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COLLABORATIVE LEARNING APPROACH TO MASTER KPK AND FPB CONCEPTS

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Abstract

This research seeks to improve students' understanding of KPK and FPB concepts at SDN Cemerlang by addressing the constraints associated with the use of concrete media in mathematics instruction. Through the ADDIE model R&D method, Dakonball media based on *Collaborative Learning* was developed with 40 students. The validation results of material experts (93%), media (100%), and practitioners (93%) stated that the product is very feasible. The implementation showed a significant increase in learning outcomes, from an average *of 35.13 pre-tests to 83.19 in the* post-test. The results of the Paired Sample T-Test showed a significance value of 0.000, which is below the significance threshold ($\alpha = 0.05$). With an *N-gain* of 0.73 (high category) and a positive response from students (90%), Dakonball media proved to be valid, practical, and statistically effective as an interactive mathematics learning solution in elementary schools.

Keywords: Collaborative Learning; Dakonball; KPK and FPB; Elementary School

INTRODUCTION

As the primary foundation of nation building, education is designed to systematically foster the comprehensive development of students' potential, including intellectual intelligence and noble character, in accordance with Law Number 2 of 2003. In the context of contemporary learning, the educational paradigm ideally leads to student-centered learning (*student centered learning*) (Firmansyah & Jiwandono, 2022). However, practice in the field shows that teaching methods are often still dominated by monotonous lecture methods. The limitation of these variations in methods has the potential to cause boredom and interfere with student learning activities, so the presence of learning media is important as an effective means of conveying educational messages.

This matter holds significant importance in mathematics education at the primary school level, particularly concerning the concepts of Least Common Multiple (KPK) and Greatest Common Factor (FPB). Although these concepts are abstract in nature, they play a crucial role in developing students' logical reasoning abilities and serve as a foundational prerequisite for learning advanced mathematics (Izzah et al., 2024). Empirical evidence from the field shows a low level of concept mastery among students, as evidenced in the context of the average score of fifth grade students (40), which is far below the minimum competency standard (71). This inadequate understanding is exacerbated by a high level of misconceptions in solving story problems and procedural errors (Pristiwanti & Yuhana, 2024). According to Fitriani et al., (2024), about 80% of elementary school students experience misconceptions in this material.

This learning difficulty arises due to a mismatch between teaching methods and the stages of students' cognitive development. Based on Jean Piaget's theory, it is explained that Elementary school students are positioned in the concrete operational phase of cognitive development, as described in Piaget's developmental theory, which requires physical objects to build understanding before turning to abstract thinking (Piaget, 1952). Unfortunately, expository learning practices that lack the use of concrete media fail to

meet this need (Firdaus et al., 2024). Beyond the cognitive aspect, factors such as math anxiety and low thinking skills also hinder problem-solving abilities (Sintika et al., 2021). Therefore, interventions that involve where learning media that are not only visual but also interactive play a crucial role.

However, despite the extensive research on Dakon-based media for mathematics, such as research conducted by Yusantika, (2025) and Setyawati, (2025), a significant research gap persists. Most existing developments focus primarily on the media's validity and its effectiveness in individual or competitive settings. There is a notable lack of research that explores the integration of Dakon media with a structured Collaborative Learning framework one that emphasizes positive interdependence and shared roles (operator, recorder, and verifier). Previous tools often fail to bridge the gap between concrete manipulation and social constructivist interaction, leaving a need for media that intentionally facilitates peer to peer knowledge construction within the Zone of Proximal Development (ZPD).

As a solution, this study proposes the development of an innovative media called Dakonball (*Dakon Ball*), which is integrated with a collaborative learning approach. This medium adapts the traditional dakon game to visualize the concept of factors and multiples (Komariah, 2020), while incorporating the principles of learning through play (Rini, 2025). The novelty of this study is characterized by a comprehensive modification spanning physical, methodological, and theoretical frameworks. Physically, Dakonball is designed as an ergonomic box game featuring a modified board labeled with the numbers 1 to 110, to accommodate more complex number operations. This innovation is combined with a collaborative learning approach that shifts the mechanics of play from mere individual or competitive tools to tools of social interaction through structured role assignments that encourage positive interdependence. In addition, this development concretely implements Vygotsky's theory of Social Constructivism, equipping the media with supporting elements such as question cards and digital guides to facilitate the construction of students' knowledge through peer-to-peer interaction in *Zone of Proximal Development* (ZPD) (Amelia & Wibowo, 2024).

