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The Effect of the REACT Learning Model on the Mathematics Learning Outcomes of Grade 11 Students at SMAN 3 Salatiga

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ABSTRACT

Indonesian students' mathematics achievement remains low, and many students find function composition hard to learn meaningfully. This study therefore examined whether mathematics learning outcomes on function composition differed before and after the REACT learning model (Relating, Experiencing, Applying, Cooperating, and Transferring) was implemented. This study used a pre-experimental one-group pretest-posttest design. The population consisted of Grade 11 students at SMA Negeri 3 Salatiga. The sample was determined using purposive sampling and comprised 23 students from Grade 11 F-9, who took part in three 90-minute REACT lessons. Data were collected using the same five-item essay test administered as a pretest and a posttest, and were analyzed using a paired-samples t-test. The paired-samples t-test yielded a t-value of −3.037 with a significance value of 0.006 (< 0.05), indicating a significant difference between the mean pretest and posttest scores. The mean pretest score was 46.35 and the mean posttest score was 59.09 (Cohen's d_z = 0.63, a medium effect), although the posttest mean remained below the minimum mastery criterion of 75. Learning outcomes therefore improved significantly after REACT was implemented, but because the study involved one class and no comparison group, the result indicates a promising association rather than proof of a causal effect. Teachers may consider REACT with real-life contexts for teaching function composition, supported by prerequisite review and follow-up for students below the criterion; future studies should use control groups, larger samples, and validated instruments.

Keywords: Function Composition; Mathematics Learning Outcomes; Pre-Experimental Design; REACT Learning Model; Paired-Samples T-Test

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1. INTRODUCTION

Mathematics is an important school subject because it relates not only to mastery of concepts and procedures but also to students' ability to understand, process, and apply knowledge to solve problems. However, Indonesian students' mathematics achievement still needs strengthening. The 2022 Program for International Student Assessment (PISA) results show that Indonesia's mathematics score was 366 points, while the average of OECD member countries reached 472 points (OECD, 2023). This gap matters for the choice of instructional model because PISA assesses whether students can formulate, employ, and interpret mathematics in real-world contexts, not

merely carry out procedures (OECD, 2023). The result therefore suggests that classroom mathematics should be directed not only toward procedural problem-solving but also toward conceptual understanding and the meaningful use of knowledge in everyday situations. This is the orientation of contextual learning approaches, which connect mathematical concepts to students' real experiences (Irawan & Fuady, 2026), and of REACT in particular, which starts from situations familiar to students and asks them to use what they learn in new contexts (Kaya & Gül, 2021; Sari & Darhim, 2020), it is the reason REACT was investigated in this study.

One indicator of the attainment of mathematics learning is learning outcomes, because they describe students' mastery of knowledge and skills after taking part in instruction (Aras & Juhari, 2020). In this study, mathematics learning outcomes refer to students' cognitive achievement on the topic of function composition, operationalized as the scores students obtained on a written essay test taken before and after the lessons. Learning outcomes cannot be separated from the instructional process teachers carry out, including the choice of a learning model that suits students' needs. This link is evident in Salam et al. (2019), who examined the effects of instructional models and spatial intelligence on mathematics learning outcomes while controlling for students' initial competency. Therefore, the choice of learning model is an aspect that deserves attention in efforts to support students' mathematics learning outcomes.

Based on the author's initial observations, mathematics lessons in Grade 11 F-9 at SMA Negeri 3 Salatiga more often followed teacher explanations, followed by practice exercises. During this process, some students still appeared to have difficulty understanding concepts. Difficulties of this kind are well documented for function composition: students struggle with the concept itself, with accurate substitution, and with problems that differ from the examples shown by the teacher (Maidiyah et al., 2024), and vocational high school students have likewise been reported to struggle with substitution, with determining the order of composition, and with relying on the teacher's examples (Saputri et al., 2026), and with memorizing formulas instead of understanding the concept, especially in word problems (Rahmi et al., 2026). The pretest results of the 23 students showed a mean of 46.35 (on a 0–100 scale), well below the school's minimum mastery criterion (KKM) of 75, which gives an overview of students' initial learning outcomes before the learning model was implemented and shows how far students were from the mastery target at the start of the topic. This condition indicates the need for a learning process that helps students connect knowledge with experience, build understanding through learning activities, and apply what they have learned in meaningful situations.

