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Development of RME-Based Cross Math Worksheets to Strengthen Pre-Service Teachers' Conceptual Understanding of Integer Properties

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Abstrak

Penggunaan LKM konvensional yang kurang interaktif di perguruan tinggi menyebabkan pemahaman konsep operasi bilangan dasar belum optimal. Penelitian ini bertujuan mengembangkan LKM berbasis game edukasi Cross Math dengan pendekatan Realistic Mathematics Education (RME), serta menguji kevalidan, kepraktisan, dan keefektifannya. Menggunakan metode Research and Development (R&D) dengan model 4D (Define, Design, Develop, Disseminate), penelitian ini melibatkan 34 mahasiswa semester I Pendidikan Matematika Universitas Muhammadiyah Bangka Belitung. Instrumen pengumpulan data meliputi lembar validasi, angket respons, serta tes pemahaman konsep (pretest dan posttest). Hasil penelitian menunjukkan bahwa LKM yang dikembangkan memenuhi kriteria sangat valid dan sangat praktis. Uji keefektifan membuktikan adanya peningkatan pemahaman konsep mahasiswa dengan ketuntasan klasikal mencapai 83,33%. Dengan demikian, LKM berbasis Cross Math dengan pendekatan RME efektif digunakan sebagai alternatif bahan ajar untuk memperkuat pemahaman konsep operasi bilangan dasar di perguruan tinggi.
***Kata Kunci**: cross math; game edukasi; lembar kerja mahasiswa; pemahaman konsep; realistic mathematics education.*

Abstract

Conventional student worksheets (LKM) in higher education often lack interactivity, resulting in suboptimal conceptual understanding of basic number operations. This study aims to develop an LKM based on the *Cross Math* educational game integrated with the Realistic Mathematics Education (RME) approach, while evaluating its validity, practicality, and effectiveness. Utilizing the Research and Development (R&D) method with the 4D model (Define, Design, Develop, and Disseminate), the study involved 34 first-semester Mathematics Education students at Universitas Muhammadiyah Bangka Belitung. Data were collected through expert validation sheets, student response questionnaires, and conceptual understanding tests (pre-test and post-test). The results indicate that the developed LKM meets the criteria for being highly valid and highly practical. Effectiveness testing demonstrated an improvement in students' conceptual understanding, with classical mastery learning reaching 83.33%. In conclusion, the *Cross Math*-based LKM with an RME approach serves as an effective alternative instructional material for strengthening the understanding of basic number operations in higher education.
Keywords: conceptual understanding; cross math educational game; number operations; Realistic Mathematics Education; student worksheet.

I. INTRODUCTION

Education is a deliberate effort to develop students' potential toward independence (Hidayat et al., 2018). In mathematics learning, students are required not only to memorize formulas but also to understand concepts, processes, and reasoning. Therefore, prospective mathematics teachers must possess strong conceptual understanding to deliver mathematical content accurately and meaningfully (Mahmudi, 2021).

However, studies show that many prospective teachers experience difficulties in mastering basic mathematical concepts, particularly number operations such as addition, subtraction, multiplication, and division (Rosyidah, 2024). Common errors include neglecting the order of operations, which is closely related to weak conceptual and arithmetic skills (Noperta, 2023; Sefriani & Darmawan, 2024). These difficulties affect achievement in foundational courses and hinder readiness for advanced mathematics, such as linear algebra and calculus. Blömeke et al. (2015) noted that low conceptual understanding contributes to insufficient initial competence among prospective mathematics teachers.

These challenges are intensified by lecturer-centered teaching methods and the limited use of engaging, contextual learning materials, resulting in passive learning and low motivation (Oktaviana & Susiaty, 2020). Moreover, instructional materials often fail to connect mathematical concepts with real-life contexts, leading to suboptimal conceptual understanding (Putri, 2019). Contextual learning has been shown to support meaningful learning by helping students relate mathematics to everyday experiences (Mutua & Obara, 2025).

Preliminary studies indicate that students in the Mathematics Education Study Program require more interactive and contextual learning media. Observations and interviews with instructors reveal persistent difficulties in solving mixed arithmetic operations, particularly in applying operation priority within contextual problems. This suggests that conventional instructional practices have not fully supported the development of students' conceptual understanding.

To overcome these issues, innovative and contextual learning approaches are needed. The Realistic Mathematics Education (RME) approach emphasizes learning based on real-life experiences, enabling students to construct mathematical understanding progressively (Natalia, 2017). RME also promotes student activeness and creativity in developing mathematical models, and has been shown to significantly improve conceptual understanding among university students (Odoh et al., 2025; Mardhiyana & Adna, 2023).

Interviews with lecturers of the Mathematics Curriculum and Instruction course indicate that the Realistic Mathematics Education (RME) approach has not yet been implemented, even though the course covers multiple mathematical objects. This condition highlights the need to apply RME to provide more meaningful and contextual learning experiences for students.

