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RME Educational Game Based on Android Mobile to Increase Students' Mathematical Understanding Ability

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Abstract: This research aims to: 1) create an RME educational game based on Android about integers called Story Math Game as an edutainment medium for 1st grade elementary school students that contains stories about basic concepts of counting (addition and subtraction), practice questions, and learning evaluations (with various varying levels of difficulty) with the characteristic of using real problems; 2) assess whether the game is suitable for learning mathematics; and 3) describe the increase in students' mathematical understanding abilities who have used RME educational games in learning. This research is research and development (R&D) with a 4D development model. There are four stages: define, design, develop, and disseminate. Data analysis techniques include expert assessment (feasibility test and media quality test) and development testing (one-group pretest-posttest design experiment). The feasibility of the RME educational game was evaluated by media and materials experts. The research results showed that 1) educational games reached a feasibility level of 75.00% with good criteria from media experts and 82.32% with good criteria from material experts, 2) the media was tested publicly by 100 parents of students, and the test results The public obtained application quality results of 83.20% with good criteria, and 3) development testing resulted in an increase in the mathematical understanding abilities of 1st grade elementary school students. Based on the results of the data obtained, it appears that the RME educational game is suitable for use as a mathematics learning medium and can increase the students' mathematical understanding abilities in 1st grade elementary school.

Keywords: RME, Android, Educational game, Mathematical understanding

Introduction

Students must have problem-solving skills (Hilda & Siswanto, 2021), creativity (Siswanto et al., 2019), and especially technological skills (Sagita et al., 2019) to face the fourth industrial revolution (Nurhayati et al., 2020). Technological progress cannot be avoided in this life; technological development goes hand in hand with the development of science, especially in education (Levano-Francia et al., 2019; Teräs et al., 2020; Tri et al., 2021). Education is a crucial aspect that benefits from advances in information technology. As technology

develops today, every innovation created must be able to provide benefits and be used appropriately to help and make things easier in various ways, especially for learning (Oke & Fernandes, 2020).

The 2013 curriculum (Indonesian education curriculum) emphasizes information and communication technology (ICT) literacy in learning, where all subjects must be integrated with the use of ICT (Hilda & Siswanto, 2021; Machmud et al., 2021; Nurhayati et al., 2020), which is known as ICT-based learning. ICT subjects are no longer part of the curriculum but are part of learning in all subjects (Akib et al., 2020; Mahdum et al., 2019). The presence of ICT is expected to improve the quality of learning, as the aim of integrating ICT into the education curriculum in Indonesia must be to support learning (Kristiawan & Muhaimin, 2019; C. Zhang et al., 2022). ICT can help solve educational problems. Especially for mathematics learning, ICT can be used to turn the abstract into concrete (Caena & Redecker, 2019; Malik et al., 2019).

Teachers and students are required to use and utilize technology in the learning process (Halili, 2019; Rachmadtullah et al., 2020; Susanto et al., 2020; Tohara, 2021). In an effort to instill concepts, learning is not enough just through lectures; ideally, teaching in schools needs to be provided with adequate media so that students can observe, explore, and try to discover principles through daily activities. Mathematics learning will be faster if it is part of classroom learning activities. Media was introduced that effectively describes the application of mathematics in everyday life, known as realistic mathematics education, or RME (Siswanto et al., 2023). Therefore, we need a learning medium that can maximize and help children learn by seeing, hearing, and carrying out mathematical activities in everyday life, known as realistic mathematics education, or RME.

RME is a mathematics learning approach that provides real things for students (Hilda & Siswanto, 2021). The main idea of the RME approach is that students must be given the opportunity to rediscover mathematical ideas and concepts with teacher guidance through exploring various situations and problems that are real to them (Suryadi, 2015). RME is based on three basic principles: guided reinvention through progressive mathematization, didactic phenomenology or phenomena in learning, and emergent models or generating models (Maudy et al., 2017). Through realistic learning, students will understand the concept and operation of integers through mental activities because RME has the potential to improve students' mathematical understanding (Saleh et al., 2018). Based on this argument, mathematics is not only to be studied but also to be implemented in daily life activities (Sumirattana et al., 2017). Therefore, the operational definition of RME in this paper is learning that utilizes contextual problems of everyday life and concrete objects to understand selected mathematical concepts and problems.

