9%	4.5%	11.9%	Not mastered
2	Low	A2	15.8%	35.6%	1.1%	47.5%	Not mastered
3	High	A2	35%	14.1%	7.3%	43.5%	Not mastered
4	High	A2	41.8%	18.6%	25.4%	14.1%	Not mastered
5	High	A3	11.9%	36.7%	19.8%	31.1%	Not mastered
6	Moderate	A3	23.2%	23.7%	21.5%	31.1%	Not mastered
7	Moderate	A3	15.3%	16.9%	8.5%	58.8%	Not mastered
8	High	A3	20.9%	28.8%	18.6%	31.1%	Not mastered
9	Low	A4	9.6%	11.9%	53.7%	24.3%	Not mastered
10	Moderate	A4	61.6%	14.7%	7.3%	15.8%	Not mastered
11	Moderate	A4	9.6%	66.1%	7.3%	16.4%	Not mastered
12	High	A4	29.9%	16.4%	27.1%	26%	Not mastered
13	Moderate	A4	16.4%.	19.2%	38.4%	25.4%	Not mastered
14	Moderate	A4	19.8%	16.4%	32.2%	31.1%	Not mastered
15	Moderate	A4	18.1%	41.8%	19.2%	20.3%	Not mastered
16	High	A5	24.9%	17.5%	17.5%	39.5%	Not mastered
17	High	A5	26%	20.9%	27.7%	24.9%	Not mastered
18	Low	A5	5.6%.	6.8%,	21.5%	65.5%	Not mastered
19	Low	A5	31.1%	6.2%	14.1%	48%	Not mastered
20	High	A5	28.2%	20.3%	32.2%	18.6%	Not mastered
21	High	A5	17.5%	9.6%	32.2%	40.1%	Not mastered
22	Moderate	A5	19.2%	13%	18.1%	48%	Not mastered
23	High	A5	8.5%	22%	19.2%	49.2%.	Not mastered

Based on Table 10, it can be concluded that students could not master the five attributes tested. However, the attribute of multiplying and dividing fractions (A5) in item 18 had a high percentage for option D3 (the correct option) compared to other items. The percentage of students choosing the options for each attribute was generated by adding the percentages of each item and dividing by the maximum percentage for each attribute. The results are elaborated in detail as follows.

Table 11. Percentage of students choosing options level for each attribute

Attribute	Percentage of Choosing Option level			
	D0	D1	D2	D3
A1	53.7%	29.9%	4.5%	11.9%
A2	30.8%	22.7%	11.2%	35%
A3	17.8%	26.3%	17.1%	38%
A4	21.2%	26.6%	26.4%	22.7%
A5	20.1%	14.5%	22.8%	41.8%

Table 11 shows the percentages for each attribute. It can be seen that attribute multiplying dan dividing fractions (A5) has the highest percentage ((41.8%) for the correct option (D3), while introducing fractions (A1) has the lowest percentage (11.9%) for the correct option (D3) (11.9%) but the highest percentage (53.7%) for D0 (the most serious errors).

The results of this study indicate that, generally, students better mastered the attributes of multiplying and dividing fractions (A5) than the attribute of introduction fractions (A1). The items testing the attributes A1 and A5 in this study are shown in Figure 3.

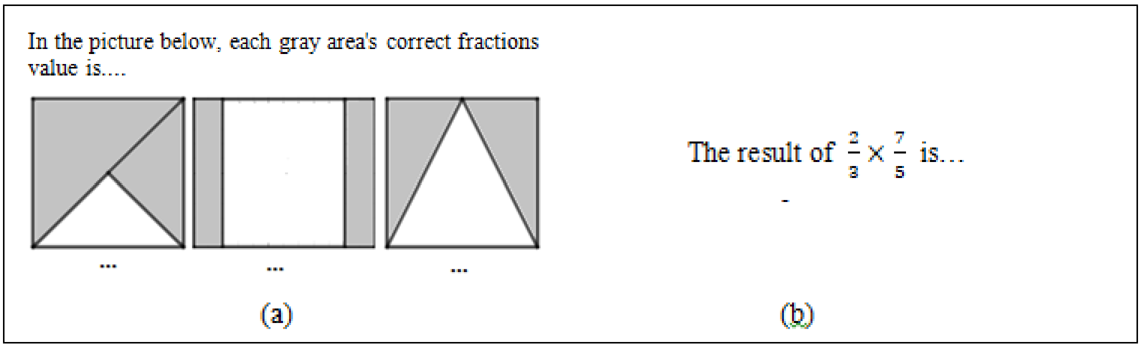


Figure 3. (a) item assessing attribute 1(A1), (b) item assessing attribute 5 (A5)