Learning media also play an important role in increasing student engagement and understanding (Arsyad, 2015; Wulandari et al., 2023). Although presentation media such as PowerPoint are used, questionnaire results show that 58.7% of students still perceive the learning process as one-directional and lacking interactivity. This indicates the need for alternative learning media, such as game-based Student Worksheets (LKM), to encourage active learning and strengthen understanding of number operations.

Student Worksheets (LKM) are designed to support conceptual understanding through guided learning activities (Aini et al., 2021). However, the LKM currently used tend to be conventional and less interactive, as they mainly contain summaries and practice questions, resulting in limited student engagement and conceptual exploration. Therefore, integrating educational games into LKM is necessary to enhance learning quality.

Educational games such as Cross Math can improve engagement, concentration, and conceptual understanding through visual and logical activities (Valentza, 2024). When combined with the RME approach, Cross Math offers a student-centered and meaningful learning alternative. The LKM developed in this study focuses on number operations through set concepts, which form a fundamental basis for understanding arithmetic operations. Questionnaire results and lecturer interviews indicate that these topics are essential yet remain difficult for students to master, despite their importance for advanced mathematics learning and the professional competence of prospective mathematics teachers (Suwarto, 2018).

Based on the literature review and current learning conditions, there is a gap between the need for interactive and contextual mathematics learning and the instructional materials currently available. Although studies on RME and game-based learning exist, research on the development of LKM integrating the Cross Math educational game with the RME approach to strengthen conceptual understanding of number operations among prospective mathematics teachers is still limited. Therefore, this study aims to develop a Cross Math educational game–based Student Worksheet using the RME approach and to examine its validity, practicality, and effectiveness.

II. Method

This study employs the Research and Development (R&D) method aimed at developing Student Worksheets (LKM) based on the *Cross Math* educational game, integrated with the Realistic Mathematics Education (RME) approach. The product development focuses on three quality criteria—validity, practicality, and effectiveness—by implementing the 4D development model: Define, Design, Develop, and Disseminate (Thiagarajan in Winaryati et al., 2021).

In the Define phase, learning needs were identified through lecture observations, interviews with course instructors, and the administration of student questionnaires. The Design phase involved structuring the LKM, developing material on number operations through set concepts, and constructing research instruments.

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Subsequently, the Develop phase included validation by subject matter and media experts, product revisions based on expert feedback, and conducting both small-scale and large-scale field testing. The Disseminate phase was carried out on a limited basis by introducing the final product to faculty members and students within the study program (Maydiantoro, 2021).

The research subjects consisted of 30 first-semester students from the Mathematics Education Study Program at Muhammadiyah University of Bangka Belitung for the 2025/2026 academic year, selected via purposive sampling. Selection criteria included active students enrolled in number operations courses, those with no prior experience using educational game-based LKM, and those willing to participate in the entire research series. The object of this research is the *Cross Math* educational game-based LKM.

Research instruments included expert validation sheets, student response questionnaires, and conceptual understanding tests in the form of pre-tests and post-tests. Instrument validation was conducted by subject and media experts to assess content suitability, the accuracy of number operation concepts, integration with the RME approach, as well as aesthetic and linguistic aspects. The practicality of the LKM was analyzed based on student feedback and learning implementation observations, while effectiveness was determined through a comparison of pre-test and post-test results, alongside individual and classical mastery learning analysis. Data were analyzed using descriptive quantitative and qualitative methods (Akbar, 2013).

III. Result and Discussion

Development of a Cross Math Educational Game–Based Student Worksheet Using the RME Approach

The development of a Cross Math educational game–based Student Worksheet (LKM) using the Realistic Mathematics Education (RME) approach employed the 4D model, consisting of the define, design, develop, and disseminate stages. The define stage aimed to identify learning needs, core concepts, evaluation components, and instructional specifications through front-end, learner, task, and concept analyses, as well as the formulation of learning objectives (Maydiantoro, 2021).

The design stage involved media and format selection, initial product design, and the development of assessment instruments. The selected medium was a Cross Math educational game–based LKM, chosen based on needs analysis indicating that activity- and game-based learning environments enhance student engagement and conceptual understanding.

The LKM serves as a structured guide that supports students in developing critical thinking and progressively discovering mathematical concepts (Aini, 2021). The integration of the Cross Math game enhances motivation and understanding of number operations, while the RME approach supports meaningful learning through real-life contexts, enabling students to construct mathematical knowledge independently (Fitriyani, 2024).

The format of the Student Worksheet (LKM) was systematically designed in accordance with the stages of Realistic Mathematics Education (RME), which consist of the situational, referential, general, and formal stages (Gravemeijer, 1994), as illustrated in the following Figure 1.