Aims to develop Dakonball media grounded in collaborative learning principles and evaluate its effectiveness in enhancing students' comprehension of Least Common Multiple (KPK) and Greatest Common Factor (FPB) concepts through iterative design processes and expert validation. In addition, mzathematics is often seen as a more innovative, creative, and interactive subject to increase student motivation and participation (Sarwoedi et al., 2025). By showing superior efficacy over lecture methods through empirical testing, this study seeks to contribute to pedagogical innovations that encourage a peer-supported learning environment. This comprehensive evaluation not only validates the practical usefulness of Dakonball media, but also provides information for education reform aimed at integrating game-based strategies and social constructivism into the curriculum.

Through the development of Dakonball media, a deep understanding of the concept structure of the KPK and FPB is the main expected result. In theoretical frameworks, KPK is defined as the smallest positive integer that is a joint multiple of two or more numbers, and serves a crucial function in the standardization of denominators during fraction operations. In contrast, FPB is defined as the greatest positive integer that divides evenly into all the given numbers, and plays a pivotal role in fraction reduction as well as determining optimal groupings (Permana et al., 2020). Although these two concepts have different orientations, they are closely related through the prime factorization method, where the KPK is obtained by multiplying all prime factors with the highest exponents that appear in the prime factorization of the numbers in question, while FPB is through the multiplication of prime factors with the

smallest rank (Fanani et al., 2024). The integration of these concepts into concrete media is anticipated to strengthen computing skills while fostering the foundation of students' analytical thinking towards the relationship between numbers in a more meaningful way.

The abstract implementation of the concepts of the KPK and FPB requires strong theoretical support through Vygotsky's Social Constructivism, which is the construction of knowledge construction through social interaction within the Proximal Development Zone (ZPD). Scaffolding from a competent teacher or friend solves collaborative problems, maximizing the internalization of mathematical concepts (Amelia & Wibowo, 2024). The effectiveness of conceptual mastery in elementary school depends on the balance of the material with Piaget's Concrete Operational Stages, in which the manipulation of physical objects and mental reversibility favor complex mathematical operations. Concrete media are needed to symbolically depict physical reality through direct experience, not memorization (Wathoni, 2024). This approach is reinforced by the Play-While Learning Principle, which makes play a safe space for cognitive and social exploration without the pressure of failure. Teachers act as facilitators with structured interventions (Maunary et al., 2025)The integration of Vygotsky's social interactions, Piaget's concrete manipulation, and play form the philosophical foundation of Dakonball's media development for Long-term mathematical proficiency.

Efforts to integrate the theoretical framework into pedagogical practice are supported by various empirical studies that utilize analog media. Yusantika et al., (2025) demonstrated that Dakota media (mathematics dakon) showed very high validity, the evaluation score of the material expert reached 95.58% and the media expert reached 88.75%, which significantly contributed to the improvement of student understanding. In line with these findings, Setyawati et al., (2025). The study revealed a substantial enhancement in learning outcomes, as evidenced by the mean score rising from 47 to 86. through the implementation of dakon media on he subjects of Least Common Multiple (KPK) and Greatest Common Factor (FPB). The effectiveness of this methodology is corroborated by the results. Trisnawati et al., (2025), which stresses the adaptive capacity of traditional games in transforming abstract concepts into concrete, interactive learning experiences through group exploration.

In addition to the cognitive dimension, the affective dimension in the learning process also receives crucial attention. Wibowo et al., (2021) reported that a dynamic and interesting learning environment through Dakon media succeeded in increasing learning outcomes from 71.30 to 81.73. Furthermore, Pandie & Manapa, (2021)) provides a strong argument that the transformation of learning through game media is the right approach to increase the effectiveness of teaching the material. Despite having similar media objects, this research offers innovation through the development of Dakonball media that specifically combines educational ball games with collaborative learning methods. The main focus of this development is not only on strengthening conceptual understanding, but also on optimizing students' collaboration skills and social interaction in the classroom environment.