The goals of learning mathematics are to solve problems, apply what has been learned in the real world, and develop mathematical abilities. As a result, mathematics lessons in schools place a strong emphasis on concepts (Herawati et al., 2010; Zulkardi, 2003, 2006). Mathematical ideas make sense in connection to other pertinent concepts and create a fundamental framework for the subject when students study it because the concepts are presented in a way that makes them interrelated (Mumcu & Aktürk, 2020). One of the most crucial skills for children to acquire in order to overcome challenges in the future is the capacity to comprehend mathematics (Auliya & Munasiah, 2016). This refers to the idea that the foundation of studying mathematics in the classroom is the capacity to comprehend mathematical ideas. This means that comprehension of mathematical ideas is a must for all math classes in the classroom. But there are a number of issues with math education in schools. First, incomplete and imprecise grasp of mathematical ideas is a common challenge that students have when studying mathematics in the classroom (Ramadhina et al., 2021). The purpose of learning mathematics itself is impeded when pupils are unable to comprehend a mathematical idea, and they face challenges in each and every math class (Banowati & Siswanto, 2023). Therefore, difficulties that students encounter in grasping concepts may have an effect on the objectives of mathematical education itself.

Polya (Banowati & Siswanto, 2023) states that there are four levels of mathematical understanding: 1) mechanical understanding, or the capacity to apply and retain laws accurately; 2) Inductive understanding may be applied to comparable circumstances by applying rules or formulas to simple examples and trusting in the laws or formulae; 3) Rational understanding, which is the capacity to demonstrate the validity of the law or formula in question; and 4) intuitive understanding, which is the capacity to accept the validity of the law as true without question and to offer evidence supporting the validity of the prediction. There are several signs that someone understands mathematical ideas. The following are the NCTM-based indicators of conceptual understanding that were used in this study: 1) verbal and written concept definitions; 2) the identification and creation of examples and non-examples; 3) the use of models, diagrams, and symbols to represent concepts; 4) the switching between different forms of representation; 5) the recognition of multiple interpretations and meanings of concepts; and 6) the identification of a concept's characteristics and conditions that determine a concept (Banowati & Siswanto, 2023).

In this research, an RME educational game based on Android about integers was developed called "Story Math Game" as an edutainment medium in mathematics learning for 1st grade elementary school students which contains material about stories about basic concepts of counting (addition and subtraction), practice questions, and learning evaluation. (with various levels of difficulty), with the characteristics of using contextual problems from daily life, focusing on improving mathematical understanding abilities, as well as the relationship between lesson material and case examples developed based on RME. Story Math Game functions as an edutainment medium that combines elements of education and entertainment. This educational game is packaged attractively on mobile devices or smartphones so that it can be used as a medium and reference source to make it easier for teachers to teach and especially to make it easier for students to learn integer material wherever and whenever (García et al., 2016), so that students' interest and independence in learning are also increasing (Hilda & Siswanto, 2021).

The consideration in developing educational games on smartphones is the basis of the system used, namely Android. According to the results of the StatCounter Globalstats survey of smartphone users in Indonesia from 2017 to 2023, Android is the dominant operating system for smartphones in Indonesia at 76.86%, followed by iOS at 5.66%, Series 40 at 4.65%, BlackBerry at 2.69%, SymbianOS at 2.4%, Nokia at 1.6%, Samsung at 0.47%, and others at 5.66% (Statcounter Global Stats, 2023). This means that the majority of smartphones in Indonesia use the Android mobile operating system. In addition, smartphones have great potential to be developed into interactive media for students because mobile technology will continue to have a big impact on the student learning process (Churchill, 2008; Churchill et al., 2015), making it easier for students to learn (Portelli & Eldred, 2016), practical and can be taken anywhere (Kennewell & Beauchamp, 2007), and has supported the presentation of various multimedia such as video recording, graphics, and integrated media (Zhang & Wu, 2016).