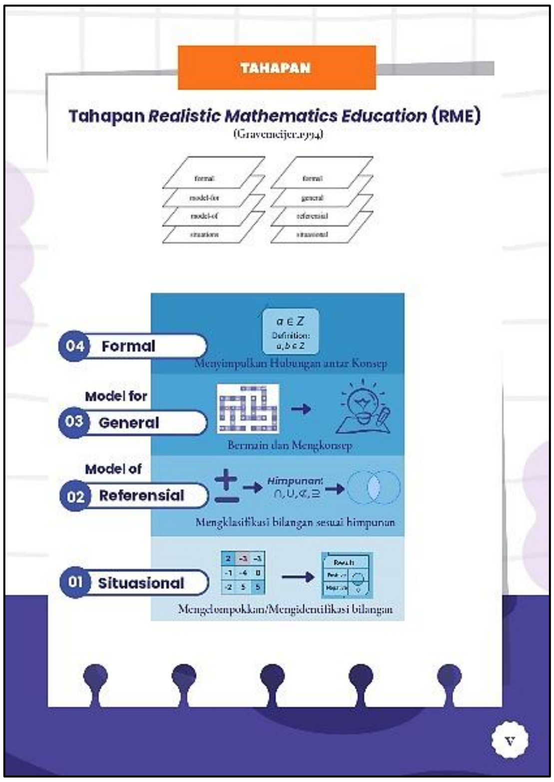

Figure 1. Stages of Realistic Mathematics Education (RME).

At this stage, the structure of the LKM was aligned with students' learning needs through the design of problem-based activities that enable students to connect gameplay processes with formal mathematical problem solving. The Realistic Mathematics Education (RME) approach emphasizes learning through real-life contexts, allowing students to construct their own understanding of mathematical concepts in a meaningful way (Fitriyani, 2024). In addition, the learning atmosphere becomes more engaging and enjoyable by incorporating real-world situations into the learning process (Destiara, 2023).

During the development stage, the researchers ensured that the LKM design was aligned with students' characteristics and the learning needs related to number operations in the Mathematics Education Study Program. The RME principles applied in this study refer to Freudenthal (1991) and Gravemeijer (1994), which emphasize the use of contextual problems as the starting point of learning, followed by a gradual mathematization process through Cross Math game activities, and concluded with reflection to strengthen conceptual understanding. The LKM was organized in a systematic sequence, beginning with contextual exploration, followed by core activities using the Cross Math game, group discussions, and reflective activities.

In addition, supporting instruments were developed, including expert validation sheets, learning implementation observation sheets, and student response questionnaires. All instruments were constructed based on established principles for developing scientific research instruments (Sugiyono, 2017). The design of the developed LKM is presented in Figure 2.

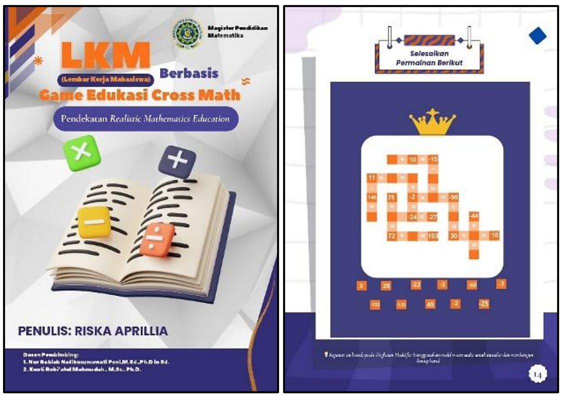

Figure 2. LKM Design.

In addition to product design, assessment instruments were also developed at this stage, including validation instruments for subject-matter experts and media experts, student and lecturer response questionnaires, as well as test instruments in the form of pretests and posttests to measure students' mathematical conceptual understanding. The development of the instruments by subject-matter and media experts referred to the guidelines for instructional material development issued by the Ministry of National Education (Depdiknas, 2008).

All instruments were constructed based on indicators of conceptual understanding and the principles of Realistic Mathematics Education (RME), and were subsequently validated by expert validators. The validation results indicated that the instruments were feasible for use with minor revisions. Therefore, these instruments were deemed appropriate for assessing the validity, practicality, and effectiveness of the developed LKM during the development and subsequent trial stages.

Validity of the Cross Math Educational Game–Based LKM with the RME Approach

After the LKM was developed, a validation process was conducted involving two types of experts, namely subject-matter experts and media experts. Prior to implementation and field testing, the initial design of the instructional media must be validated by experts to ensure its appropriateness and quality (Batubara, 2020). Instructional media should be accurate and precise in order to effectively present educational content that reflects essential characteristics such as phenomena, concepts, theories, and abstractions (Alti et al., 2022). Furthermore, Ulfah et al. (2025) emphasize that expert validation is a crucial stage in ensuring the quality and feasibility of instructional materials.

The validity of the LKM was examined through evaluations by subject-matter experts and media experts. Subject-matter validation focused on the alignment of content with the curriculum, the accuracy of numerical operation concepts, the integration of the Realistic Mathematics Education (RME) approach, as well as the clarity of learning objectives and activities. Meanwhile, media expert validation assessed aspects related to visual appearance, presentation, language use, and graphic design of the LKM.

The validation results indicate that the Cross Math educational game–based LKM with the RME approach falls into the very valid category. The results of the subject-matter expert validation are presented in the following Table 1.

