

## The effect of coupled inquiry-5E in enhancing the understanding of Meiosis concept

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### Article Info

#### Article history:

Received Nov 19, 2019

Revised Jan 19, 2020

Accepted Feb 26, 2020

#### Keywords:

Couple inquiry

Meiosis understanding

Pre-service teacher

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### ABSTRACT

The purpose of this study is to investigate the effectiveness of coupled inquiry-5E approach on the understanding of meiosis concept among pre-service teachers. The research design of this study is one-group design with a pre-test -post-test-delayed post-test. A total of 31 pre-service teachers from one public university involved in this study. An instrument, Meiosis Conceptual Test with 19 items was used. Data was analysed using One Way Repeated Measure ANOVA. The result showed that there is a statistically significant effect for time, Wilks' Lambda = .80,  $F(2,29) = 3.65$ ,  $p < .05$ , multivariate eta squared = .20. From the analysis, it can be concluded that there is a statistically significant effect for time. Thus, this finding showed that couple inquiry learning approach has an effect on enhancing meiosis understanding among pre-service teachers. From this study, it is suggested that couple inquiry learning approach is a good method to be used in learning abstract concept such as meiosis.

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## 1. INTRODUCTION

Biology is a difficult subject for most of students [1, 2] because of its abstract concepts [1, 3] and its teaching methods [1] are mostly teacher-oriented [4]. According to Zeidan [5], biology learning environment ignored students' interest to learn biology. Because of these, students tend to memorise important facts in order to pass the biology examination without understanding what they have learned. Thus, teachers need to review and reflect their teaching methods in ensuring biology learning is more meaningful. Students must should be involved in their learning process. They should have ownership in their learning [6].

In Malaysia, the biology curriculum for secondary school aims to produce students who are active learners through the inquiry approach [7]. This approach will enable students to understand and appreciate biology concepts and be able to apply it in their daily life. Yet, studies have found that students are facing difficulties in many topics such as water transport in plants, protein synthesis, respiration and photosynthesis, gaseous exchange, energy, cells, mitosis and meiosis, organs, physiological processes, hormonal regulation, oxygen transport, genetics, Mendelian genetics, genetic engineering, and the central nervous system [1, 2]. Nevertheless, cell division is a hard topic to teach especially in meiosis [8]. Students in Malaysia are found to be on the satisfactory level of achievement in meiosis [9]. Meiosis is a challenging subject to the students due to its abstract nature. It is also a complicated and difficult topic for the student teachers [10, 11].

Reasons for students had difficulties in understanding meiosis because of they were lacking knowledge about chromosomes and their importance [12]. The learning difficulties in meiosis are carried on from the secondary level to the undergraduate level [13]. Researchers have shown that students have difficulties in grasping the concepts and process in meiosis [12-14]. This fact is supported by the finding in the analysis done by the Malaysian Examination Syndicate on students' answers in the Malaysian Certificate of Education examination. In the year 2014, analysis for Biology Paper 2 shows a low level of understanding in meiosis. The students did not master the concepts of cell division and were not able to deliver their ideas using the correct terms and science concepts. They lacked the understanding of the dynamic process of crossing over, formation of chiasma in meiosis that contribute to the exchange of genetic material between maternal and paternal chromosome occurring [15].

In a study done by Chattopadhyay [16] on higher secondary students, results shows that a significant number of the students did not understand the significance of haploid number of the chromosomes. He also mentioned that the students did not understand the significance and implications of recombination events during meiosis. In another study, students' understanding of cell division was measured through a two-tiered multiple-choice diagnostic test. It was found that performance dropped on the second tier [17]. This means that the students were not able to give the correct reasoning for their choice of answer in the first tier. Both of these studies show that students have a weak understanding in meiosis. Chattopadhyay [16] suggested that students cannot understand meiosis concept because they lacked reasoning ability which is triggered through critical thinking. This is because in assessment where reasoning and problem solving is needed, critical thinking affects students' achievement and performance.