METHODS

This research was implemented utilizing the Research and Development (R&D) framework to produce products that have gone through the stages of development and validity tests systematically (Scott, 2024), This development design adopts the ADDIE model encompasses five sequential and cyclical stages, consisting of Analysis, Design, Development, Implementation, and Evaluation. Below is an elaborated explanation of each phase within the ADDIE model utilized in the development process of Dakonball media.

Figure 1. ADDIE Plot

The adoption of this model is grounded in a systematic structure in solving learning problems and its flexibility to make improvements at every stage to ensure that the product aligns with the developmental characteristics of elementary school students. This study employs the ADDIE model as a developmental framework within the Research and Development (R&D) approach, given that the model encompasses systematic, flexible, and iterative stages, thereby enabling improvements at each phase (Waruwu, 2024).

This research was conducted at SDN Cemerlang, Sukabumi City during the 2025/2026 school year. The research subjects consisted of 40 students in class V who were selected through purposive sampling. The sample selection was predicated upon students' difficulties in comprehending the concepts of KPK and FPB, as well as the school's support for the implementation of collaborative learning through innovative media.

Data collection techniques interviews, questionnaires, and assessments. The research instruments encompass validation sheets (for media experts, material specialists, and practitioners) to evaluate feasibility, student response questionnaires to determine practicality, as well as learning outcome tests (pre-test and post-test) to measure the effectiveness of the developed media. The data analysis technique is divided into two. First, the product feasibility analysis from experts and practitioners is analyzed in a quantitative descriptive manner using the following percentage formula:

$$P = \frac{f}{N} \times 100\%$$

Remarks
P = Percentage number
F = Score obtained
N = Maximum score

Second, the effectiveness analysis is carried out statistically implementing a single-group preexperimental design with before and after testing design. In this design, the treatment effect is determined by comparing the pre-test scores before using the Dakonball media with the post-test scores after the intervention. The research instrument used was a learning outcome test consisting of 10 essay items. Prior to use, the instrument underwent an item analysis which included validity and difficulty level tests. The instrument's internal consistency was assessed through Cronbach's Alpha reliability coefficient to confirm the stability and dependability of the test items. The Shapiro-Wilk normality test was utilized as a prerequisite assessment, following the methodology of (Mellita & Lestari, 2023), because n < 50) was conducted, followed by a paired samples t-test to determine the significance of differences in learning outcomes (Rahmani et al., 2025). Improved understanding of concepts is measured using the Normalized Gain (N-Gain) formula as follows:

$$N - Gain = \frac{Xpostest - Xpretest}{Xmaksimum - Xpretest}$$

The results of the N-Gain calculation are then interpreted into the effectiveness category (High, Medium, or Low) (Sundayana, 2018) to determine the success of the media developed. Data collection techniques used Gain Score to interpret the level of effectiveness of the Dakonball media in improving student learning outcomes.

RESULTS AND DISCUSSION

Needs Analysis Results (*Analysis*) in the development of this media began with an in-depth study through observation and interviews to map learning problems at SDN Cemerlang. Based on observations conducted in class V, The analysis revealed that mathematics instruction continues to be dominated by a teacher-centered approach. The limited availability of concrete props forces educators to rely entirely on lecture methods, which has an impact on decreased levels of attention and active participation of students during learning activities. This condition is in line with the findings Syamsurijal et al., (2023) that the dominance of lecture methods in learning causes mathematics students to play a passive role and decrease active participation in class, because it tends to convey information in one direction providing opportunities for students to explore concepts independently.

Furthermore, these empirical findings are strengthened by the results of interviews with classroom teachers, which confirm that the main obstacle to learning lies in the abstract nature of the KPK and FPB materials. The teacher explained that students often experience misconceptions in distinguishing factors and multiples, as well as difficulty performing calculation procedures on large numbers without visual assistance. In line with that, interviews with students revealed a saturation of one-way learning methods. Students expressed the need for a more interactive, fun, and group play-based learning atmosphere. Based on the accumulated data, it is concluded that the development of concrete media that is able to visualize abstract concepts while facilitating collaboration is an urgent solution that must be carried out.