Research on the development and use of ICT has been widely carried out, such as by Hilda & Siswanto, (2021), who designed and developed an Android application about learning permutations of the same elements based on realistic mathematics education, or RME, and Siswanto et al. (2019), who developed an RME-based combinatorics learning application for an Android-based smartphone. Meanwhile, in this research, it is an RME educational game based on Android about integers called "Story Math Game" as an edutainment medium in mathematics learning for 1st grade elementary school students that contains material about stories about basic concepts of counting (addition and subtraction), practice questions, and evaluation of learning (with varying levels of difficulty) of integer material with the characteristics of using contextual problems from daily life, focusing on developing mathematical understanding abilities, as well as the relationship between lesson material and case examples developed based on RME.

Method

This research is development research. Development research is research used to develop or produce products or improve existing products (Widodo, 2017) and test the effectiveness of these products (Sugiyono, 2019). The result of product development is an RME educational game based on Android called "Story Math Game" as an edutainment medium in mathematics learning for 1st grade elementary school students, which contains material about stories about basic concepts of counting (addition and subtraction), practice questions, and learning evaluations (with various variations in level of difficulty) from integer material with the characteristic of using contextual problems of daily life, focusing on improving mathematical understanding abilities, as well as the relationship between lesson material and case examples developed based on RME.

The product development model used refers to the 4-D model developed by Thiagarajan et al. (1974) Thiagarajan et al. (1974) and Gall & Borg (1996), namely definition, design, development, and dissemination. The advantages of the 4-D model include: it is more appropriate to use as a basis for developing learning tools and media rather than developing learning systems; the description seems complete and systematic in its development involving expert judgment, so that before being tested in the field, the learning tools have been revised based on assessments, suggestions, and input from experts (Hilda & Siswanto, 2021; Siswanto et al., 2019; Widodo, 2017, 2020).

In the definition stage, in principle, it is a preliminary study that does not attempt to test a hypothesis, but rather to obtain information related to the variables to be studied. The definition stage includes (1) front-end analysis; (2) analysis of student characteristics (learned characteristics analysis); (3) task analysis; (4) concept analysis; and (5) specific instructional objectives (Thiagarajan et al., 1974). Meanwhile, the design stage includes designing an RME educational game based on Android (Story Math Game) and research instruments. At the

development stage, we obtain an RME educational game based on Android product (Story Math Game final) that is fit and good and a valid instrument for measuring research variables (final instrument) that is fit and good. The development stage includes expert assessment with feasibility tests and media quality tests (Thiagarajan et al., 1974). Product feasibility criteria include validity, practicality, and effectiveness (Hilda & Siswanto, 2021; Siswanto et al., 2019; Widodo, 2017, 2020). The validity criteria were performed by presenting experts in the fields of mathematics and media, namely 1 mathematics education lecturer, 2 grade 1 elementary school teachers as experts, and 1 educational technology lecturer as an expert. Practicality criteria are based on teacher activities in managing learning. Meanwhile, the effectiveness criteria will be seen in ordinary learning with teachers who teach mathematics using RME educational games in mathematics learning at school. To determine the quality of the application that has been developed, a public test was performed on 100 parents of students at partner schools before it was distributed widely. The choice of parents as respondents was because the educational game application was developed for 1st grade elementary school students, while these students could not provide objective assessments. Furthermore, at the dissemination stage, development testing or small-scale limited trials were performed with a one-group pretest-posttest design experiment to see the increase in students' mathematical understanding abilities. This experimental research design didn't have a control group, but a group of students were given special treatment during some time. After the pretest and posttest data are collected, the data will be collected, reused, and anatomized descriptively and statistically to determine the results of the trials that have been performed.

