Jurnal Ilmiah Sekolah Dasar
Volume 8, Number 3, 2024 pp. 579-588
P-ISSN: 2579-3276 E-ISSN: 2549-6174
Open Access: https://doi.org/10.23887/jisd.v8i3.69714

Measuring Learning Outcomes of Integer Arithmetic Operations through E-MoBil Media in Primary Education

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ARTICLE INFO

Article history:
Received October 30, 2023
Accepted July 2, 2024
Available online August 25, 2024

Kata Kunci:
Skala Hasil Belajar, Analisis Faktor Konfirmatori, Media Pembelajaran

Keywords:
Learning Outcomes Scale, Confirmatory Factor Analysis, Learning Media

ABSTRAK

Kemampuan siswa dalam menyelesaikan soal ujian matematika, khususnya pada operasi hitung bilangan bulat, masih menjadi tantangan di Indonesia, mengindikasikan pemahaman konsep yang belum optimal. Penelitian ini bertujuan untuk menguji validitas dan reliabilitas konstruk skala hasil belajar operasi hitung bilangan bulat pada numerasi AKM bagi siswa kelas V SD melalui pengembangan media E-MoBil berbasis Flip PDF Professional. Metode pengembangan yang digunakan mengacu pada model Borg & Gall, tetapi hanya mencakup sembilan langkah utama: pengumpulan informasi, perencanaan, pengembangan produk awal, uji coba lapangan awal, revisi produk awal, uji coba lapangan utama, revisi produk, uji coba lapangan operasional, dan revisi produk akhir. Instrumen utama pengumpulan data adalah angket, yang dianalisis menggunakan analisis faktor konfirmatori dengan perangkat lunak LISREL 8.80. Hasil analisis menunjukkan bahwa skala hasil belajar yang dikembangkan memenuhi kriteria kecocokan model, validitas konvergen, validitas diskriminan, dan reliabilitas konstruk. Hal ini membuktikan bahwa media E-MoBil berbasis Flip PDF Professional efektif dalam meningkatkan pemahaman siswa terhadap operasi hitung bilangan bulat dan layak digunakan dalam pembelajaran. Penelitian ini memberikan kontribusi penting dalam pengembangan instrumen evaluasi hasil belajar berbasis teknologi untuk meningkatkan literasi numerasi siswa sekolah dasar.

ABSTRACT

The ability of Indonesian students to solve math exam questions, particularly in integer arithmetic operations, remains a challenge, indicating incomplete mastery of mathematical concepts. This study aims to test the construct validity and reliability of a learning outcome scale for integer arithmetic operations in AKM numeracy for fifth-grade elementary school students through the development of E-MoBil media based on Flip PDF Professional. The development method used follows Borg & Gall's model but focuses on nine key steps: information gathering, planning, initial product development, preliminary field testing, initial product revision, main field testing, product revision, operational field testing, and final product revision. The primary data collection instrument was a questionnaire, analyzed using confirmatory factor analysis with LISREL 8.80 software. The results show that the developed learning outcome scale meets the criteria for model fit, convergent validity, discriminant validity, and construct reliability. These findings demonstrate that the E-MoBil media developed using Flip PDF Professional is effective in enhancing students' understanding of integer arithmetic operations and is suitable for use in learning activities. This study provides significant contributions to the development of technology-based learning evaluation tools to improve elementary students' numeracy literacy.

1. INTRODUCTION

The national education system is a planned effort to realize the learning process and atmosphere so that students actively develop their potential. With this system, it is hoped that students will possess intelligence, moral character, self-control, and useful skills for themselves, society, and the nation. The national education system functions to develop abilities and shape dignified civilization in order to educate the nation's life (Hermanto, 2020; Ilham, 2019). The goal of the national education system is to develop the potential of students to become faithful and pious individuals to Almighty God, to have noble character, to be healthy, knowledgeable, capable, creative, independent, and to be responsible and democratic citizens

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(Diantoro et al., 2021; Wardani et al., 2019). Based on these objectives, a curriculum needs to be arranged, which will become a plan and regulate the content, goals, methods, and teaching materials to be used. After the learning process is implemented, an evaluation will be conducted. Evaluation activities are an inseparable part of the education process (Bryan & Clegg, 2019; Suardipa & Primayana, 2023). However, not all types of evaluation can be used to measure the success of educational goals. If the appropriate measuring tools are used, the success of education can be clearly measured.