Furthermore, the results of product development in the development stage are focused on the realization of physical design of the media based on strong theoretical studies. Referring to the Theory of Cognitive Development Jean Piaget, (1952) stated that elementary school students (ages 7-11 years) are at the concrete operational stage. Through this phase, the child is not yet fully able to think abstractly without the help of physical objects. Therefore, Dakonball media was developed as a cognitive bridge (*scaffolding*) which turns the abstract concept of the KPK and FPB into manipulative activities using balls and Dakon holes. The design of Dakonball media is as follows:

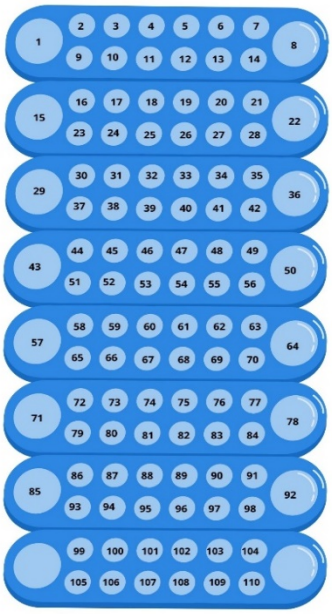

Figure 2. Product Design

The Dakonball design is equipped with 110 holes that are specially designed to be in harmony with the Learning Outcomes (CP) of the Independent Curriculum Phase C grade 5 (Merdeka, 2025), where students are expected to be able to overcome problems related to multiples and factors in a wider range of numbers. Taking into account the 5th grade competency standards that require an understanding of the KPK and FPB up to 100, the number of 110 holes provides optimal exploration space for students to visualize larger multiples of numbers endlessly in the middle of the process. Furthermore, the existence of an additional hole at the end of the board acts as a storage area for the number sphere and the classification of the calculation results, thus ensuring that the teaching aids remain well organized when used to instill the theory of numbers in accordance with the demands of the curriculum that is under the pressure of the use of concrete objects.

After the design stage, the final product is packaged in the form of an ergonomic Game Box containing a modified dakon board. This design allows students to explore patterns of multiples and factors in more complex numbers, overcoming the limitations of conventional media that often fail to visualize LCMs from large numbers.

In addition to the cognitive aspect, the development of this media also integrates the Social Constructivism Theory Vygotsky, (1978) that mathematics learning is considered most effective if it occurs through social interaction within the Proximal Development Zone (ZPD). Applying this theory, Dakonball is not designed to be played individually, but rather uses strategy *Collaborative Learning*. The media is equipped with rules of the game that demand positive dependency (*positive interdependence*), where each student has a specific role (such as ball operator, recorder, and verifier) so that active interaction between students is inevitable.

The use of colorful balls (red, blue, yellow, green) in this medium also refers to the principle of multisensory. This is reinforced by Nurwahidah et al., (2023) Which confirms that the development of cognitive abilities in early childhood is achieved through providing opportunities to gain hands-on experience through various activities. Using the medium of colorful balls, children engage in activities that include perception and conveying information, in which they actively group, sort, and move balls based on the color and number set to understand the surrounding environment. Contrasting colors help students visually distinguish sets of multiples from different numbers. For example, the KPK is determined by looking at which holes contain the meeting of balls of different colors. This situation is in line with the opinion Arsyad, (2014) which revealed that the use of visual-based media can significantly increase students' memory retention compared to the verbal lecture method. Thus, every physical element in the Dakonball from the number board 1-110, colored balls, to group task cards is a concrete implementation of the synthesis of Piaget and Vygotsky's theory to answer the learning needs of students. The media display is as follows:

Figure 2. Media Dakonball

In addition to the game board, this medium is designed with Collaborative Learning rules. Students play in groups with specific roles (such as operators, recorders, and verifiers) to solve the problems of the KPK and FPB listed on the Question Card or LKPD. The results of the development of Dakonball media products were measured through a validation stage involving three expert validators comprising one material expert, one media expert, and one pedagogical practitioner. The evaluation

used a four-point Likert scale rubric assessing several criteria, including content accuracy, linguistic clarity, visual ergonomics, and pedagogical suitability.

After conducting a revision stage based on qualitative feedback from the experts, the final recapitulation of the assessment stated that this media is of excellent quality. The material expert gave a score of 93%, while the practitioner expert also provided a score of 93%. Notably, the media expert gave a perfect score of 100%, which was achieved after the researcher implemented all technical suggestions regarding the board's contrast and font legibility. Overall, the media is categorized as "Very Worthy" with an average validation score of 95.3%. This is reinforced by research by Hima & Istianah, (2025), stating that visual design, material suitability, and the pedagogical function of media are in harmony with the characteristics of elementary school students.

