

CHANGES IN JUNIOR HIGH SCHOOL STUDENTS' ENVIRONMENTAL LITERACY FOLLOWING PJBL-STEM IMPLEMENTATION THROUGH A WATER FILTRATION PROJECT

Yuanda Purnamasari ^{*1)}, Hari Wisodo ²⁾, Ferdi Dwi Sagitha ³⁾

¹⁾ Professional Teacher Education Programme, Postgraduate School, State University of Malang, East Java, Indonesia

²⁾ Physics Education, Faculty of Mathematics and Natural Sciences, State University of Malang, East Java, Indonesia

³⁾ State Junior Secondary School No. 5 Malang, Malang, East Java, Indonesia

**Corresponding author*

e-mail: yuanda.purnamasari.2531297@students.um.ac.id ^{*1)}, hari.wisodo.fmipa@um.ac.id ²⁾, ferdidwisagitha@gmail.com ³⁾

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ABSTRACT

This study aimed to examine changes in junior high school students' environmental literacy following the implementation of Project-Based Learning integrated with STEM (PjBL-STEM) through a water filtration project. This quantitative study employed a pre-experimental one-group pretest-posttest design involving 31 seventh-grade students at SMPN 5 Malang. Data were collected using ecological knowledge and cognitive skills tests, an attitude questionnaire, and observation sheets. The three-session intervention involved investigating water pollution, designing, building, testing filtration devices, and presenting findings. Data were analyzed using descriptive statistics, the Shapiro-Wilk normality test, paired-samples t-test, and normalized gain (N-Gain). Results showed average scores increased from 73.48 to 89.81, with an overall N-Gain of 0.49 (moderate). N-Gains for ecological knowledge, cognitive skills, and environmental attitudes were 0.58, 0.44, and 0.47, respectively. These findings indicate improved environmental literacy. However, lacking a control group, improvements cannot be attributed solely to PjBL-STEM. The project provided contextual learning connecting scientific concepts with practical environmental problem-solving.

Keywords: environmental literacy; PjBL-STEM; water pollution

INTRODUCTION

At present, the greatest challenges facing the 4.0 industrial revolution and which require attention are environmental issues, including pollution, deforestation, the climate crisis, waste disposal, the biodiversity crisis and the scarcity of natural resources (Apriyanti et al., 2025). Global public concern is currently focused on environmental protection and conservation, which are frequently discussed and addressed. The environment plays a vital role in sustaining life and all human activities (Jannah et al., 2024). There are many challenges that need to be addressed and that require special attention in environmental issues, including climate

change, water scarcity, biodiversity loss, and greenhouse gas emissions (OECD, 2012). Environmental problems have evolved from ecological concerns into strategic issues that can affect the sustainability of human development.

The world is facing a series of crises related to extreme climate change, an energy crisis stemming from dependence on fossil fuels and petroleum, a shortage of clean water, and waste management issues particularly plastic waste. (Nasution & Kahpi, 2025). In Indonesia today, environmental issues are increasingly drawing public attention. One such issue in Indonesia is water pollution. Indonesia's

major rivers, which serve as a source of life for people, have become a source of disease and social problems due to pollution from industrial and household waste, as well as plastic waste.

Plastic waste is one of the environmental issues that consistently draws the attention of the Indonesian public. The accumulation of plastic waste is caused by high population density in each region, a lack of public awareness and concern, and ineffective waste management systems (Widyaswati Aisha, 2023). Therefore, it is essential for the public to care about the environment. Given the many environmental problems we face today, individuals must change their attitudes to reduce environmental damage. This change can be achieved by providing environmental education to teach students about the importance of protecting the environment so that the balance of nature is maintained. Among various environmental projects that can be implemented in science learning, a water filtration project was selected because it directly addresses the issue of water pollution through a practical and contextually relevant activity. Unlike projects that primarily focus on raising environmental awareness, such as waste sorting or recycling, a water filtration project allows students to investigate the characteristics of polluted water and explore a potential solution through an engineering design process.

In this project, students can apply scientific concepts related to water pollution and filtration, select and combine appropriate materials, and design a simple filtration device. The project also incorporates technology and engineering by involving students in constructing, testing, and evaluating their filtration designs. These activities provide opportunities for

students to connect scientific knowledge with practical problem-solving while developing an understanding of how technology and engineering can be applied to address environmental issues. Environmental education needs to be established as a required academic discipline in order to address (SEREN & GUL, 2022). Environmental education serves as a means to achieve the goal of fostering pro-environmental knowledge and behavior (Georgiou et al., 2021).