Evaluation activities are carried out on students and institutions, both formal and non-formal, at each level and type of education (Asria et al., 2021; Souto-Otero, 2021). Therefore, in carrying out evaluations, principles should be followed to achieve better outcomes, so that each evaluation conducted by the respective institutions aims to achieve better education than before. The National Examination is an evaluation tool to measure students' knowledge simultaneously across Indonesia from elementary to high school levels (Bryan & Clegg, 2019; Mukhlishoh & Bakar, 2021; Rohim, 2021). The national examination has become a polemic and sparked debate among educators. Using national exam results as the sole indicator of student success during the learning process is not appropriate. According to the PISA 2015 report, Indonesia's education system quality ranked 62 out of 72 participating countries (Novita et al., 2021). This indicates that the development of education in Indonesia is still far behind compared to other countries in the world. Therefore, the Ministry of Education and Culture has implemented a new program called the National Assessment as a replacement for the National Examination, which will begin in 2021. The National Assessment includes three aspects: Minimum Competency Assessment (AKM), character surveys, and learning environment surveys (Nasution et al., 2021; Rohim, 2021). AKM and learning environment surveys are aimed at students, while character surveys are aimed at all school residents, including principals, teachers, and students.

The Minimum Competency Assessment (AKM) is an assessment of the fundamental competencies needed by all students to develop themselves and actively participate in society in positive activities (Meriana & Murniarti, 2021; Sani, 2021). AKM is the basis of the competency assessment tested on students to measure their reasoning abilities when faced with problems requiring literacy and numeracy skills (Nurhikmah et al., 2021; Rokhim et al., 2021). Mathematical literacy or numeracy assessment is conducted to measure the extent to which students can think using mathematical concepts, procedures, facts, and tools (Andiani et al., 2021; Hwang & Ham, 2021). The scope of numeracy literacy includes the ability to apply mathematical concepts and rules in real-life situations that are often unstructured, have multiple ways of solving, and may not have a complete resolution. Numeracy is also an individual's ability to use mathematical concepts and procedures to solve daily problems in various relevant contexts as individuals and citizens of Indonesia and the world (Genc & Erbas, 2019; Mutawah et al., 2019; Ozgen, 2019).

The problems of mathematics learning in elementary schools in Indonesia encompass various aspects that create serious challenges (Bybee & McCrae, 2011; Permatasari, 2021). Firstly, many students tend to be passive in the learning process of mathematics. This could be due to various factors, including lack of interest or motivation in mathematics, unengaging teaching methods, and lack of student involvement in decision-making in their learning process (Azzahra & Nurrohmatul Amaliyah, 2022; Kurniawan, 2021). Additionally, many students in Indonesia may take a long time to complete mathematics exams, which indicates that they have not fully mastered mathematical concepts. The ability to quickly and efficiently solve mathematical problems is an indicator of deep understanding (Saraswati & Agustika, 2020; Sukmawarti et al., 2021). Another challenge is the low learning outcomes. Many students may not achieve the expected mathematics achievements for elementary school level (Hidayat et al., 2020; Utami & Cahyono, 2020). This could be due to factors such as lack of understanding of mathematical concepts, ineffective teaching methods, and a curriculum that does not always align with students' needs. Based on observations, documentation, and interviews conducted with fifth-grade teachers at SD Negeri 2 Pandansimping, SD Negeri 2 Cucukan, SD Negeri 2 Kokosan, and SD Negeri Gadungan from September 9-13, 2022, several issues were identified. Teachers face challenges during teaching and learning activities because students are not active. This is evident from the students' behavior during lessons: they remain silent, show little interest, and display a lack of enthusiasm for learning activities (Purpura et al., 2011; Salvia et al., 2022). They frequently complain of headaches or stomachaches before certain lessons, often find excuses to leave the classroom (such as frequent bathroom breaks to avoid tasks), do not provide opinions or answers, often appear lethargic as if tired, and rarely smile in class. Exploratory factor analysis is a technique to detect and assess the latent sources of variation or covariation in a measurement. EFA explores empirical data to discover and detect the characteristics and relationships among variables without specifying a model beforehand. In this analysis, researchers do not have a priori theory to formulate hypotheses (Bragg et al., 2021; Liu et al., 2020). Due to its exploratory nature, the results of EFA are weak. The analysis results, which explain the relationships among variables, are not based on existing theory. The results depend solely on empirical data, and if many observed variables are involved, the analysis becomes difficult to interpret