Table 1.
Results of Material Expert Validation

Validator	Total Score
Validator 1	128
Validator II	142
Validator III	146
Total Score	416
Average Total Score	138,7
Category	Very Valid

During the validation process, subject-matter experts evaluated the accuracy of the concepts, the alignment of the content with the curriculum and the RME approach, as well as the clarity of the learning activities presented in the LKM. The validation results show that the total score obtained from subject-matter expert 1 was 128, from expert 2 was 142, and from expert 3 was 146. The average score from the three subject-matter experts was 138.7, which falls into the very valid category. Therefore, the developed LKM is considered feasible for use in terms of content quality.

In addition, media experts provided feedback related to visual quality, layout suitability, typographic consistency, and the attractiveness of the page design. The results of the media expert validation are presented in the following Table 2.

Table 2.
Results of Media Expert Validation

Validator	Total Score
Validator 1	101
Validator II	89
Total Score	190
Average Total Score	95
Category	Very Valid

Based on the media expert validation results, the average score obtained from the two media experts was 95, which falls into the very valid category. These results indicate that the developed LKM is valid and feasible for use from a media perspective. From a theoretical standpoint, the validity of the LKM demonstrates that the integration of educational games with the Realistic Mathematics Education (RME) approach is capable of presenting number operation concepts in a contextual and meaningful manner. This finding is consistent with Batubara (2020), who stated that valid instructional materials should systematically represent concepts and align with students' characteristics. Therefore, the developed LKM is suitable for use as a learning material in mathematics instruction at the higher education level.

Practicality of the Cross Math Educational Game–Based LKM with the RME Approach

The next stage was implementation as part of the dissemination phase. The trial implementation of the Cross Math educational game–based LKM with the Realistic Mathematics Education (RME) approach was conducted with 30 third-semester students of the Mathematics Education Study Program at Universitas Muhammadiyah Bangka Belitung. The learning implementation focused on number operations and set concepts, with all learning activities centered on the use of the LKM.

The implementation was initially carried out in a small-group trial involving six Mathematics Education students. The process began with an explanation of the learning objectives and instructions for using the LKM. During the implementation, students were guided to understand the given contextual problems, complete the Cross Math game as a bridge to understanding number operations, and discuss the problem-solving strategies they applied.

The learning activities were structured according to the stages of the Realistic Mathematics Education (RME) approach to strengthen students' conceptual understanding through task-based activities. The first stage was the situational stage, in which students were introduced to contextual problems related to number operations and real-life situations familiar to their experiences. The activities in the LKM guided students to identify and classify numbers. The Cross Math format is commonly perceived as a procedural drill tool that emphasizes computational accuracy. However, in this study, the integration of the RME approach transformed Cross Math from a mechanical exercise into a learning medium that supports conceptual understanding. The RME approach emphasizes meaningful contexts, mathematical reasoning, and active student engagement in knowledge construction.

Through the stages of RME, students are not only required to complete Cross Math tasks but also to understand the problem context, identify relationships among number operations, and discuss the strategies they employ. In the initial stage, Cross Math functions as a *model of*, helping students visually and systematically represent number operation concepts. Through reflection and discussion, Cross Math then evolves into a *model for*, enabling students to generalize rules and relationships among number operations.

Thus, the application of the RME approach shifts Cross Math from a purely mechanical drill into a tool for the gradual and meaningful construction of conceptual understanding. This integration allows students to develop deeper conceptual insight into number operations, rather than merely procedural skills. Examples at the situational stage of the LKM development are presented in Figure 3.

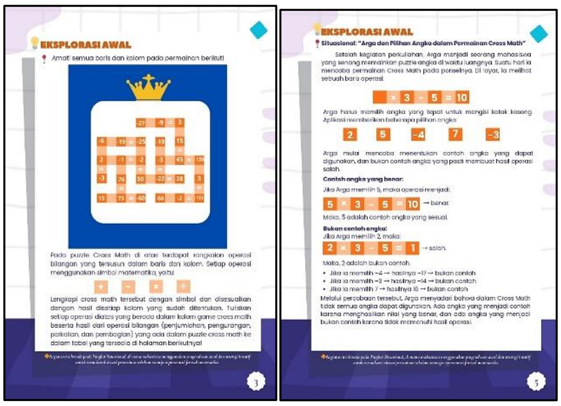

Figure 3. Activity 01 – Situational.

The second stage was the referential stage (model of). At this stage, students began to use representations or models to describe the situations they had previously understood. In this study, students related number operations to set concepts, such as integers, positive numbers, and negative numbers. Examples of students' work on the Student Worksheet (LKM) at the referential stage are presented in Figure 4.

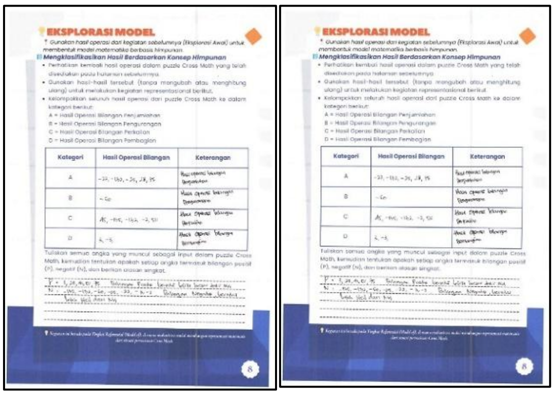

Figure 4. Activity 02 – Referential Stage (Model of).