One learning model with these characteristics is the REACT learning model (Relating, Experiencing, Applying, Cooperating, and Transferring), a contextual learning strategy that goes back to Crawford (2001). REACT is oriented toward contextual learning through connecting knowledge with experience, gaining understanding through experience, applying knowledge, cooperating, and transferring knowledge to other situations. These characteristics allow students to engage in constructing and using knowledge rather than merely receiving information directly. Therefore, REACT is relevant to the needs of mathematics learning that emphasizes the understanding and application of concepts (Aras & Juhari, 2020). A recent systematic review of contextual teaching and learning in mathematics education identifies direct implementation of the REACT strategy as one way of putting contextual learning into practice (Kusnirova et al., 2026).

Each REACT stage can be matched to a difficulty reported for function composition. Relating links the new idea to familiar situations such as business profit or shopping discounts, so that functions are seen as meaningful processes rather than symbols to be manipulated. Experiencing, through tables in which students compare f(g(x)) with g(f(x)), lets students discover for

themselves that the order of composition matters, which targets errors in order and substitution (Maidiyah et al., 2024; Saputri et al., 2026). Applying provides individual practice in computing results and domains, which builds procedural accuracy. Cooperating asks students to explain and justify their reasoning in groups, and a meta-analysis of studies in Turkey found a moderate positive effect of cooperative learning on mathematics achievement (Turgut & Turgut, 2018). Transferring requires students to construct functions for new situations, such as a receipt with a discount and tax or a shipping cost with a member discount, which addresses students' reliance on the teacher's examples (Maidiyah et al., 2024; Saputri et al., 2026). These links are the theoretical expectation behind the study; they were not measured directly.

Several earlier studies provide empirical support for implementing REACT to improve learning outcomes. At the elementary level, Aras & Juhari (2020) found an effect of REACT on Grade 5 students' mathematics learning outcomes, while Biusnawati et al. (2023) reported an improvement in mathematics learning outcomes after REACT was implemented with Grade 5 students, and (Mulyani et al., 2024) reported an effect of REACT assisted by manipulative media on Grade 4 students' learning outcomes. At the junior high school level, REACT has also been reported to improve Grade 7 students' learning outcomes (Amsikan et al., 2023). Findings at the senior high school level also point in the same direction, as reported by Sihotang & Dirgantoro (2024) for the improvement of Grade 11 students' conceptual understanding of inverse functions. However, REACT is not always more effective than other active learning models. Amsikan et al., (2023) also compared REACT with the Jigsaw cooperative model: both improved learning outcomes, but Jigsaw gave better results. That study compared the two models directly, using a posttest-only control-group design with Grade 7 junior high school students, so its result describes relative effectiveness: REACT can improve learning outcomes and still be outperformed by another model. The difference may therefore reflect the comparison itself, the grade level and content studied, or how each model structured group work; these explanations are plausible but were not tested in that study. These mixed findings indicate that the effect of REACT needs to be considered in light of students' characteristics and the learning context in which it is applied.

The finding of Amsikan et al. (2023) does not make Jigsaw the better choice for every topic and context, and the present study does not aim to decide which model is superior. REACT was chosen for three reasons related to the topic studied. First, function composition is abstract and is often introduced symbolically, whereas REACT begins from familiar situations (relating) and ends with transfer to new ones, which allows the concept to be tied to meaningful contexts. Second, the difficulties reported for function composition correspond to specific REACT stages, as described above. Third, REACT already contains a cooperating stage, so it keeps the benefits of group work within a contextual sequence instead of excluding it. Contextual approaches have been applied in mathematics learning from primary school onward (Selvianiresa & Prabawanto, 2017) and in senior high school mathematics (Sari et al., 2023), and a meta-analysis concluded that realistic mathematics and contextual teaching-learning approaches can serve as alternatives for strengthening students' mathematical communication ability (Putri et al., 2022).

REACT has also been linked to other mathematical abilities, which are used here only selectively because this study concerns learning outcomes. Sari & Darhim (2020) showed that REACT can support mathematical representation, reasoning, and disposition through students' active involvement in learning. Alyani et al. (2020) similarly reported improved problem-solving skills. These studies do not measure learning outcomes directly, but they point to mechanisms (active involvement, linking of ideas, and discussion) that could plausibly contribute to better learning outcomes.