According to Chattopadhyay [16], Dikmenli [10], Ozcan, Yildirim, and Ozgur [18], the difficulties in meiosis stems from the students' secondary school educations. In a study by Karagoz and Cakir [19], it was found that prospective biology teachers failed to emphasize the role and process of meiosis in gamete formation. It showed that, these pre-service teachers had an incomplete understanding of the meiosis concept. In another study, Kurt, Ekici, Aksu, and Aktas [20], found that pre-service biology teachers have incomplete mental structures of the reproduction concept which is linked with meiosis. Biology pre-service teachers were found to have serious problems with the concept of meiosis by being confused with the stages and the events in the stages [10]. These studies showed that pre-service teachers have a low understanding in meiosis. If this problem was not resolved, they would inherit the meiosis misunderstanding to their students. Thus, an effective teaching approach is needed so that it will not be transferred to their students in school [10, 20].

As pre-service teachers, they need to master meiosis concepts since understanding is defined as a matter of being able to do a variety of thought-demanding things with a topic-like explaining, finding evidence and examples, generalizing, applying, analogizing, and representing the topic in a new way [21]. In the meiosis, when they understood the topic, they should able to explain with examples, applying and analogizing the terms of meiosis which includes diploid chromosomal numbers, haploid gametes, bivalent/tetrad, crossing over, homologous chromosomes and non-sister chromatids. Yet, the knowledge about meiosis is vital to understand genetics [22] in particular the process of gamete formation. A strong understanding of biological inheritance necessitates a clear comprehension of cell division and the importance of meiosis [12]. Therefore, meiosis provides the basic for genetics and inheritance rendering it crucial to have a strong understanding of the concepts in meiosis.

One method to achieve this is through the implementation of the inquiry approach which was stated in the Biology curriculum specification [23]. The implementation of inquiry-based approach is strongly advocated for the teaching and learning of science [24]. In a meta-analysis comparing inquiry to other forms of instruction, it was found that inquiry teaching enhances learning [25]. Studies have shown that inquiry-based learning had a positive impact on achievement [26-28] which means that there is a positive impact on the understanding. Studies have shown that inquiry-based learning is an approach that upholds students' growth in problem solving [26, 29-31].

## **2. LITERATURE REVIEW**

### **2.1. Couple-inquiry based approach**

The advantage of an inquiry-based learning is that students are equipped to build their own conceptual knowledge which will translates into a long-term memory by a repeated exposure to the science concepts [32]. Thus, inquiry-based learning is an approach which can address both the need to enhance the pre-service teachers' understanding and triggers critical thinking in the process of constructing knowledge in meiosis. Essentially, in the inquiry-based learning there are five types of inquiry learning which are confirmatory inquiry, structured inquiry, guided inquiry, coupled inquiry and open inquiry. However, in this study, coupled inquiry approach is suggested as a teaching approach since it can be considered as an intermediate level

between guided inquiry and open inquiry. Furthermore, this would be an exposure for them to experience the open inquiry, a higher level of inquiry. Thus, the main objective of this study is to investigate the effect of coupled-inquiry approach towards meiosis understanding among pre-service teachers.

According to Dunkhase [33], coupled inquiry is a combination of the “teacher guided” inquiry followed by a “full” or “open” inquiry. According to him, coupled inquiry is appropriate for the teachers who wanted to try inquiry-based learning but are hesitant due to issues of control over content and curriculum goals. He also mentioned that coupled inquiry addresses the need for control and confirmation to make sure that the students have learnt what they are supposed to learn. This is made possible due to the structure of the coupled inquiry in which the teachers may make modifications for an effective learning environment.

The coupled inquiry learning cycle begins with a guided inquiry investigation and proceeded to an intermediate platform which enables the students to go onto the open inquiry investigation. According to Martin-Hansen [34], the approach of having a guided inquiry before an open inquiry results in students generating questions to be investigated in the open inquiry phase which are closely related to the benchmark from the teacher-guided investigation. This ensures that what the students are investigating is fulfilling the learning objective or intended learning outcome. All the stages are in a form of cycle as shown in Figure 1.