The third stage was the general stage (model for). At this stage, students began to generalize the patterns and relationships identified in the previous stage. The Cross Math game was no longer perceived merely as a playing activity, but as a means to conceptualize the general rules of number operations. Students started to recognize the relationships among operations, the rules of operational precedence, and the connections among elements within number sets. This process indicates a transition from context-dependent models to more general models that can be applied to solve a variety of mathematical problems. Examples of students' work on the Student Worksheet (LKM) at this stage are shown in Figure 5.

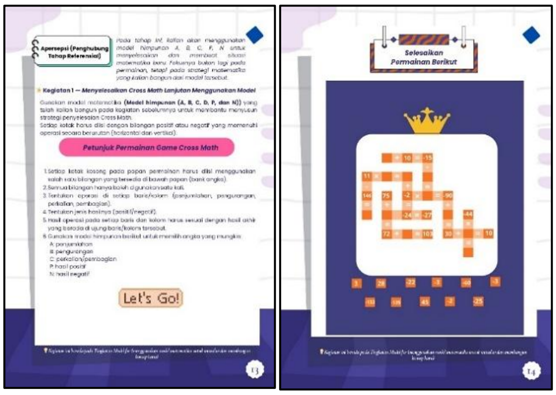

Figure 5. Activity 03 – General Stage (Model for).

The fourth stage was the formal stage. At this stage, students were guided to draw conclusions about the relationships among concepts using formal mathematical symbols and notation. Students expressed their understanding through standard symbols, definitions, and established rules of number operations. Examples of students' work on the Student Worksheet (LKM) at this stage are presented in Figure 6.

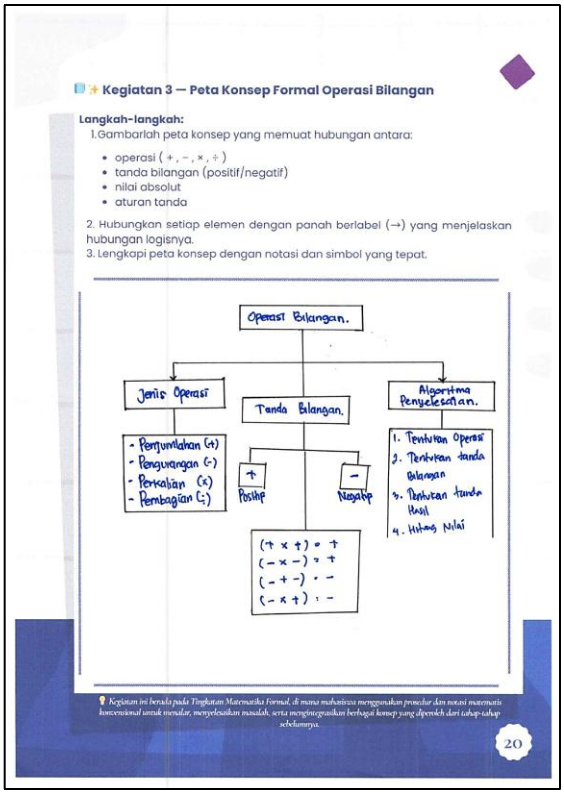

Figure 6. Activity 04 – Formal Stage

Based on the observation results, the implementation of the learning activities proceeded effectively. Students were more actively engaged in discussions, demonstrated greater creativity in determining problem-solving strategies, and showed high enthusiasm for game-based activities. These findings are consistent with Prihaswati et al. (2018), who reported that activity-based student worksheets can enhance students' engagement and conceptual understanding through exploratory tasks and group discussions. Students' learning activities using the Student Worksheet (LKM) are presented in Figure 7.

Figure 7. Implementation Activities of the LKM by Students

The course instructor also provided positive feedback, stating that the use of the LKM made the learning process more interactive, created an enjoyable learning experience, and helped students understand number operation concepts that were previously perceived as abstract. This finding aligns with the study by Rasul et al. (2022), which reported that the use of student worksheets significantly improves students' mathematical understanding.

In addition to classroom observations, students' responses were analyzed using a questionnaire consisting of 14 components. The results showed a total score of 364 from six respondents, with an average score of

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60.67. When compared with the maximum ideal score of 70 and the established assessment criteria, this average score falls into the "very practical" category.

Furthermore, the results of the large-class trial demonstrated a similar trend. The large-class implementation involved 24 third-semester students of the Mathematics Education Study Program at Universitas Muhammadiyah Bangka Belitung. During the trial, the LKM served as the primary learning medium in classroom activities. After the implementation, a student response questionnaire was administered to evaluate the practicality of the LKM. The average response score was 59.46, which also falls into the "very practical" category, indicating that the developed LKM is practical based on the practicality evaluation.