Latent class analysis shows a low percentage of students who can solve questions on attribute introduction fraction (A1). Attribute A1 requires students to find out how to determine the fractional part of the proposed model in the form of incongruent parts. Students have difficulty solving problems on attribute A1 because they are required to find out how the unit is divided so that it is congruent. In this case, students have more control over the multiplication and division of fractions because only the procedures are standard and clear.

Figure 3 (a) shows that for item 1, students generally choose D0 (the most serious error). The error analysis concluded that students could not associate the fraction $\frac{a}{b}$ with the geometric area separated in part b, which has the same area but is not congruent. Students compare two shaded parts with one unshaded part without dividing areas to be congruent. Novilliis (1976) defined that item 1 with the term part-whole, visual equivalent (students associating fractions $\frac{a}{b}$ with the geometric regions separated in part b, which has the same area but not congruent). All diagnostic test items are presented in the appendix.

The individual analysis of one student, as an example, from a low-level school who identified as having learning loss had the highest average for D0 (47.8%). His errors occurred in items 1, 2, item 3, 8, 10, 12, 13, 15, 19, 20, and 21. Meanwhile, D1 was selected by 13% (items 5, 6, and 11). D2 was chosen by 17.4% (Items 4, 9, 14, and 17). This demonstrates that students are unable to figure out fractions using visuals and cannot represent fractions in various representations. However, they can only compare fractions from the smallest to largest and the addition and subtraction of fractions in contextual problems.

Learning loss due to distance learning during Covid-19 was also found by Yuhasriati, Johar, Khairunnisak, Rohaizati, Al Jupri and Zubaidah (2022). They founs that, during the Covid-19 transition period students had difficulty solving algebraic problems due to students' prerequisite knowledge of integer operations inadequate. This prerequisite knowledge was learned by students through distance learning during Covid-19. These data indicate that learning during the Covid-19 pandemic was not effective so that junior high school students in Banda Aceh City experienced learning loss. Candraningsih and Warmi (2023) found a learning loss due to students' mistakes in understanding word problems, student mistakes in sentences in the form of mathematical modeling problems, and a lack of creative thinking skills. Then research conducted by Ferlia, Putra, Meyronita, and Fajar (2023) within two years of the Covid-19 pandemic found that there was a learning loss of 10-20% in the first year, in the second-year learning loss reached 70-80% with One of the contributing factors is that students do not understand multiplication.

Based on the findings that occurred to one of the students above show that students are only able to solve problems using standard procedures, such as fraction multiplication. Whole numbers and fractions have different concepts (Şiap & Duru, 2004), so fractions are considered one of the most difficult materials for students (Deringöl, 2019). Student's difficulties in fractions are due to the need for multiplicative reasoning in finding the denominator and the simplest form (Barbieri, Rodrigues, Dyson, & Jordan, 2020). Student failure in multiplicative reasoning leads to more than 90% of students being unable to solve problems involving fractions (Wijaya, Retnawati, Setyaningrum, & Aoyama, 2019) and the number of errors shown by students in solving fraction problems. Students with difficulties in learning mathematics are five times more likely to experience difficulties with fractions than with integers (Namkung & Fuchs, 2019).

This study suggests that future researchers can use the items developed in this study to examine the effectiveness of diagnostic tests to identify learning loss in mathematics before semester exams. So, these items are not only used for post-Covid-19 conditions. In addition, it is hoped that there will be further research on the implications for the results of learning loss in fractions. The decrease in student learning is not merely information or an evaluation of student abilities but a follow-up to improve student learning loss in fractions.