Subsequent to validation, the effectiveness of the media was evaluated through a pretest-posttest design involving 40 fifth-grade students at SDN Cemerlang. Initial data analysis revealed that the mean student score was merely 35.13, which falls within the 'very poor' category. This low achievement demonstrates students' difficulties in comprehending fundamental concepts. Nevertheless, following instruction utilizing collaborative-based Dakonball media, a substantial improvement in learning outcomes was observed. The mean post-test score escalated to 83.19, corresponding to the 'very good' category. This finding aligns with the research conducted by Fitriani et al., (2024). Which indicates that approximately 80% of elementary school students encounter misconceptions regarding LCM and GCF materials. The pronounced enhancement in student learning outcomes before and after the intervention is illustrated in the following comparative graph

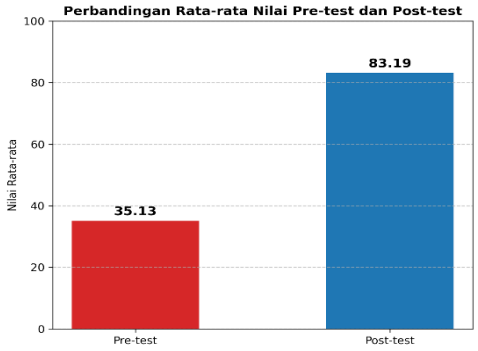

Figure 4. Comparison of Pretest and Posttest Mean Score

validate the statistical significance of the improvement, a series of analytical tests were conducted. Initially, the normality test using Shapiro-Wilk revealed that the data followed a normal distribution (Sig. > 0.05), thereby fulfilling the assumptions required for parametric analysis.

	Shapiro-Wilk		
	Statistic	df	Say.
Pretest	,978	40	,607
Posttest	,962	40	,192

Table 1. Results of the Normality Test

As the significance levels of both data groups (0.607 and 0.192) were above 0.05, it can be concluded that the student learning outcome data follow a normal distribution. This result is consistent with the provisions stated by the Mellita & Lestari, (2023) that the Shapiro-Wilk test is a very appropriate approach for small samples (n < 50), where the data is judged to meet the assumption of normality if the significance value exceeds 0.05. The fulfillment of this assumption of normality is an essential prerequisite for continuing the analysis to the hypothesis testing stage through the Paired Sample T-Test. The application of parametric statistics allows researchers to assess the significance of differences in learning outcomes more precisely, so as to determine the effectiveness of the Dakonball media developed.

Subsequently, hypothesis testing was conducted using paired samples t-test. The analysis results demonstrate that the significance value (two tailed p value) is 0.000, which is considerably lower than the significance threshold of 0.05. This finding provides statistical evidence that the utilization of Dakonball media exerts a substantial and significant effect on enhancing students' conceptual understanding.

Hasil Uji Paired Sample T-Test

Pasangan	Mean Difference	Sig. (2-tailed)	Kriteria	Kesimpulan
Pre-test - Post-test	-48.06	0.000	< 0.05	Terdapat Perbedaan Signif

Table 2. Paired Sample T-Test Results

This improvement in learning outcomes is reinforced by a statement from Trisnawati et al., (2025) which explains that the use of manipulative media such as dakota (mathematics dakon) can effectively improve the understanding of FPB and KPK concepts, because students are able to build knowledge through direct experience. Furthermore, these findings are in line with research Wathoni, (2024) which emphasizes that concrete media plays a role as a cognitive link for elementary school students in understanding abstract mathematical concepts, thus making a significant contribution to improving learning outcomes.

Finally, to measure how effective the increase is, calculations are carried out *N-Gain Score*. The calculation results show an average N-Gain score of 0.73. Based on the effectiveness criteria, this score falls into the "High" category. These findings were reinforced by the response of students who reached 90% (Very Positive), who felt helped by the visualization of the ball and group interactions.