These findings indicate that students perceived the LKM as easy to use, visually appealing, clearly presented, and highly supportive in understanding number operation materials. This result is in line with Buyung and Hendriana (2020), who stated that student worksheets designed with a well-structured sequence of activities can enhance students' conceptual understanding through guided exploration. Students also reported that the use of the Cross Math game provided a challenging yet enjoyable learning experience and increased their motivation to complete each assigned activity. This finding supports Ningrum (2018), who found that game-based learning media can improve students' motivation and persistence in completing mathematical tasks, as elements of challenge and immediate feedback create a more engaging learning environment.

By the end of the research implementation period, all required outputs had been successfully achieved. The final version of the LKM was completed, research instruments were applied, validation and revision processes were conducted, and the implementation was successfully carried out. In addition, the researcher disseminated the research findings through publication in a nationally accredited journal. Overall, this study makes an important contribution to the development of innovative instructional materials that strengthen students' conceptual understanding of number operations.

Effectiveness of the Cross Math Game-Based Student Worksheet with the RME Approach

The effectiveness of the developed Student Worksheet (LKM) was evaluated through the administration of a pretest prior to the implementation of the learning activities. The pretest aimed to identify students' initial abilities related to number operation concepts before using the LKM. The pretest results provided an overview of students' baseline conceptual understanding and served as a reference for examining learning gains after the implementation.

Following the pretest, learning activities were conducted using the Cross Math game-based LKM in the large-class setting. During the implementation phase, students engaged in a complete sequence of learning activities, including contextual problem understanding, completion of Cross Math game tasks, group discussions, and final reflections in accordance with the characteristics of the Realistic Mathematics Education (RME) approach. Throughout the learning process, observations were conducted to document instructional implementation and students' active participation as part of the evaluation of the LKM.

After the learning activities were completed, a posttest was administered to measure students' conceptual understanding after using the LKM. The posttest results were compared with the pretest results to identify changes in students' learning outcomes. Differences between pretest and posttest scores served as initial indicators of the effectiveness of the LKM in improving students' understanding of number operation concepts.

Furthermore, the effectiveness of the LKM was analyzed by examining the increase in students' learning scores using appropriate statistical techniques, including the analysis of individual mastery and classical mastery. The pretest and posttest data were interpreted to determine whether a significant improvement occurred after students participated in learning activities using the Cross Math-based LKM. This analysis formed the basis for concluding whether the developed product met the established effectiveness criteria. The posttest results indicate an improvement in students' conceptual understanding, as described in the following analysis.

1. Individual Learning Mastery

Based on the posttest results, out of 24 students, 20 students (83.33%) achieved the mastery criterion with a score percentage of ≥ 70, while the remaining 4 students (16.67 %) did not reach mastery. This result suggests that the effectiveness of the developed worksheet was not uniformly distributed across all learners. The lack of mastery among a small proportion of students may be attributed to differences in prior knowledge, learning styles, and limited adaptation time to game-based learning and the RME approach. These findings indicate that the majority of students were able to understand the learning material effectively through the use of the developed LKM, although several students still require remedial instruction to address their learning gaps.

This achievement is consistent with the perspective of Sitepu and Lestari (2018), who emphasize that learning outcome assessment in higher education serves to determine the extent to which learning objectives have been achieved by students. Furthermore, Akbar (2016) states that learning instruments can be used to assess students' level of mastery of the instructional material, thereby providing an overview of their learning completeness. The high proportion of students achieving mastery in this study suggests that the developed LKM is effective in strengthening students' conceptual understanding. To better support students who did not achieve mastery, the worksheet could be adapted by incorporating additional reinforcement activities, such as simplified contextual problems, step-by-step examples, and more structured reflection prompts. Furthermore, the application of scaffolding strategies and small-group discussions may assist students in developing deeper conceptual understanding. With these adaptations, the Cross Math game–based worksheet is expected to better accommodate diverse student needs and enhance learning outcomes more comprehensively.

2. Classical Learning Mastery

After analyzing individual student mastery, the results were used as the basis for calculating classical learning mastery following the implementation of the Cross Math-based LKM with the Realistic Mathematics Education (RME) approach, as presented below.

$$\mathrm{CLM} = \frac{20}{24} \times 100\,\% = 83{,}33\,\%$$

Based on the calculation results of 24 students, 20 students achieved learning mastery, indicating that the overall level of conceptual understanding attainment reached 83.33%. This result demonstrates that the majority of students met the mastery criteria established by the higher education institution. This finding is in line with Kusuma and Afriliana (2018), who state that classical learning mastery is an important indicator in evaluating the effectiveness of instructional implementation.

3. Analysis of Conceptual Understanding Ability

The test results were further analyzed to examine the extent to which students' conceptual understanding abilities were achieved. A more detailed analysis revealed variations in students' performance, ranging from very low to very high categories. Although a small number of students remained in the low and very low categories, the majority of students were classified within the moderate to high categories, and one student achieved a very high level of conceptual understanding. These findings indicate that the Cross Math–based educational game LKM is capable of supporting most students in achieving satisfactory learning outcomes, although individual differences continue to influence final achievement.