(Shrestha, 2021). Typically, factor analysis is closely related to questions of validity (Clark & Watson, 2019; Tobón & Luna-Nemecio, 2021). When identified factors are connected, EFA addresses questions of construct validity, determining whether a score measures what it is supposed to measure. In contrast, CFA is used to test a hypothesized model to describe and explain the empirical data with fewer parameters than the observed variables. The model is built based on a priori information about the data structure in the form of specific theories or hypotheses (Aguirre, 2013; Auerswald & Moshagen, 2019). These specific theories or hypotheses are based on existing theories or previous research findings.

CFA aims to examine the validity of several factors as they exist within a variable and the relationship between each item and its factor. The difference between exploratory and confirmatory factor analysis lies in the perspective on how a factor is formed. In EFA, theoretical hypotheses are not used to form factors. The formation of factors is based on the analysis results. In contrast, the formation of factors in CFA is based on hypotheses developed in earlier stages, where the researcher already knows the latent structure. Thus, construct validity testing can be conducted using CFA, which is considered an appropriate method to examine the relationship between observed variables and latent variables. CFA assumes that the observed variables are imperfect indicators of specific latent variables or underlying constructs (Roos & Bauldry, 2021; Steenkamp & Maydeu-Olivares, 2023). In CFA, researchers posit a specific a priori model and then test whether the collected data fits the hypothesized model. Therefore, in CFA, the number of factors is determined, as well as the hypothesized items to be measured. Concerning the number of items for each factor, at least three items are required (Goretzko et al., 2021; Mardhotillah & Yulhendri, 2022). In this way, CFA provides information on how well the hypothesized factor model fits. This study aims to test a learning outcomes scale that meets two psychometric criteria: construct validity and construct reliability. Construct validity includes convergent validity and discriminant validity.

Many studies have explored similar topics. However, few have specifically evaluated the construct validity and reliability of the E-Mobil instrument developed with Flip PDF Professional in improving learning outcomes in integer arithmetic operations in AKM numeracy for fifth-grade elementary students. Although there are studies on the use of technology in mathematics education, most focus on other aspects such as learning software (Karim & Savitri, 2020; Manik et al., 2023; Saraswati & Agustika, 2020) or online learning (Melani et al., 2021), whereas the E-Mobil instrument developed with Flip PDF Professional in the context of integer arithmetic operations and fifth-grade numeracy has not been thoroughly tested for its construct validity and reliability. The novelty of this research lies in its specific focus on evaluating the construct validity and reliability of the E-Mobil instrument developed with Flip PDF Professional for improving learning outcomes in integer arithmetic operations within the AKM numeracy framework for fifth-grade elementary students. While previous studies have explored the use of technology in mathematics education, they primarily focus on aspects such as learning software or online learning. This study, however, uniquely aims to develop and test an assessment instrument that meets two psychometric criteria—construct validity and reliability—in the context of integer arithmetic operations and numeracy for fifth-grade students. This particular focus and the use of the E-Mobil instrument represent a novel contribution to the field.