Although many studies have shown positive results, empirical evidence on the effect of REACT on mathematics learning outcomes still varies across educational levels, student characteristics, and learning contexts. Research on learning outcomes is found more often at the elementary and junior high school levels, while empirical evidence at the senior high school level remains more limited. At the senior high school level, REACT has often been studied in science subjects (Kaya & Gül, 2021; Sugita et al., 2020), and evidence in mathematics is limited to topics such as inverse functions (Sihotang & Dirgantoro, 2024). This condition indicates the need for additional empirical evidence on implementing REACT in senior high school contexts with different student characteristics and learning conditions. The same need was found in Grade 11 F-9 at SMA Negeri 3 Salatiga, based on the initial learning conditions and students' pretest results. Therefore, this study was conducted to add empirical evidence on the effect of REACT on mathematics learning outcomes at the senior high school level by measuring learning outcomes before and after the model was implemented. Specifically, it examines Grade 11 learning outcomes on function composition, taught through real-life contexts (business profit, receipts with a discount and tax, and shipping cost), and reports the size of the change as well as its statistical significance.
Based on the above, this study aims to examine the difference in the mathematics learning outcomes of Grade 11 students at SMA Negeri 3 Salatiga before and after the REACT learning model was implemented on the topic of function composition. The research hypothesis is that there is a difference in students' mean mathematics learning outcomes before and after the REACT learning model is implemented (the formal hypotheses are stated in Section 2). The results are expected to provide empirical evidence that teachers can consider when choosing an active and contextual mathematics learning model.

2. METHODS

This study used a quantitative approach with a pre-experimental method and a one-group pretest-posttest design (Bierer et al., 2025). The design was used to examine differences in students' mathematics learning outcomes before and after the treatment. This design was chosen because, when the study was conducted, the school was in a transition period of remapping class groups (rombel), so forming a control group could not be done optimally. Because a one-group design has limited internal validity, the steps taken to limit the threats are described below.

The population of this study was Grade 11 students at SMA Negeri 3 Salatiga in the odd semester of the 2026/2027 academic year. The sample was determined using purposive sampling, that is, by selecting one intact class, Grade 11 F-9, which the researcher taught in the Teacher Professional Education (PPG) program, for practical reasons rather than representativeness. Of the 36 students on the class register, the 23 who completed both the pretest and the posttest were analyzed, because the remaining students had not yet joined the class while class regrouping (rombel remapping) was still in progress. The sample was therefore not random and may not represent all Grade 11 students at the school, so the findings are interpreted for this class only (Andrade, 2021). Before the study, the researcher made informal initial observations of mathematics learning in the class. These observations provided an overview of the initial conditions and were not analyzed as research data.

The study was carried out in three stages. The researcher administered a pretest before instruction, then implemented the REACT learning model on the topic of function composition in three meetings of 90 minutes each through five stages, namely relating, experiencing, applying, cooperating, and transferring, and ended with a posttest. The same teacher (the first author) taught all three meetings, and the activities of each stage in each meeting are shown in Table 1.

Table 1. Distribution of REACT Activities Across the Three Meetings

REACT stage	Meeting 1: Operations on functions	Meeting 2: Composition of functions	Meeting 3: Review
Relating	Students recall how to calculate the profit of a business.	Students examine a shopping receipt that includes a discount and tax.	Students check their initial understanding of the previous meetings.
Experiencing	Students fill in a table to discover the pattern of operations on functions and the condition for division.	Students fill in a table to compare f(g(x)) with g(f(x)).	Students clarify concepts through quick questions.
Applying	Students individually determine the results of operations on functions together with their domains.	Students individually determine the results of function compositions.	Students work on problems on operations on functions and domains.
Cooperating	In groups, students determine the form, domain, and range of functions.	In groups, students prove that $(f\circ g)(x) \neq (g\circ f)(x)$.	Groups assemble a "Function Puzzle".
Transferring	Students construct a profit function for a beverage business.	Students construct discount and tax functions from the receipt to calculate the final price.	Students calculate shipping cost with a member discount.