A comparison of the pretest and posttest score distributions shows a substantial improvement. During the pretest, most students were categorized in the very low and low levels. However, after participating in learning activities using the developed LKM, the achievement levels shifted toward the moderate, high, and very high categories. This shift indicates that the use of interactive LKM integrated with the Realistic Mathematics Education (RME) approach is effective in gradually developing and strengthening students' conceptual understanding of numerical operations.

Improvements in conceptual understanding were also observed across all indicators of mathematical conceptual understanding. Scores on the indicators of restating concepts, classifying objects, relating various concepts, and concluding as well as integrating concepts showed notable increases from the pretest to the posttest. The results of the percentage analysis of pretest and posttest achievement for each aspect of conceptual understanding, based on the students' test data, are presented in the following Figure 8.

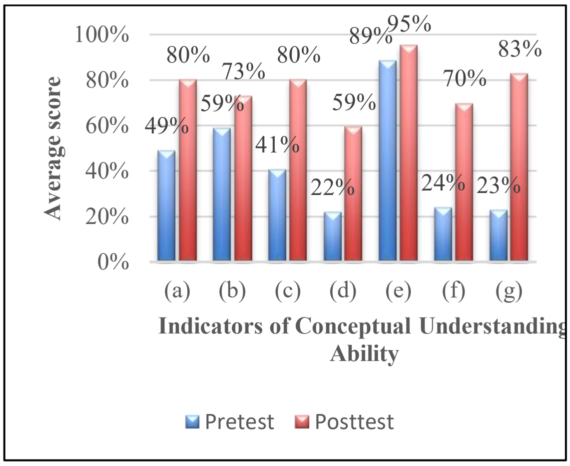

Figure 8. Percentage of Achievement for Aspects of Conceptual Understanding Ability.

Based on the figure above, it can be observed that there was an improvement between the pretest and posttest across all indicators of conceptual understanding ability. For indicator (a), *restating the learned concepts*, the score increased from 49% in the pretest to 80% in the posttest. Indicator (b), *providing examples and non-examples*, showed an increase from 59% in the pretest to 73% in the posttest. Indicator (c), *classifying objects based on a particular concept*, improved from 41% in the pretest to 80% in the posttest. Indicator (d), *representing concepts in various forms*, increased from 22% in the pretest to 59% in the posttest. Indicator (e), *implementing concepts algorithmically*, rose from 89% in the pretest to 95% in the posttest. Indicator (f), *relating mathematical concepts internally or externally*, increased from 24% in the pretest to 70% in the posttest. Finally, indicator (g), *drawing conclusions and integrating all indicators*, showed a substantial increase from 23% in the pretest to 83% in the posttest.

These results indicate that learning through the developed LKM not only enhances students' procedural abilities but also strengthens their overall conceptual understanding. For a clearer description, the results of students' performance on the pretest items are presented in the following Figure 9.

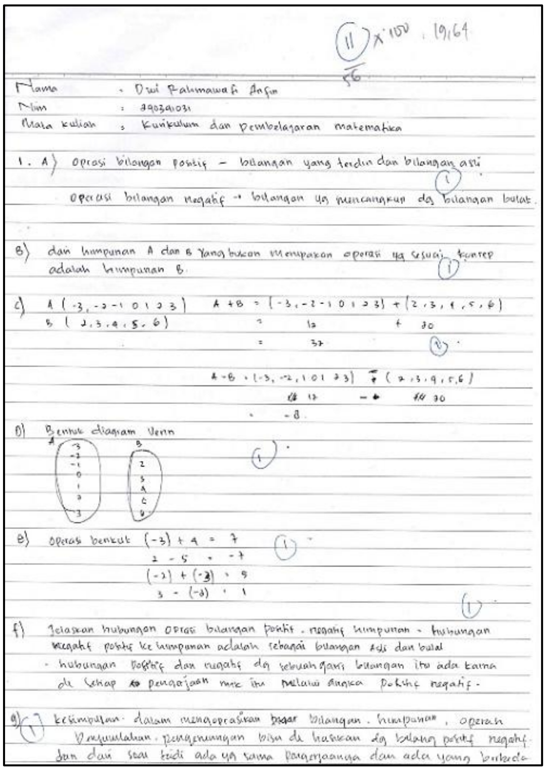

Figure 9. Students' Pretest Results on Conceptual Understanding Aspects.

The pretest was administered prior to the implementation of learning using the Cross Math educational game–based Student Worksheet (LKM) with the Realistic Mathematics Education (RME) approach, aiming to identify students' initial abilities in understanding number operation concepts. An example of students' pretest work is presented in Figure 9. Based on the figure, it can be observed that students attempted to solve problems related to number operations and set concepts. However, the given responses still indicate several conceptual misconceptions, particularly in relating positive and negative number operations to set representations. These errors suggest that students tended to apply computational procedures mechanically without sufficient conceptual understanding.