2. METHOD

This study employs a research and development (R&D) approach aimed at developing and validating educational products (Aka, 2019). The product of this research is a learning outcomes scale that meets validity and reliability criteria. The research procedure is adapted from the theory developed by McCoach et al. (2013), which involves 13 steps as follows: (1) identifying problems and needs, (2) determining variables, (3) conducting a comprehensive review of curiosity, (4) writing conceptual and operational definitions, (5) developing indicators, (6) selecting instruments, (7) designing a blueprint, (8) writing materials based on the blueprint, (9) performing qualitative and quantitative content validation by several experts, (10) revising items based on expert suggestions, (11) conducting empirical field tests, (12) performing validity and reliability tests using confirmatory factor analysis (CFA) with LISREL 8.80 software, and (13) designing the final instrument. Categorize sample sizes as follows: 50 - very poor, 100 - poor, 200 - fair, 300 - good, 500 - very good, and 1000 - excellent. Previous study suggests that to achieve accurate calculations with CFA, a researcher needs 250 to 500 respondents (Comrey & Lee, 2013). Additionally, other study propose a sample size of 150 or more to achieve minimal standard error. Accordingly, 225 respondents were randomly selected from thousands of elementary school students in Klaten Regency, Central Java Province, Indonesia (Liang et al., 2022).

The instrument used in this study is a student learning outcomes questionnaire consisting of four aspects: addition, subtraction, multiplication, and division. The indicators for these four aspects total 16 indicators. The instrument grid for construct validity and reliability of the e-mobil instrument developed

with Flip PDF Professional to enhance learning outcomes in integer arithmetic operations for fifth-grade numeracy is detailed as show in Table 1.

Tabel 1. Instrument Grid

Variable	Aspect/Material	Indicator	Item Number
Student Learning Outcomes	Addition	Determining the result of adding negative integers using a number line	1
		Performing addition operations involving negative integers	2
		Applying relational symbols (=, <, >, ≤, ≥) to two presented integer	3
		Calculating the sum of integers in word problems	4
	Subtraction	Determining the result of subtracting two negative integers using a number line	5
		Ordering presented integers	6
		Determining the result of subtracting two negative integers	7
		Determining the result of subtracting two integers with different signs	8
	Multiplication	Determining the result of multiplying two integers using the commutative property	9
		Performing multiplication operations involving integers with different signs	10
		Performing multiplication operations involving integers with the same signs	11
		Calculating the result of multiplication of integers in word problems	12
	Division	Performing division operations involving negative integers	13
		Performing division operations involving integers with different signs	14
		Performing division operations involving integers with the same signs	15
		Calculating the result of division of integers in word problems	16
Total			**16**

According to previous study the analysis can be conducted using first-order CFA, and if the results are not conclusive, a second-order analysis may be necessary (Guillén-Gámez et al., 2023). In CFA, construct validity is specifically demonstrated using a measurement model. This study employs confirmatory factor analysis with second-order analysis (2nd order CFA). Other study state that CFA is suitable for determining the construct validity and reliability of an instrument (Brown et al., 2016; Griffith, 2016). CFA allows for the examination of factors, variances, and the relationships between latent constructs (Idoga et al., 2022). Both convergent validity and discriminant validity are achievable within this study.

3. RESULT AND DISCUSSION

Result

The scale model developed uses two alternative answers, with 1 for correct answers and 0 for incorrect answers, to ensure the distribution of respondents' attention to answer options is not too broad, thereby increasing the precision of their choices. The number of statement items is 16. The results of the second-order confirmatory factor analysis (2nd order CFA) include determining the factor loadings (λ) for each item and factor that develop the scale. Initially, the researchers provided 4 factors involving 16 items. After conducting a preliminary analysis, all 16 items were found to be valid. According to the confirmatory factor analysis results, all items and factors show factor loadings > 0.5. As a result, all items and factors are practically significant and suitable for use in data collection, as shown in the path diagram below. From the

path diagram, it can be concluded that all item questions are valid. The result of second order analysis is show in Table 2.