The researcher collected learning outcome data using an essay test developed from indicators of mathematics learning attainment for the topic (operations on functions and their domains, composition of functions, and contextual problems). The test consisted of five essay items and was scored on a 0–100 scale using a scoring guideline, with the researcher scoring the students' answers. Before use, the test was examined by a mathematics teacher at the school for its suitability for Grade 11 students; no empirical validity or reliability analysis was carried out. The same instrument was used for the pretest and the posttest so that the data obtained could be compared. During the treatment, the researcher also recorded how the lessons proceeded in class as supporting information, which was described narratively.

To limit threats to internal validity, the same teacher taught all three meetings, the same instrument and the same five-stage sequence were used throughout (Table 1), and the study covered one topic over a short period. The pretest was given before the first meeting and the posttest after the third meeting, under the same classroom conditions, supervision, and duration, and the pretest items and answers were not discussed with students before the posttest.

Data analysis used descriptive and inferential analysis. Descriptive analysis described students' learning outcomes on both tests, including the minimum, maximum, mean, and standard deviation. Next, the Shapiro-Wilk test was used to assess normality because the sample size was below 50 (Mishra et al., 2019). Homogeneity was not tested, because the paired-samples t-test analyzes within-student differences and does not require equal variances. If the data were

normally distributed, hypothesis testing was performed using a two-tailed paired-samples t-test at a significance level of 0.05. The hypotheses were H_0: $\mu_{pre} = \mu_{post}$ and H_1: $\mu_{pre} \neq \mu_{post}$, and H_0 was rejected if Sig. (2-tailed) was < 0.05 ($|t| > 2.074$ for df = 22). Cohen's d_z with a 95% confidence interval was also reported, and mean scores were compared with the school's minimum mastery criterion (KKM) of 75.

3. RESULT AND DISCUSSION

3.1 Data Description

The mathematics learning outcome data on function composition were obtained from 23 students (of the 36 students on the class register) who completed both the pretest and the posttest. The descriptive statistics for the pretest and posttest data are presented in Table 2.

Table 2. Descriptive Statistics of Pretest and Posttest Data

	N	Min	Max	Mean	Std. Deviation	Std. Error Mean
Pretest	23	10	81	46.35	18.946	3.951
Posttest	23	13	97	59.09	20.622	4.300

The mean pretest score was 46.35 and the mean posttest score was 59.09, a mean difference of 12.74 points. In addition, six students scored lower on the posttest than on the pretest. Relative to the minimum mastery criterion (KKM) of 75, the pretest mean was 28.65 points below the criterion and the posttest mean was 15.91 points below it, so the class average had not yet reached mastery after the three meetings. The maximum scores (81 on the pretest and 97 on the posttest) show that some individual students were above the criterion. The comparison of the mean scores on the two tests is shown in Figure 1.

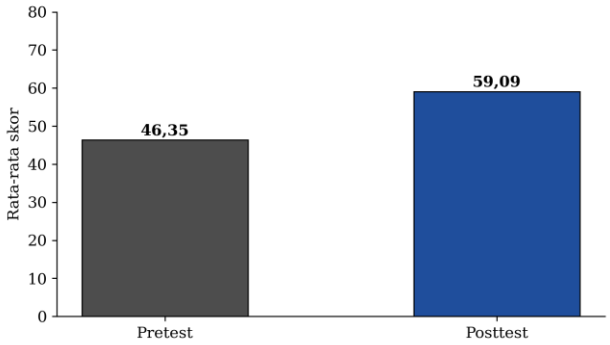


Figure 1. Mean Pretest and Posttest Scores

3.2 Prerequisite Tests

The Shapiro-Wilk test was used because the sample size was below 50. The normality test results are presented in Table 3.

Table 3. Results of the Shapiro-Wilk Normality Test

	Statistic	df	Sig.
Pretest	0.919	23	0.062
Posttest	0.969	23	0.666

The Shapiro-Wilk significance values for the pretest (0.062 > 0.05) and the posttest (0.666 > 0.05) indicate that both datasets were normally distributed. Homogeneity of variance was not tested, because the paired-samples t-test analyzes the within-student differences between the two tests and does not require the two sets of scores to have equal variances. With the normality assumption met, the data were suitable for analysis with a parametric test.