In 21st-century education, environmental education is not limited to enhancing knowledge and sensitivity toward the environment but also fosters individuals' attitudes and behaviors toward the environment (Özer-Keskin & Aksakal, 2020). Environmental education not only teaches students about the environment but also instills a sense of social responsibility in them (Fang et al., 2023). The goal of environmental education is to shape people's attitudes and behaviors so that they act more wisely in preserving and protecting the quality of the environment both now and in the future through educational activities (Mulà & Tilbury, 2023). One form of environmental education that can be implemented is environmental literacy education. Strengthening environmental literacy is a key component in achieving the goals of environmental education. Environmental literacy encompasses not only an understanding of basic environmental concepts but also the ability to think critically about environmental issues, find solutions, and act in an environmentally responsible manner in daily life (Roth, 1992; Ardoin et al., 2020).

In the context of 21st-century education, environmental literacy is viewed as an essential competency that integrates

knowledge, attitudes, and skills needed to address environmental sustainability issues (UNESCO, 2021; Nugraha & Putri, 2022). An environmentally conscious person is someone who is sensitive to the environment and can offer solutions to environmental problems (NAAEE, 2000). Understanding how nature works and how humans contribute to its sustainability is the foundation of environmental literacy (Istianingsih & Dharma, 2022). According to McBeth et al. (2011) in NAAEE, there are four key indicators of environmental literacy: ecological knowledge, attitudes, cognitive skills, and behavior.

Environmental literacy is a multidimensional concept that involves not only environmental knowledge but also the ability to analyze environmental problems, develop responsible attitudes, and demonstrate environmentally responsible behavior. The framework proposed by McBeth et al. (2011) reflects these dimensions through four indicators: ecological knowledge, cognitive skills, attitudes, and behavior. This framework remains relevant to the present study because it provides a structured basis for examining students' environmental literacy. However, environmental literacy development may require different learning experiences and assessment methods for each indicator. Therefore, this study focuses on ecological knowledge, cognitive skills, and environmental attitudes, while recognizing that behavioral change requires longer-term observation. Environmental literacy among Indonesian students has emerged as a key concern in fostering a sense of appreciation and responsibility for preserving Indonesia's natural resources. Furthermore, environmental literacy plays a crucial role in addressing issues related to

environmental sustainability (Fahlevi dkk., 2023; Kuruppuarachchi et al., 2023).

However, it is essential to improve students' environmental literacy through innovative and contextual learning approaches. The implementation of PjBL provides students with the opportunity to actively engage in meaningful learning activities. The results of a systematic review indicate that PjBL in science education has a positive impact on student learning outcomes, creativity, and active engagement. (Ningrum et al., 2026). This will ensure that students not only gain a deep understanding of environmental concepts but are also able to relate them to real world situations. Using water treatment activities as a learning context can also help connect scientific concepts with their real-life applications (Wulan et al., 2026). Project-Based Learning (PJBL) integrated with STEM (Science, Technology, Engineering, Mathematics) is an educational framework that emphasizes students' understanding of the environment through five disciplines: art, technology, science, and mathematics. This learning model is applicable and relevant to environmental literacy (Fitria & WH, 2025).

By using this model, students can become more creative, critical, and capable of solving problems (Nyaaba et al. 2024; Kartikasari et al., 2024). The characteristics of PJBL which involve students in formulating questions, designing products, carrying out projects, overcoming obstacles, and evaluating results can support the development of students' creative thinking and problem-solving skills (Ni'mah & Usman, 2026). The STEM PJBL model can provide students with opportunities to learn through hands-on experiences in solving real-world

problems, such as water pollution, through project activities that require them to conduct investigations, design solutions, and apply concepts across disciplines (Azfa & Ellianawati, 2026).