Conclusion

A set of 23 diagnostic test items was developed to assess students' understanding of fractions, and 20 of them were found to be valid, with a reliability coefficient of 0.889. Teachers can use these valid items to identify students' prior knowledge or potential learning gaps. Our study revealed extensive evidence of learning loss in fractions among Grade 8 students, with 167 out of 177 students identified as having difficulty in this area. Future research should evaluate the efficacy of diagnostic tests that incorporate the items developed in this study to effectively identify mathematical learning weaknesses. Base on the diagnostic test, the next researcher design remedial to overcome students’ difficulties or learning loss.

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Appendix

DIAGNOSTIC TEST QUESTION OF FRACTION

1. The corresponding fractional value for each gray area in the image below is….

A. $\frac{2}{1}, \frac{2}{1}, \frac{2}{1}$ (D0)

B. $\frac{2}{3}, \frac{2}{3}, \frac{2}{3}$ (D1)

C. $\frac{3}{4}, \frac{2}{4}, \frac{2}{4}$ (D2)

D. $\frac{3}{4}, \frac{2}{6}, \frac{2}{4}$ (D3)

2. The decimal form of $\frac{37}{5}$ is....

A. 0,37 (D1)

B. 7,4 (D3)

C. 18,7 (D0)

D. 61,2 (D2)

3. The percent form of $\frac{4}{5}$ is....

A. 80% (D3)

B. 20% (D0)

C. 4% (D1)

D. 0,8% (D2)

4. The percent form of 12.5 is....

   A. 0,125% (D1) C. 125% (D2)

   B. 12,5% (D0) D. 1250% (D3)

5. In class VII-1, during the learning process Mrs. Yuli distributed 1 of 4 types of cards to each student, Bima held a card inscribed 25%; Dinda holds a card inscribed 1.7; Fina holds a card inscribed $2\frac{5}{3}3$ and Galih holds a card inscribed $\frac{7}{6}$. They were told to line up in the order of the numbers they held. The correct order from smallest is....

   A. Fina, Galih, Dinda dan Bima (D1) C. Bima, Galih, Dinda, dan Fina (D3)

   B. Bima, Dinda, Galih, dan Fina (D2) D. Bima, Dinda, Fina, dan Galih (D0)

6. Consider the following statements:

   (i) $0{,}50 > 0{,}4$ (iii) $0{,}2 < 0{,}22$

   (ii) $1{,}14 > 1{,}2$ (iv) $1{,}5 < 1{,}15$

   The correct statement is....

   A. (i) dan (ii) (D2) C. (iii) dan (i) (D3)

   B. (ii) dan (iv) (D0) D. (iv) dan (iii) (D1)

7. Yusuf gets $\frac{3}{10}$ pizza and Rara gets $\frac{5}{8}$ of the same pizza.

   The number indicating which statement is true from the table below is….

No	Statement
1	Yusuf gets a bigger pizza than Rara
2	Yusuf gets a smaller pizza Rara
3	Rara gets a bigger pizza than Yusuf
4	Yusuf and Rara got the same size pizza

   A. 1 (D1) C. 2, 3, dan 4 (D2)

   B. 2 dan 3 (D3) D. 4 (D0)

8. Consider the following statements:

   (i) $2{,}5 < \frac{4}{3}$ (iii) $\frac{1}{5} = 0{,}2$

   (ii) $0{,}25 > \frac{23}{10}$ (iv) $1{,}5 > \frac{1}{3}$

   The correct statement is....