3.3 Hypothesis Testing

The hypothesis test was conducted to determine whether students' mean learning outcomes differed significantly before and after the REACT learning model was implemented. The statistical hypotheses were H_0: $\mu_{pre} = \mu_{post}$ (there is no difference between the mean pretest and posttest scores) and H_1: $\mu_{pre} \neq \mu_{post}$ (the mean pretest and posttest scores differ). The test used the two-tailed paired-samples t-test at a significance level of 0.05, with H_0 rejected if the sig. (2-tailed) value was < 0.05 (equivalently, $|t| > 2.074$ for df = 22). The test results are presented in Table 4.

Table 4. Results of the Paired-Samples t-Test (Pretest – Posttest)

Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
-12.739	20.114	4.194	-3.037	22	0.006

The difference and t values are negative because the difference was calculated as pretest minus posttest. The sig. value of 0.006 (< 0.05) and the |t| value of 3.037, which is greater than the critical t of 2.074 (df = 22; $\alpha = 0.05$), lead to the rejection of H_0. Thus, students' mean mathematics learning outcomes differed before and after the REACT learning model was implemented, with higher scores after implementation. The mean gain was 12.74 points (95% CI [4.04, 21.44]), and the standardized effect size was Cohen's $d_z = 0.63$, a medium effect by the conventional benchmarks (Brydges, 2019). This indicates a significant improvement in the mathematics learning outcomes of Grade 11 F-9 students at SMA Negeri 3 Salatiga after REACT was implemented. Because the design has no comparison group, this result shows that outcomes improved after the REACT lessons, but it does not by itself establish that REACT caused the improvement.

3.4 Discussion

The characteristics of the REACT stages offer a plausible explanation for this improvement. The relating and experiencing stages allow students to connect the concept of functions with experience and build understanding through learning activities. The experiencing stage is regarded as the core of contextual learning (Crawford, 2001; Hasibuan & Daulay, 2025). The applying and transferring stages encourage students to use the concept of function composition in different situations, while the cooperating stage opens space for group discussion. This explanation is interpretive because students' learning processes were not specifically measured in this study.

Compared with earlier studies of mathematics learning outcomes, the direction of the present result is consistent with the pattern reported at several levels of schooling: REACT-based instruction was followed by better learning outcomes at the elementary level (Aras & Juhari, 2020; Biusnawati et al., 2023; Mulyani et al., 2024), the junior high school level (Amsikan et al., 2023), and, most relevant here, the senior high school level (Sihotang & Dirgantoro, 2024). The studies differ, however, in design. Aras & Juhari (2020) used a one-group pretest-posttest design like the present study, and Biusnawati et al. (2023) reported improvement in classroom action research, so neither can separate the effect of REACT from the effect of instruction itself, whereas Amsikan et al. (2023) used a control group. They also differ in what was measured: Sihotang & Dirgantoro (2024) used a descriptive qualitative design and reported an average conceptual understanding of 70% (high category) among Grade 11 students after REACT instruction on inverse functions, an outcome and metric that cannot be compared directly with the 12.74-point gain found here. Differences in outcome measure, topic, and length of instruction therefore limit direct comparison across these studies.

Evidence from outside mathematics at the senior high school level points in the same direction. REACT has been used to improve understanding of physics concepts (Sugita et al., 2020), and an effect of REACT-based instruction on Grade 11 students' attitudes and motivation has been reported (Kaya & Gül, 2021).

Studies of other mathematical abilities are useful here mainly for the mechanisms they suggest. Improvements in problem solving (Alyani et al., 2020) and in representation, reasoning, and disposition (Sari & Darhim, 2020) indicate that the active involvement, linking of ideas, and discussion that REACT promotes can strengthen several processes involved in understanding and using mathematics. These processes are plausible contributors to the learning outcomes measured here, but they were not measured in the present study.

Finally, the finding of Amsikan et al. (2023) that Jigsaw outperformed REACT is a reminder that a significant improvement under REACT does not mean that REACT is the best available model. This study did not compare REACT with other models, so it cannot assess its relative superiority. The result should be read as evidence that outcomes improved after the REACT lessons, not as evidence that REACT is better than Jigsaw or other models.