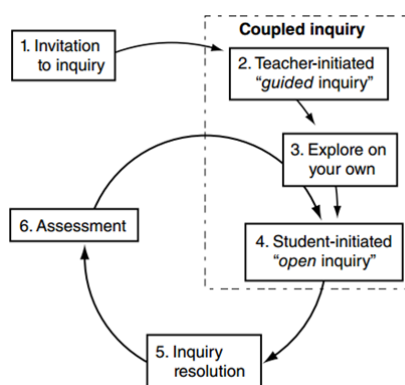


Figure 1. The complete coupled-inquiry cycle model Dunkhase [33]

Based on Figure 1, the first stage is “Invitation to inquiry”. In this stage, students’ interest in the topic or concept to be investigated is stimulated by using a designed activity such as a demonstration by the teacher, current events, field trips or the presence of a guest speaker. This is an opportunity for the teacher to get the students personally involved, engaged and invested in the quest of understanding the topic or concept to be investigated. Next is the couple inquiry stage. It starts with “Initiated Guided inquiry”. In this stage, a teacher gives an opportunity to direct the students towards the specific concept objectives required by the curriculum. It gives the teacher control over the direction and outcome of the investigation. Although the teacher designed the question and investigation, it is the students who make the prediction, conduct the investigation, record the data, interpret the results, form claims, explain and present their findings.

The third stage is “Explore on your own”. This is the most important stage of the coupled inquiry cycle since it explicitly stimulates learners’ curiosity by providing the opportunity to try out their ideas with additional materials and to generate their own questions. This is a mirror of how scientists operate when they are exploring a new idea or phenomena before embarking on a formal research project.

Fourth stage is “Open” inquiry where the students design the investigation, carry out the investigation, record data, analyze the data, interpret the result, present and explain their findings to the teacher and the rest of the class. The stage is similar to those in the guided inquiry stage, but the difference is that the question under investigation and the procedure for the investigation are generated by the students.

The fifth stage is “Inquiry Resolution”. In this stage, the teacher reviews the students’ inquiry presentation to find common understandings. The teacher may ask them what they have learnt, what they would investigate next, and may challenge or support their findings by doing a demonstration. If it is necessary to clarify the definition and science concept, the teacher may even do some direct instruction.

As for the final stage, it is “Inquiry assessment” and for this stage, two types of assessment will be involved, formative assessment and summative assessment. The formative assessment is done in each of the stages in the coupled inquiry cycle. It is important since it inform the teacher about the students’ progress

and what content issues or questions need to be addressed by direct instruction in the inquiry resolution stage. While for a summative assessment, it is a test to confirm that the students have understood the science concept in depth which enables them to use the understanding in the given situation.

With all these stages, students' cognitive ability would be maximised. Dunkhase [33] posited that coupled inquiry learning cycle balance the needs of the teachers to control content and curriculum goal while at the same time complying to the vision of a true student-centered "full" inquiry. He also proposed that the coupled inquiry cycle is embedded in traditional instructional cycle models such as the Bybee 5E model [35] and Search, Solve, Create and Share (SSCS) model by Pizzini [36]. However, the 5E instructional cycle model is chosen to be applied in this study on the basis that it has been shown that each phase of the 5E instructional cycle model is clearly applicable in an inquiry-based teaching [37] and can be considered as an effective approach of learning [38]. This model has not only been used widely in the literature, it has also been extensively used in actual classrooms [39] and it was suggested in Malaysian Curriculum Instruction. The 5E instructional model is solidly grounded in educational theory such as constructivism [40] and in addition to having a growing base of research to support its effectiveness, it has a powerful impact on science education [41]. Furthermore, it is suitable to students with variety of learning style [42].

## 2.2. Coupled inquiry approach-5E

The 5E learning cycle consisted five stages and each stage has a distinct function which contributes to the teacher's systematic instruction and the student's developing a better understanding of scientific knowledge, attitudes and skills [43]. The first stage of the 5E learning cycle is the engagement stage. In this stage, the role of the teacher is to present the situation, identify the instructional task, sets the rules and procedures for establishing the task. The teacher elicits students' prior knowledge and helps them to become engaged in a new concept by the use of short activities which promote the students' curiosity.

The second stage in the 5E learning cycle is the exploration stage. Once the students are engaged in the activities in the first stage, they have a psychological need for time to explore objects, events or situations. Thus, the activities in the second stage are designed as hands on and concrete to provide students with a common and concrete experience on which they will be able operate on to formulate concepts, processes and skills. As a result of their mental and physical involvement in the activities, students-built relationships, observe patterns, identify variables and question events. The teacher's role is as a facilitator who initiates the activities and allows students time and opportunity to probe objects, tangible materials and situations based on their own ideas.