   A. (i) dan (iii) (D1) C. (iii) dan (iv) (D3)

   B. (ii) dan (i) (D0) D. (iv) dan (ii) (D2)

9. The result of $\frac{7}{9} + \frac{5}{9}$ is....

   A. $\frac{12}{81}$ (D1) C. $\frac{12}{9}$ (D3)

   B. $\frac{12}{18}$ (D2) D. $\frac{35}{81}$ (D0)

10. The result of $\frac{3}{2}+\frac{2}{3}$ is….

A. $\frac{5}{5}$ (D0)
C. $\frac{5}{6}$ (D1)
B. $\frac{5}{12}$ (D2)
D. $\frac{13}{6}$ (D3)

11. The result of $\frac{5}{3}-\frac{3}{2}$ is....

A. $\frac{2}{1}$ (D1)
C. $\frac{2}{6}$ (D0)
B. $\frac{5}{2}$ (D2)
D. $\frac{1}{6}$ (D3)

12. The result of 1,25 + 3,8 is....

A. 1,63 (D0)
C. 4,105 (D1)
B. 4,05 (D2)
D. 5,05 (D3)

13. The result of 2,06 – 1,5 is....

A. 0,56 (D3)
C. 1,91 (D0)
B. 1,56 (D2)
D. 2,11 (D1)

14. The result of $\frac{1}{2}+1{,}6$ is....

A. 0,66 (D1)
C. 1,7 (D2)
B. 1,11 (D0)
D. 2,1 (D3)

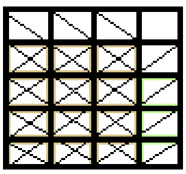
15. The result of $12\%+\frac{1}{4}$ is...

A. 13% (D2)
C. 16% (D1)
B. 37% (D3)
D. 12,25% (D0)

16. Ayu will make a cake that requires 3 kg of butter. He only has $\frac{3}{4}$ kg and $\frac{1}{2}$ kg butter in different containers. There is a lot more butter that Ayu needs to buy to make the cake….

A. 0,33 kg (D0)
C. 0,57 kg (D2)
B. 0,50 kg (D1)
D. 1,75 kg (D3)

17. Look at the following picture!



The multiplication of numbers illustrated in the picture beside is...

A. $\frac{1}{5}\times\frac{1}{4}$ (D0)
C. $\frac{3}{5}\times\frac{4}{4}$ (D1)
B. $\frac{3}{5}\times\frac{3}{4}$ (D2)
D. $\frac{4}{5}\times\frac{3}{4}$ (D3)

18. The result of $\frac{2}{3}\times\frac{7}{5}$ is....

A. $\frac{9}{15}$ (D1)
C. $\frac{10}{21}$ (D2)
B. $\frac{14}{15}$ (D3)
D. $\frac{14}{3}$ (D0)

19. The result of $\frac{3}{4} \div \frac{6}{7}$ is....
    A. $\frac{7}{8}$ (D3)
    B. $\frac{18}{28}$ (D0)
    C. $\frac{23}{12}$ (D2)
    D. $\frac{45}{28}$ (D1)
20. Anisa has $\frac{1}{4}l$ of honey then $\frac{2}{3}$ of the honey is put in a glass. The amount of honey in the glass is....
    A. $-\frac{5}{12}l$ (D1)
    B. $\frac{5}{12}l$ (D0)
    C. $\frac{3}{8}l$(D2)
    D. $\frac{1}{6}l$ (D3)
21. Aisyah needs $\frac{3}{5}$cup flour to make one sponge cake recipe and will make $\frac{1}{3}$ of the recipe, while Santi needs $\frac{2}{3}$ cup flour and will make $\frac{1}{2}$ of the recipe. A lot of flour used by Aisyah and Santi is....
    A. $\frac{2}{9}$ (D2)
    B. $\frac{1}{3}$ (D0)
    C. $\frac{8}{15}$ (D3)
    D. $\frac{17}{30}$ (D1)
22. Inaya has $\frac{3}{2}m$eter of tape. The tape will be cut to $\frac{1}{4}m$ each. The number of ribbons that Inaya got is...
    A. 1 piece (D0)
    B. 6 piece (D3)
    C. $\frac{3}{8}$ piece (D2)
    D. $\frac{5}{4}$ piece (D1)
23. At Zoya's shop, shoes are sold for IDR. 240,000.00 and bags for IDR. 200,000.00. Coincidentally, today the shop owner is having a birthday and is giving discounts of 15% and 10%, respectively. The selling price of shoes and bags at Zoya's shop after discount is....
    A. Shoes IDR 24,000.00 and Bags IDR 30,000.00 (D0)
    B. Shoes IDR 36,000.00 and Bags IDR 20,000.00 (D2)
    C. Shoes IDR 204,000.00 and Bags IDR 180,000.00 (D3)
    D. Shoes IDR 216,000.00 and Bags IDR 170,000.00 (D1)