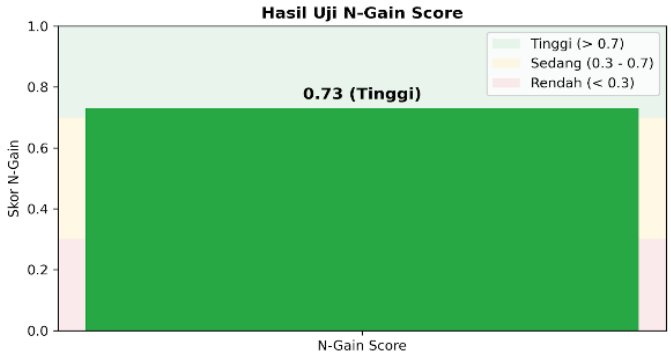

Figure 4. N-Gain Index Results

The substantial rise in average achievement from 35.13 to 83.19 is reinforced by the view Sundayana, (2018), which states that the use of teaching aids in mathematics learning plays a role in reducing the level of abstraction of concepts, so that students can more easily grasp the essence of the object being studied. This significant increase also confirms Dienes' theory (in Ruseffendi, 2021) which emphasizes that learning mathematics will be more effective when it involves the manipulation of concrete objects, because children understand mathematical structures faster through structured games and physical activities.

Furthermore, the effectiveness of this media which achieved an N-Gain score of 0.73 (high category) shows that Dakonball media is not just a tool, but a learning instrument that is able to have a long-term impact. According to M. Arsyad, (2021), quality learning media must be able to generate motivation and stimulation in the learning process. In this case, the design of 110 holes in Dakonball which is adjusted to the Independent Curriculum allows students to conduct collaborative independent exploration, which according to Stephen Hake, (1999), is a key element in achieving optimal gain or improvement of understanding in science and mathematics education.

CONCLUSION

utilizing the ADDIE model, it can be concluded that collaborative learning-based Dakonball media has been successfully developed and adheres to rigorous feasibility standards as an elementary school mathematics instructional medium. Regarding validity, this media has been proven to be "Highly Feasible" based on exhaustive assessments conducted by content experts, media specialists, and practitioners. This validates that the innovation inherent in the Box Game design, incorporating numerical sequences from 1 to 110 and the incorporation of collaborative gameplay mechanics, aligns with curriculum requirements and corresponds to the developmental psychological attributes of fifth-grade students at the concrete operational stage. Furthermore, the practicality aspect was validated through overwhelmingly positive student feedback (at a rate of 90%), demonstrating its capacity to transform the perception of mathematics into an engaging and interactive learning endeavor.

In terms of effectiveness, the implementation of Dakonball media had a significant impact on increasing students' cognitive learning outcomes. This is statistically proven as evidenced by the paired samples t-test findings (significance = 0.000 < 0.05). Furthermore, the achievement of an N-Gain score of 0.73 places the effectiveness of this medium in the "High" category. The success of improving learning outcomes is due to the combination of concrete visualization and social interaction, where the Collaborative Learning method facilitates peer tutoring that effectively overcomes individual learning difficulties.

A single institutional context (SDN Cemerlang), which may affect the generalizability of the findings to other educational settings. Second, attributable to the pre-experimental design, this study did not involve a control group, making it difficult to compare the results with conventional methods more rigorously. Third, the relatively short implementation duration means that the long-term retention of the material and the sustainability of students' social skills after using the media have not been fully observed. Future studies are encouraged to involve a larger, more diverse sample and utilize a true experimental design to further validate these findings.

RECOMMENDATIONS

Based on research findings that show the positive effectiveness of Dakonball media, researchers formulated several operational and academic recommendations. First, for education practitioners, it is recommended that the use of this media be disseminated more widely to various elementary schools, not only limited to research locations. Teachers can use Dakonball as a variation of active learning strategies to reduce the

dominance of lecture methods in abstract materials. Second, regarding product availability, considering the high need for concrete and collaborative teaching aids, it is hoped that there will be efforts to downstream products so that Dakonball can be mass-produced at affordable costs. This aims to ensure that media accessibility can reach schools in areas with minimal technology facilities. Third, for future researchers, it is recommended not to stop at physical development alone. Further research may focus on testing the effectiveness of Dakonball media on other psychological variables (such as interest or learning independence) or expanding the scope of other math materials. In addition, the development of this media into a hybrid format (physical and digital integration) is also an interesting research opportunity to answer the challenges of digitizing education in the future.

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