The third stage is the explanation stage. In this stage, the teacher asks the students to present their explanation before introducing scientific explanation in a direct, explicit and formal manner. The process of explanation focuses the students' attention on a particular aspect of their engagement and exploration experiences while providing them with an opportunity to demonstrate their conceptual understanding and process skills. The teacher has the opportunity to directly introduce a concept, process or skill to guide learners toward a deeper understanding after the students' explanation. The key in this stage is to present concept, processes or skills in a brief, simple, clear and direct manner and to move on to the next stage.

The fourth stage in the 5E learning cycle is the elaboration stage. This phase facilitates the transfer of concepts by involving the students in new situations and problems which requires the transfer of identical or similar explanations. By doing so, the students are challenged to extend their conceptual understanding and skills to develop a deeper and broader understanding through new experiences. Elaboration activities also provide additional time and additional experiences of learning for students who may still have misconceptions.

The final stage of the 5E learning cycle is the evaluation stage. Informal evaluation may take place at the beginning and throughout the 5E cycle and a complete formal evaluation is completed after the elaboration stage. In this stage, students are given an important opportunity to use their acquired skills and to evaluate their own understanding by receiving feedback on the adequacy of their explanations. In this stage, the teacher must assess educational outcomes and administer assessments to determine each student's level of understanding.

Thus, in this study, the coupled inquiry learning stages is embedded in 5Es learning stages as shown in Figure 2.

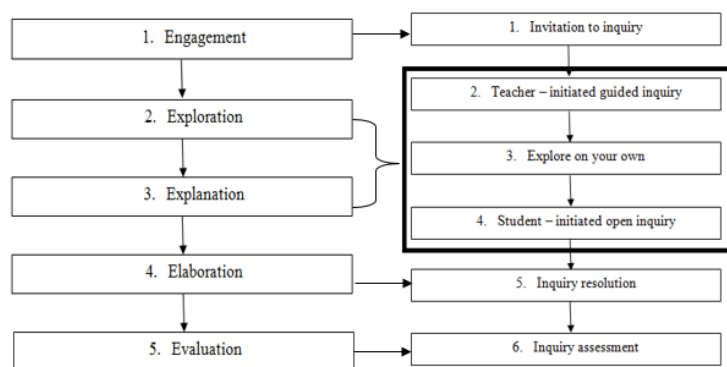


Figure 2. The coupled inquiry learning stages embedded in 5Es learning stages (Adapted from Dunkhase [33] and Bybee [35])

This study used this framework on how to implement coupled inquiry through 5Es learning stages. For example, in engagement stage, teacher will invite students to inquire about the learning concepts. In the exploration and explanation stage, teacher will put into practise the coupled inquiry stage. This is where inquiry takes place in the sense that students carry out investigation to test their prediction, collect data, interpret result, find explanation and present their claim and findings. The teacher acts as a facilitator and the activities and materials are hands-on so that students have a concrete learning experience. Exploration stage provides concrete experience which is established through the guided inquiry stage.

In the elaboration stage, the teacher will apply the inquiry resolution stage. The teacher review students’ presentation and may also challenge their findings to extend their conceptual understanding. In some cases, direct instruction might be necessary to clarify science content. Finally, in the evaluation stage, the teacher will implement the inquiry assessment stage. This stage is important since it will inform the teacher about students’ learning progress included evaluating students’ understanding and give feedback on the adequacy from their explanations. Besides, in this stage, students are given an opportunity to apply their knowledge in a novel problem-solving activity.

### 3. RESEARCH METHOD

#### 3.1. Sampling

A total of 31 pre-service teachers from one public university involved in this study since this was the only cohort for the science education programme. They were selected since they were in the third year and they will undergo their teaching practical next semester. Based on Gay et.al [44] a minimum sample size is 30. Thus, a sample of 31 was acceptable and fulfilled the sample size.

#### 3.2. Intervention and Instruments

This study performed a single group pretest-posttest (Figure 3) design since the true experimental design was not applicable in the social setting due to the limit number of the sample. According to Thompson [45], this design was flexible and reduced interpretation bias [46]. In addition, random assignment of the participants of the study cannot be made since they are already assigned to their classes [47].