Table 2. Result of Second Order Analysis

Aspect	Indicator	Loading Factor (λ)	Error (ε)	AVE	C.R
Addition	Addition1	0.720	0.490	0.549	0.830
	Addition2	0.780	0.390		
	Addition3	0.710	0.490		
	Addition4	0.750	0.430		
Subtraction	Subtraction1	0.750	0.440	0.570	0.841
	Subtraction2	0.750	0.440		
	Subtraction3	0.750	0.430		
	Subtraction4	0.770	0.410		
Multiplication	Multiplication1	0.740	0.450	0.541	0.823
	Multiplication2	0.740	0.460		
	Multiplication3	0.630	0.600		
	Multiplication4	0.820	0.330		
Division	Division1	0.710	0.500	0.620	0.866
	Division2	0.890	0.200		
	Division3	0.740	0.460		
	Division4	0.800	0.360		

Base on Table 2, the development of the scale in this study involves four constructs: perseverance in completing tasks, resilience in facing difficulties, showing interest in various problems, and preferring to work independently. The AVE values for the four constructs are 0,549, 0,570, 0,541, and 0,620, respectively. All constructs exceed the AVE threshold value of >0.50, indicating that they can measure latent variables. Meanwhile, the CR values for the four constructs are 0,830, 0,841, 0,823, and 0,866, respectively. The construct can be said as have a good realibility is when the value of Construct Reliability (CR) is ≥ 0,07 and variance extracted value is (AVE) ≥ 0,50. Next, for the model fit, it is generally good. The criteria for the model fit are as shown in Table 3.

Table 3. Fit Model Criteria

Goodness of Fit Indices	Cut-Off Value	Model Value	Description
Chi-Square	Expected less	118.76	Good Fit
RMSEA	< 0.08	0.05	Good Fit
NFI	> 0.90	0.97	Good Fit
NNFI	> 0.95	0.97	Good Fit
CFI	> 0.95	0.97	Good Fit
RMR	< 0.05	0.03	Good Fit
GFI	> 0.90	0.97	Good Fit
AGFI	> 0.90	0.82	Marginal Fit

Based on Table 3, the analysis results, it is known that all 8 out of 8 fit indices indicate that the model is fit. This result shows that the theoretical model of the Student Learning Outcomes variable is consistent (fit) with the empirical data. Based on the results of construct validity and construct reliability analysis, all aspects and items that form the Student Learning Outcomes are declared valid and reliable, so all these aspects and indicators are capable of reflecting and forming the Student Learning Outcomes.

Discussion

Mathematics occupies a crucial position in the elementary education curriculum. This subject provides the foundation for cognitive development and problem-solving skills crucial in everyday life (Cai & Hwang, 2021; Sugianto & Darmayanti, 2022). However, teaching and learning mathematics at the elementary school level often encounter significant challenges for both educators and students. One fundamental challenge faced by elementary school students in learning mathematics is the abstract nature of mathematical concepts. Mathematics often deals with abstract concepts such as numbers, operations, and mathematical relationships (Peng & Kievit, 2020; Verschaffel et al., 2020). Understanding these concepts requires strong cognitive development and the ability to think abstractly. At the elementary school level, students may not be fully prepared to grasp these abstractions effectively.