These findings indicate that, at the initial stage, students' conceptual understanding abilities were still in the low category, especially on the indicators of relating various mathematical concepts and representing concepts appropriately. This condition reinforces the urgency of developing a Cross Math educational game–based LKM integrated with the RME approach, which is designed to support students in gradually constructing conceptual understanding through real-life contexts, game-based activities, and reflective processes. The posttest results showed that the average student score was higher than the average pretest score, with an increase in the mean score of 33.48 points. The results of students' performance on the posttest items are presented in the following Figure 10.

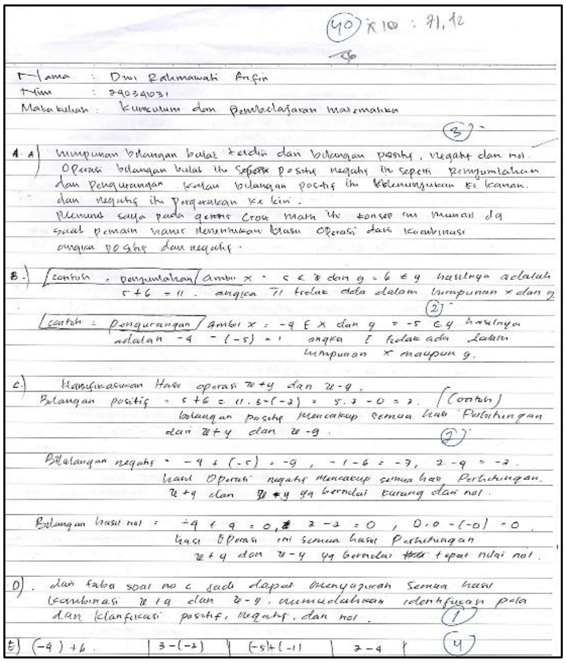

Figure 10a. Students' Posttest Results on Conceptual Understanding Aspects [1].

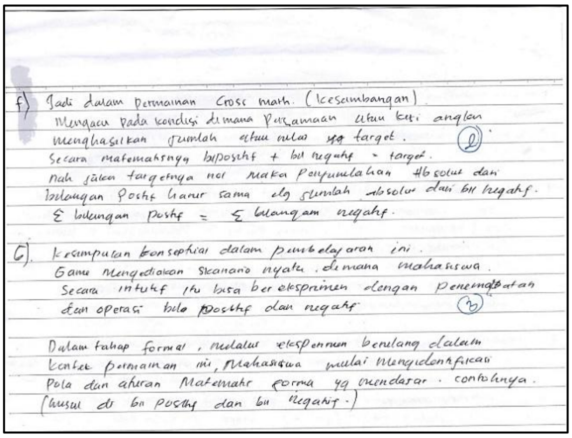

Figure 10b. Students' Posttest Results on Conceptual Understanding Aspects [2].

After the entire learning process using the Cross Math educational game–based Student Worksheet (LKM) integrated with the Realistic Mathematics Education (RME) approach was completed, students were administered a posttest to measure their level of mastery of number operation concepts after the instructional intervention. The posttest aimed to compare students' final abilities with their initial abilities obtained from the pretest stage. Based on the posttest results, students' conceptual understanding scores showed a very significant improvement. All students demonstrated an increase in their scores.

These results indicate that students experienced not only quantitative improvements but also qualitative enhancements in their understanding of number operation concepts. The observed improvement suggests that learning through the Cross Math educational game–based LKM with the RME approach effectively supports students in constructing conceptual understanding progressively, starting from real-life contexts, moving through model representations, and culminating in formal mathematical understanding. Therefore, the developed LKM is proven to be effective in comprehensively improving students' conceptual understanding of number operations.

IV. Conclusion

This This study resulted in the development of a Student Worksheet (LKM) based on the Cross Math educational game integrated with the Realistic Mathematics Education (RME) approach to strengthen students' conceptual understanding of number operations. Developed using the 4D model, the LKM was found to meet the criteria of validity, practicality, and effectiveness. The validity of the product was confirmed through evaluations by material and media experts, indicating that the content, presentation, and design were appropriate for learning purposes. The practicality of the LKM was supported by positive student responses in both small-group and large-group trials, demonstrating that the worksheet was easy to use, visually engaging, and supportive of learning activities.

The effectiveness of the developed LKM was evidenced by an increase in students' conceptual understanding, as reflected in a classical mastery level of 83.33%, which exceeded the minimum effectiveness criterion, as well as a shift in achievement levels from low to moderate, high, and very high categories after the implementation of the LKM. These results indicate that the integration of Cross Math with the RME approach transforms the game from a mere drill-based activity into a meaningful learning tool. Through contextual problems, guided exploration, and reflective discussion, Cross Math functions as a medium for conceptualizing number operations rather than simply practicing procedures.

Overall, the findings demonstrate that the Cross Math–based LKM supported by RME not only enhances procedural skills but also strengthens students' conceptual understanding by encouraging active engagement, reasoning, and reflection. However, this study is limited by the number of participants and the scope of the material, which focused on number operations through set concepts. Therefore, future research is recommended to expand the application of game-based LKMs to other mathematical topics, involve larger and more diverse samples, and further investigate the affective impact of game-based learning, such as students' motivation, engagement, and perceptions of mathematics as a subject often considered challenging or intimidating.

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