This effect should be interpreted carefully. The variation in learning outcomes among students was wide. The standard deviations on both tests were large (18.946 and 20.622), with score ranges of 10–81 on the pretest and 13–97 on the posttest. This indicates that the mean effect does not mean that all students obtained results in the same direction. In addition, although the mean score increased significantly, it remained below the KKM of 75, so three REACT meetings were associated with improvement but not with mastery for the class as a whole. Possible explanations include the limited treatment time of only three meetings, the need to master prerequisite concepts about functions for function composition, and differences in students' conditions when taking the tests. These possibilities were not tested in this study and therefore need to be confirmed in further research, for example by examining the characteristics of students whose results differed from the class trend.

In addition to the learning outcome data, the researcher noted that students appeared involved in learning activities during lessons, such as asking questions of the teacher and group mates and discussing while working on group tasks in the cooperating stage. These notes are the researcher's observations, were not measured with an instrument, and were not analyzed as a variable, so they are not intended as evidence of an effect of REACT on learning activeness. Nevertheless, the notes are in line with the findings of Aras & Juhari (2020), who observed that

students were fairly active during learning with REACT, and Sari & Darhim (2020), who reported that REACT implementation engaged students actively. In the affective domain, Kaya & Gül (2021) reported an effect of REACT-based instruction on Grade 11 students' attitudes and motivation in biology. Student involvement can be examined further using a structured observation instrument.

Beyond confirming the direction of earlier findings, the study makes three specific contributions. First, it provides evidence from Grade 11 mathematics on function composition, a topic for which REACT evidence at the senior high school level is scarce. Second, it documents a replicable three-meeting sequence in which each REACT stage is tied to an everyday context (business profit, receipts with a discount and tax, and shipping cost with a member discount), so that teachers can adapt the lessons (Table 1). Third, it reports the size and precision of the change (a medium effect, 95% CI [4.04, 21.44]) together with a comparison against the school's mastery criterion, which shows that a statistically significant gain can still leave the class mean below the KKM.

Several limitations should be noted. The sample was small (23 students from one class in one school), non-random, and excluded 13 of the 36 registered students, so selection bias is possible and the results cannot be generalized (Andrade, 2021). The one-group design has no comparison group (Bierer et al., 2025); because the pretest preceded instruction on the topic and identical items were used twice, some of the improvement may reflect instruction in general, history, maturation, or a testing effect rather than REACT itself. The instrument was examined by a teacher but not tested empirically for validity and reliability (see Taber, 2018, on Cronbach's alpha), and the researcher who taught the lessons also scored the tests, so measurement error and bias cannot be ruled out. The intervention was short (three meetings), with no delayed posttest and only a cognitive outcome. The findings are therefore best read as preliminary evidence of improvement in one class, not as evidence of a general causal effect.

For teachers, a REACT sequence built around everyday contexts such as profit, receipts with discounts and tax, and shipping costs (Table 1) can be a workable way to teach function composition in Grade 11; however, because the class mean stayed below the KKM, three meetings should not be expected to suffice for every student, and checking prerequisite knowledge beforehand and planning remedial practice would be sensible. Future studies should use a comparison class (taught conventionally or with another active model such as Jigsaw), more classes or schools, validated instruments with independent scoring, and a delayed posttest.

4. CONCLUSION

This study found a significant improvement in the mathematics learning outcomes of Grade 11 F-9 students at SMA Negeri 3 Salatiga on the topic of function composition after three REACT lessons: the mean score rose from 46.35 to 59.09 ($t(22) = -3.037$, Sig. = 0.006; Cohen's $d_z = 0.63$, a medium effect). The result should be read as a promising association rather than proof of a causal effect, because the study involved a single class, no comparison group, and identical pretest and posttest items, and because the posttest mean (59.09) remained below the school's minimum mastery criterion of 75. The study contributes Grade 11 evidence on function composition, a topic with little prior REACT research at the senior high school level, together with a replicable three-meeting sequence that links each REACT stage to everyday contexts. In practice, teachers can use this sequence as one way to make function composition more meaningful, while planning prerequisite review and follow-up support for students who do not reach the criterion. Future studies should test REACT against a comparison group or another active model such as Jigsaw,

use validated instruments, involve more classes and schools, and examine retention and student involvement with structured instruments.

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