Results and Discussion

In this research, an RME educational game based on Android called "Story Math Game" was produced as an edutainment medium in mathematics learning for Grade 1 elementary school students. It contains material about stories about basic concepts of counting (addition and subtraction), practice questions, and learning evaluations (with various variations in level of difficulty) from integer material with the characteristic of using contextual problems from daily life, focusing on improving mathematical understanding abilities, as well as the relationship between lesson material and case examples developed based on RME.

At the define stage, the researcher determines and defines development terms. At this definition stage, development needs analysis activities are performed, product development requirements are according to user needs, as well as research and development of models suitable for product development. Analysis can be performed through literature studies or preliminary studies. Determining the term for the product being developed begins with (a) curriculum analysis, (b) material analysis, (c) analysis of student characteristics, and (d) formulating objectives. Curriculum and material analysis are based on the book Thematic Integrated Curriculum 2013 Revised for Elementary/Class I/MI," published by the Ministry of Education and Culture in 2017. At the design stage, researchers designed a draft design or prototype of the RME (Story Math Game) educational game and appropriate research instruments within the framework of the analysis of the curriculum, materials, and student characteristics. Figure 1 shows basic illustrations at the design stage, as graphic designs for the characters that will be used in the RME educational game.

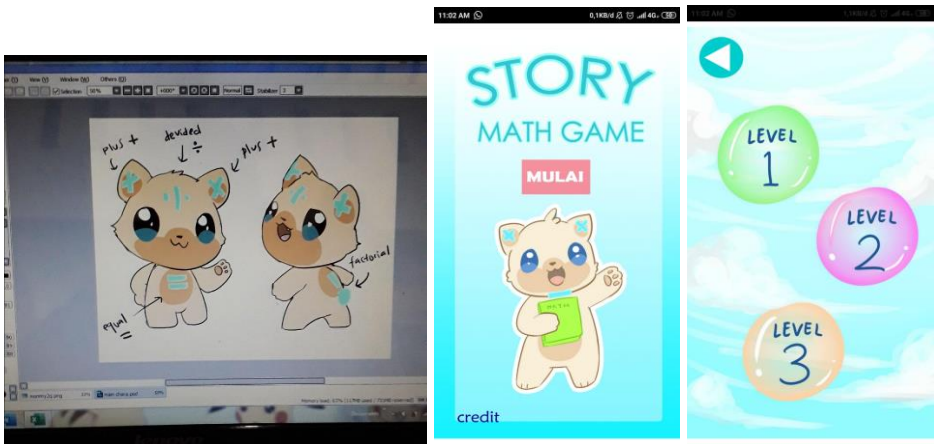

Figure 1. Characters in the rme educational game

At the development stage, researchers obtained an Android-based RME educational game product (Story Math Game final) that was fit and good and a valid instrument for measuring research variables (final instrument) that was fit and good based on feasibility testing and product quality testing by the team expert judgment consisting

of mathematics lecturers or teachers through Focus Group Design (FGD). The results of the FGD, as criticism and suggestions, are then used as a basis for revising the product.

The feasibility of the RME educational game was evaluated by media and materials experts. Product eligibility criteria include validity, practicality, and effectiveness. Validity testing is done by experts in educational technology, namely Mr. GA as an expert lecturer who tests display aspects, writing aspects, software engineering aspects, and dubbing. Meanwhile, the validity test was performed by experts in mathematics education, namely Mr. JS as an expert lecturer and Mrs. M and Mrs. SR as 1st grade elementary school teachers, who tested aspects of material, learning, evaluation, and practicality based on teacher activities in managing learning. Meanwhile, the effectiveness criteria will be seen in ordinary learning with teachers who teach mathematics using the RME educational game in mathematics learning at school. To determine the quality of the application that has been developed, a public test was performed on 100 parents of students at partner schools.