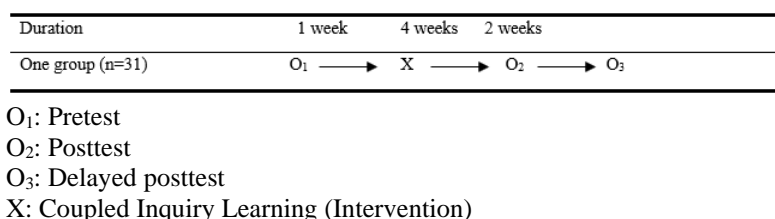


Figure 3. One group pretest-posttest with delayed posttest design

Pretest is done one week before the intervention. Then, they will undergo the coupled-inquiry approach for four sessions in four weeks. Four weeks' intervention period is sufficient since this study focuses on a single well-defined topic [48]. During the intervention, four lessons were used which followed the Couple inquiry-5E stages. In the first lesson plan, students did hands-on activities, extract DNA using fishes and plants while in the second lesson plans, students did internet exploration using guided questions posted by a teacher. In the 3<sup>rd</sup>, meiosis model was provided, and students need to discuss and raised questions and issues on meiosis. In the 4<sup>th</sup> lesson plan, students tried to find solutions on the issues using videos exploration. Finally, students presented their solutions.

The posttest is administered immediately after the intervention is completed. In order to minimize maturation effect, a delayed posttest is conducted two weeks after the posttest to assess the retention of the intervention impact [49]. According to Amirian and Heshmat [50], if the interval was more than two weeks, it may cause further learning on their own. Thus, the delayed posttest is conducted two weeks after the posttest to evaluate if there is any retention of the intervention effect over time. The teacher who will be carrying out the intervention has been trained for two weeks on how to use the lesson plans, materials and questions to be asked in the class. To measure the students' understanding towards meiosis, a 19 multiple choice adopted from Kalas *et al.* [51] and Sadiyah [52] and three structured questions. All the questions used cognitive domains of Bloom's Taxonomy. Based on Crowe, Dirks, and Wenderoth [53], by implementing Bloom's Taxonomy multiple choice questions, it has the characteristic of concepts' understanding. In addition, they claimed that the possible answers include significant distracters which are answers that represent common students' misconception. Thus, the reliability, KR-20 for this test at .82. This study applied ANOVA one-way repeated measures ANOVA. All assumptions have been fulfilled. The significant value for the inferential statistic is set at .05 ( $p < 0.05$ ).

#### 4. RESULTS AND DISCUSSION

According to Table 1, it showed that the mean of the posttest is higher compared to the mean of the pretest. This means that there is a significant change of understanding in meiosis four weeks after the intervention. However, there is only a slight increase in the mean score of the delayed posttest which shows that there is no significant change of the understanding in meiosis two weeks after the posttest. This means that the respondents retained the level of understanding in meiosis.

Table 1. Results of the descriptive statistics for pretest, posttest and delayed posttest

Tests	N	Mean	Standard deviation
Time 1 (Pretest)	31	10.19	4.31
Time 2 (Posttest)	31	12.26	3.38
Time 3 (Delayed posttest)	31	12.45	3.82

In order to assess the effect of couple inquiry towards the meiosis understanding, one-way ANOVA repeated measures was conducted to compare scores on the understanding in meiosis with statistic test at pretest (prior to intervention), posttest (following the intervention) and delayed posttest (2 weeks follow-up). The finding showed that there was a statistically significant effect for time, Wilks' Lambda = .80,  $F(2,29) = 3.65$ ,  $p < .05$ , multivariate eta squared = .20 as shown in Table 2.

Table 2. Multivariate tests result for the understanding in meiosis

Effect	Value	F	Hypotesis df	Error df	Sig.	Partial Eta Squared	
Time	Wilks' Lambda	.80	3.65	2.00	29.00	.04	.20

Therefore, it can be concluded that there is a statistically significant effect for time. This suggests that there was a change of understanding in meiosis across the three different time periods. The value of the Eta squared in this study is .20. Using the commonly used guidelines proposed by Cohen, Manion and Morrison [54] (01 = small, .06 = moderate, .14 = large effect), this result suggest a large effect size. In order to identify the effect of coupled inquiry based on different times (pretest, posttest and delayed posttest), post-hoc test has been used. The finding for the pairwise comparisons for the post-hoc test on understanding in meiosis is shown in Table 3.