Mathematics is also cumulative, meaning a good understanding of basic mathematical concepts, such as integers, basic arithmetic operations, and geometry, forms a crucial foundation for comprehending more complex mathematical (Abrahamson et al., 2020; Gersten et al., 2009). Gaps in understanding these basic concepts can hinder students' ability to comprehend and apply further mathematical concepts. Several mathematical concepts, such as fractions, decimals, or coordinate geometry, may also be challenging for elementary school students to visualize. Visualization plays a crucial role in understanding these concepts, and if students struggle to form a clear mental picture of what these concepts represent, they may face difficulties in effectively applying them (Deng et al., 2020; Gilligan et al., 2019). The topic of integer numbers is a key aspect of the education curriculum that plays a significant role in students' cognitive development. Proficiency in basic mathematical operations, including addition, subtraction, multiplication, and division, is an invaluable foundation in learning mathematics (Ahdhianto et al., 2020; Kellems et al., 2020). The success or failure of students in understanding integer concepts is highly determined by their abilities in these basic mathematical operations. Basic mathematical operations are the initial steps in building an understanding of integers. Addition and subtraction, as the most basic operations, form the basis for understanding positive and negative numbers. Students' ability to solve addition and subtraction problems involving integers will enable them to master basic concepts in integer topics (Noviyanti, 2019; Rosyidah et al., 2020). In efforts to optimize learning, educators and researchers have been seeking new and innovative ways to enhance the effectiveness of the education process. One promising breakthrough is the use of technology-based learning media, such as Flip PDF-based E-Mobil, to facilitate mathematics learning at the elementary school level. The use of technology-based learning media has been a topic of significant research interest in recent years. Many studies have been conducted to evaluate its impact on student learning outcomes. One study supporting the effectiveness of technology-based learning media is the research by previous study reviewed various studies on the use of software in mathematics learning at the elementary school level and found that students using this software achieved significant improvements in mathematical understanding and learning outcomes (Pasambo & Radia, 2022).

Furthermore, research by other study also provides strong evidence of the benefits of using technology-based learning media in mathematics learning at the elementary school level. Effective and engaging learning media can help improve students' ability to solve mathematical problems and understand difficult concepts (Widiarti et al., 2021). Additionally, research conducted by other highlights the importance of interactivity in technology-based learning media (Aliyah & Purwanto, 2022). Technology-based media allows students to actively participate in learning through interactive modules. The results of this research indicate that students who are engaged interactively in mathematics learning tend to achieve better learning outcomes. In the specific context of mathematics teaching, research by previous study reveals that technology-based learning media enables teachers to present mathematical concepts visually and more easily understood by students (Engelbrecht et al., 2020). This has a positive impact on students' understanding of concepts and mathematical learning outcomes. Meanwhile, multiplication and division also play a key role in understanding integers. Multiplication involves the concept of grouping or repetition, which is highly relevant in understanding integers. Similarly, division can help students understand division of integers and the concept of balance. More than just mathematical operations, addition, subtraction, multiplication, and division are computational skills that serve as essential foundations in solving more complex mathematical problems in the future. Students proficient in these basic operations will feel more confident in facing higher-level mathematical challenges. Furthermore, basic mathematical operations also have strong relevance to everyday life. Students often encounter situations where they need to calculate, measure, or solve problems using these operations. Success in applying these basic operations will enable students to tackle daily tasks more effectively (Gersten et al., 2009; Noviyanti, 2019). Therefore, proficiency in addition, subtraction, multiplication, and division plays a central role in ensuring understanding of integer concepts. Teachers and students need to pay special attention to ensuring that students have a strong foundation in these basic operations, as this will help them understand and successfully tackle more complex mathematical concepts in the future (Farhadiba & Nunuk Wulyani, 2020; Umbara et al., 2021). Mastery of these basic operations is the key to success in learning mathematics, especially in integer topics.

4. CONCLUSION

The four aspects of integer arithmetic operations, namely addition, subtraction, multiplication, and division, meet the criteria of construct fit, validity, and reliability. Moreover, the scale has comprehensively met the reliability criteria. The developed scale is suitable for use in collecting data to measure student learning outcomes in integer arithmetic operations. Therefore, the professional flip PDF-based E-MoBil on integer arithmetic operations qualifies as highly satisfactory and is suitable for supporting the teaching and learning process. As for recommendations, this professional flip PDF-based E-MoBil can be used as a

reference for school learning implementation, can serve as a tool to support the teaching process for teachers, and can facilitate learning for students to better understand learning materials.

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