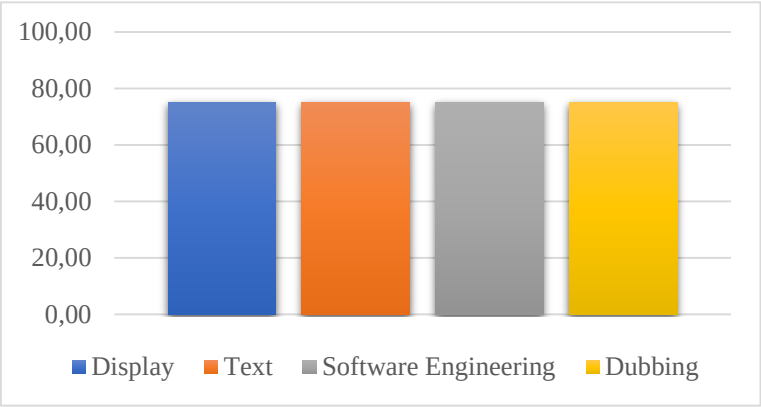

Figure 2. Media expert's assessment

The results of the media expert assessment carried out by educational technology lecturers on the display quality aspect were 75.00% with good criteria, the writing aspect 75.00% with good criteria, the software engineering aspect 75.00% with good criteria, and the voice dubbing aspect 75.00% with good criteria. Overall, the quality of learning media assessed by media experts is 75.00% with good criteria.