Table 3. Pairwise comparisons for the post-hoc test on understanding in meiosis

(I) factor1	(J) factor1	Mean Difference (I-J)	Sig <sup>b</sup>
Pretest	Posttest	-2.065*	.030
	Delayed Posttest	-2.258*	.025
Posttest	Pretest	2.065*	.030
	Delayed Posttest	-.194	.849
Delayed Posttest	Pretest	2.258*	.025
	Posttest	.194	.849

Findings showed that there was a significance difference between the pretest and posttest and between pretest and delayed posttest. Thus, it can be concluded that the coupled inquiry has an effect on the understanding in meiosis. However, in the posttest and delayed posttest, there is an increment of 0.19 but the mean difference was not significant,  $p > 0.05$ . Thus, it showed that coupled inquiry was effective in retaining the understanding in meiosis.

In this Couple inquiry- 5E approach, the teachers' role in the lesson was as a facilitator who scaffolds the learning process by providing support according to the student's cognitive ability and gradually withdrawing it as the learner gain confidence. The scaffolding was provided in each stage of the coupled inquiry learning and especially evident during the hands-on activity. In the third lesson plan, a meiosis model was provided with different sets of chromosomes as a stimulus for visualising the abstract concept of meiosis.

By working on the meiosis model, the students embark on self-discovery learning. At the same time, their reflective thinking was activated to figure out the logical arrangement of the different sets of chromosomes. They have to think why and how was the first attempt to arrange the model wrong and how to correct it. In other words, students were trying to find and make a meaning to the arrangement of the chromosome. By gaining meaning, the students build understanding of the concept of chromosome separation in meiosis. Because meiosis was an abstract concept, scaffolding is a need since it provides support in a concrete way to accommodate the learner's cognitive ability. This will help students to retain the knowledge and understanding. Most of the students' previous experience and existing knowledge was not in the concrete form since drawing and picture was a 2D form. The model in the hands-on activity was 3D in the sense that it can be touched, handled and manipulated. This was a concrete form of scaffolding the student's cognitive ability by providing a concrete model for the abstract concept of meiosis.

During the coupled inquiry learning, active support was provided by the teacher by asking questions which facilitate reflective thinking and self-discovery learning. As the students were arranging the chromosomes in a wrong way, the teacher came over and provides support by asking them questions which made them think in a reflective manner. The students' understanding in meiosis was increased because of the features of couple inquiry. First, the coupled inquiry learning approach generates self-direction learning. Second, the hands-on activity in the coupled inquiry learning were provided with different stimulus which leads to reflective thinking and self-discovery learning while assisting in visualising abstract concept. Third, the questions asked by the teacher facilitate reflective thinking and self-discovery learning.

The findings indicated that the cycle in the coupled inquiry was effective in enhancing the students' understanding in meiosis especially in stage 2, 3 and 4 of the cycle. The reason was in those stages, they were provided with a concrete experience to explore the abstract concept of meiosis, generate their own question to be investigated, explore the answers and decide on the best explanation for their investigation. Thus, students were actively engaged in their learning process and took the responsibility of their own learning which contributed towards their meiosis understanding. However, the teacher's role in the three stages is still important as a facilitator to ensure that the students attain the correct concept understanding. While in stage 5 and 6, students strengthen their understanding by presenting the solutions using power point and mind-map.

## 5. CONCLUSION

Therefore, to inculcate a strong understanding in meiosis, coupled inquiry-5E approach was recommended as an effective tool. A change in the teaching method from conventional teaching where facts of abstract concept are memorized should be altered to coupled inquiry-5E approach which encouraged learners' conceptualization of the abstract concept into a concrete concept. The change is crucial in order to produce students who have a strong understanding in the abstract concept of meiosis. The coupled inquiry-5E approach has a large potential to be implemented in the 21<sup>st</sup> century since it promoted the role of students as active learners with the teacher providing support in facilitating the learning process. It is time for teachers to make a paradigm shift to implement coupled inquiry in the classroom. Coupled inquiry-5E facilitated the progress of inquiry from the guided inquiry to the open inquiry by providing an intermediate platform would benefit students and teachers.

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