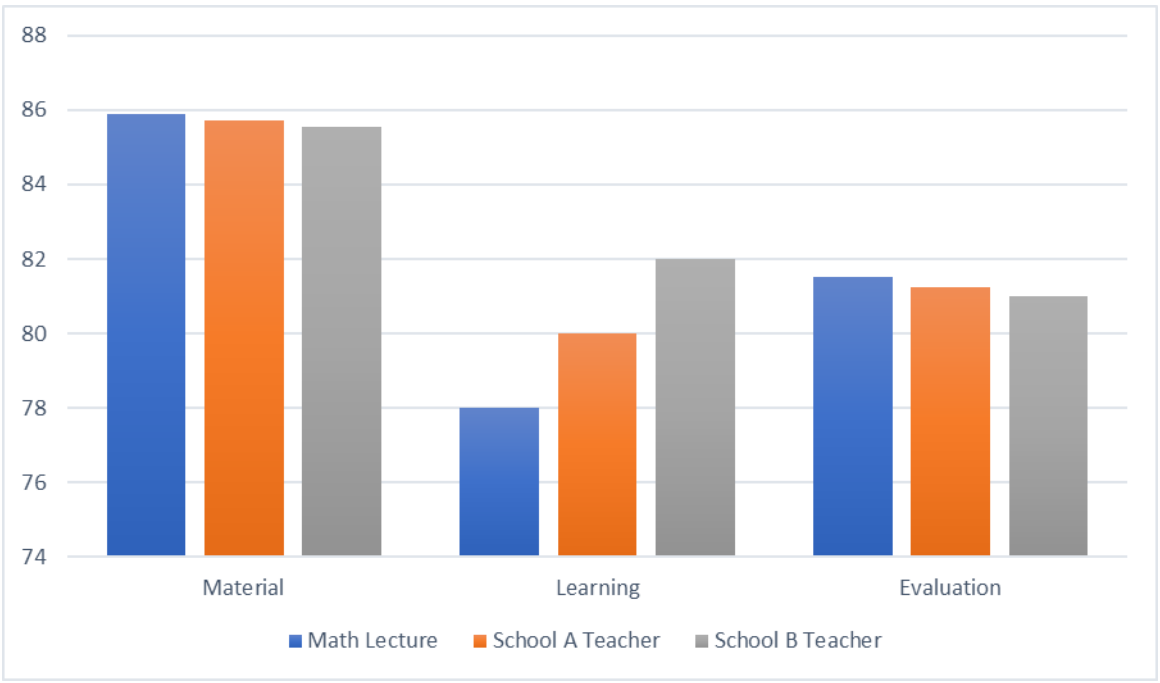

Figure 3. Material expert's assessment

The results of the assessment as the first material expert were mathematics education lecturers in the material aspect 85.88% with good criteria, the learning aspect 78.00% with good criteria, and the evaluation aspect 81.5% with good criteria. The results of the second material expert assessment, 1st grade elementary school teachers at school A, in the material aspect, were 85.71% with good criteria, the learning aspect was 80.00% with good criteria, and the evaluation aspect was 81.25% with good criteria. The results of the third material expert assessment, 1st grade elementary school teachers at school B, in the material aspect, were 85.54% with good criteria, the learning aspect was 82.00% with good criteria, and the evaluation aspect was 81.00% with good criteria. Overall, the quality of the material in learning media as assessed by 3 material experts was 82.32% with good criteria.

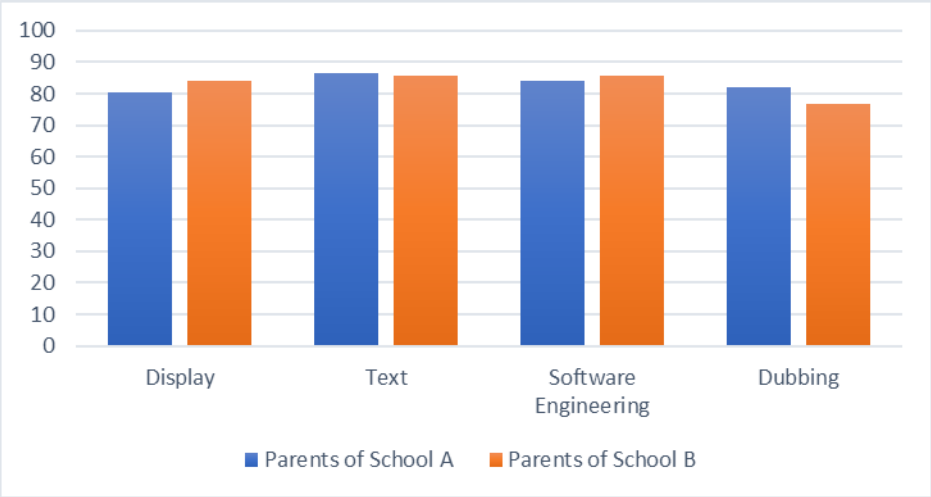

Figure 4. Application trial result

The results of a public trial of 57 parents of school A, obtained the results of application quality in the aspect of display quality by 80.56% with good criteria, writing aspects by 86.34% with very good criteria, software engineering aspects by 84.26% with good criteria, and sound dubbing aspects of 82.10% with good criteria. The results of a public trial of 43 parents of school B, obtained the results of the quality of the application in the aspect of display quality by 84.24% with good criteria, writing aspect by 85.60% with good criteria, software engineering aspects by 85.73% with criteria good, and the sound dubbing aspect is 76.81% with good criteria. Overall, the quality of learning applications assessed by 100 parents of partner schools was 83.20% with good criteria. Based on the results of data acquisition, it shows that the RME educational game based on Android called "Story Math Game" is suitable for use as a source or media for mathematics learning for 1st grade elementary school students.

The RME educational game prototype (Story Math Game final) is used to carry out limited or small-scale trials at the dissemination stage performed at partner schools with the aim of describing improvements in students' mathematical understanding abilities who have used the RME educational game in learning. At the dissemination stage, development testing was performed using a one-group pretest-posttest design experiment to see the increase in students' mathematical understanding abilities.

The results of the mathematical understanding ability test accord of pretest and posttest scores, which are used to decide the increase in students' mathematical understanding ability in learning with the RME educational game RME (Story Math Game). rested on data processing from pretest and posttest scores, the maximum score (Xmax), minimal score (Xmin), average score ($\overline{X}$) and standard deviation (Ds) were earned. Complete data can be noticed in Table 1

Table 1. Students' mathematical understanding ability

Data	N	X_{min}	X_{max}	$\overline{X}$	Ds	Achievement (%)
Pretest	30	7	11	9,23	1,25	51,27
Posttest	30	10	17	13,43	1,92	74,61
N-Gain	30	0,10	0,67	0,39	0,17	2,16

*Ideal Maximum Score = 18

Data analysis was conducted using the mean difference test. Before the data is anatomized, the prerequisite tests for statistical analysis are first conducted, videlicet the normalcy test and the variance homogeneity test. Normalcy testing of mathematical understanding ability data was calculated using the Shapiro- Wilk test with the support of SPSS 20 software. The results of computations and normalcy testing for students' mathematical understanding ability data for the pretest and posttest can be noticed in Table 2

.

Table 2. Normality test results for mathematical understanding ability

Data	Shapiro-Wilk			Conclusion
	Statistic	df	Sig.	
Pretest	0,911	30	0,015	H_0 is rejected
Posttest	0,938	30	0,079	H_0 is accepted

From table 2, it can be seen that the pretest of mathematical understanding ability obtained a significance value smaller than 0.05, meaning that H_0 was rejected, or, in other words, the pretest score data was not normally distributed. Meanwhile, in the posttest, mathematical understanding ability obtained a significance value greater than 0.05, which means that H_0 was accepted; in other words, the posttest score data was normally distributed. Because one of the data comes from a population that is not normally distributed, a non-parametric test, namely Mann-Whitney, was used to determine the significance of the difference in data improvement in mathematical understanding ability between the pretest and posttest. The results of calculations and testing of differences in ranking of pretest and posttest data on students' mathematical understanding abilities can be seen in Table 3.

Table 3. Test Results for differences in pretest and posttest rankings of mathematical understanding ability

Data	Mann-Whitney U Sig. (2-tailed)	Conclusion
Enhancement	0,000	H_0 is rejected

Based on Table 3, the test results for differences in ranking of pretest and posttest data on students' mathematical understanding abilities with Mann-Whitney obtained a significance value of 0.000, so H0 was rejected. It can be concluded that in learning with the RME educational game (Story Math Game), the ability to understand mathematics before treatment (pretest) and after treatment (posttest) is significantly different. Furthermore, based on Table 1, it can be seen that in learning with the RME educational game (Story Math Game), the student's mathematical understanding ability increased by 2.16%, thus it can be concluded that in learning with the RME (Story Math Game) educational game, students' mathematical understanding ability increased.

ICT in education is a learning innovation to foster student enthusiasm and motivation as well as assist teachers in the teaching process so that learning becomes practical and effective (Guma et al., 2013; Muhaimin & Dasari, 2022; Siswanto et al., 2023; Zakaria & Khalid, 2016). This statement is in line with research results that found that the use of Android games in learning can help students' mathematical understanding (Enjelita et al., 2023). In their research, Nisa & Susanto (2022) and Mujahadah et al. (2021) also show that the use of Android games in learning mathematics increases interest and motivation to learn, so that mathematics learning outcomes also increase.

Conclusion

Based on the development research that has been carried out, it can be concluded that 1) an Android-based RME educational game about integers called Story Math Game as an edutainment medium for 1st grade elementary school which contains stories about basic concepts of counting (addition and subtraction), practice questions and learning evaluation (with various levels of difficulty) with the characteristic of using real problems reached a feasibility level of 75.00% with good criteria from media experts and 82.32% with good criteria from material experts, 2) the media was tested publicly by 100 parents students, and the results of public trials obtained application quality results of 83.20% with good criteria, the RME educational game is suitable for use as a mathematics learning medium, and 3) Development testing resulted in an increase in the mathematical understanding abilities of 1st grade elementary school students, based on the results of data acquisition. The results show that the RME educational game can improve the mathematical understanding abilities of 1st grade elementary school students.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the authors.

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