Project-Based Learning (PjBL) integrated with Science, Technology, Engineering, and Mathematics (STEM) provides opportunities for students to develop environmental literacy through active engagement with real-world environmental problems. In the context of water pollution, students are not only introduced to scientific concepts but are also involved in identifying problems, designing solutions, constructing prototypes, and evaluating the effectiveness of their projects. These activities may support different dimensions of environmental literacy through interconnected learning processes. First, the science component helps students understand the causes and impacts of water pollution, thereby supporting their ecological knowledge. Second, the engineering design process encourages students to identify problems, formulate solutions, test their ideas, and evaluate the results. These activities provide opportunities to develop cognitive skills, particularly problem-solving and critical thinking. The technology and mathematics components further support students in selecting appropriate materials, considering the functions of filtration media, and comparing the results of their water filtration projects. Furthermore, engaging directly with environmental problems and

developing solutions collaboratively may foster students' environmental attitudes, including awareness of the importance of clean water and concern for environmental preservation. Thus, the integration of PjBL and STEM offers a learning process that connects environmental knowledge with problem-solving experiences and the development of environmental attitudes.

According to the results of the observations, students' environmental literacy skills have not developed optimally. This is because, based on the students' behavior observed during the study, they still lack discipline and concern for the environment at their school, for example by littering in the classroom. This situation indicates a gap between the goals of environmental education and its implementation in practice. Furthermore, research on the application of STEM Project-Based Learning (PJBL) to measure students' environmental literacy levels particularly regarding water pollution at the junior high school level remains relatively limited. Therefore, this study aims to examine how a water filtration learning project using a STEM-based PJBL model can influence seventh-grade students' ability to understand environmental issues. It is hoped that this study will help develop a learning model that is useful for improving students' environmental literacy and enabling them to address environmental issues in their local communities.

METHOD

A quantitative method was used in this study, employing a pre-experimental design with a one-group pretest-posttest model. The design used in this study was a

one-group pretest-posttest design. In this method, a class was administered a pretest before the intervention, then received an intervention in the form of PJBL STEM instruction, and finally took a posttest to assess changes in students' environmental

literacy skills (Sugiyono, 2022). The PjBL-STEM intervention was implemented through a structured project-based learning process. Students were introduced to the problem of water pollution, planned and designed a simple water filtration device, and selected appropriate materials. They then constructed and tested their devices, evaluated the filtration results, and presented their findings. These activities integrated scientific concepts and engineering design to develop students' problem-solving skills and environmental literacy. The research subjects included a science teacher serving as a validator and the students of Class VII B at SMPN 5 Malang, totaling 31 students. The research instruments consisted of pretest and posttest sheets to measure students' ecological and cognitive knowledge indicators, an attitude questionnaire, and an observation sheet to assess students' attitudes of care toward the surrounding environment.

According to McBeth et al. (2011), environmental literacy consists of four indicators: ecological knowledge, cognitive skills, attitudes, and behavior. This study measured three indicators: ecological knowledge, cognitive skills, and environmental attitudes. These indicators were selected because they could be assessed through tests and questionnaires administered during the three-session learning intervention. The behavioral indicator was not measured independently because changes in environmental behavior generally require longer observation periods and repeated assessment. Although students' activities were observed during the project, these observations were used to support the assessment of learning activities and attitudes rather than to establish changes in environmental

behavior. Therefore, the findings of this study represent changes in the three measured indicators and do not cover all dimensions of environmental literacy.

This study utilized instruments such as observation sheets, questionnaires, and tests. Subsequently, validity and reliability tests were conducted on the validated results. In addition to expert judgment, empirical construct validity and reliability testing were conducted on the instrument using SPSS 16.0 with 31 students ($N=31$). Construct validity was evaluated using Pearson's product-moment correlation coefficient, where items were considered valid if $r_{\text{hitung}} > r_{\text{tabel}}$ (0.355 at $\alpha=0.05$). Instrument reliability was evaluated using Cronbach's Alpha, with a threshold value of $\alpha > 0.60$ for acceptable internal consistency.

Once the instruments were deemed valid and reliable, classroom testing was conducted in accordance with the planned intervention PjBL STEM learning through a water filtration project to assess students' environmental literacy skills. Data were analyzed using a quantitative statistical approach with SPSS 16.0. The data were processed and analyzed using normality tests, hypothesis testing, and the N-Gain test. The N-Gain test was used to determine the effectiveness of the implemented PjBL STEM learning model. The interpretation of the N-Gain result criteria according to Hake (1998) is presented in Table 1.

Table 1. Interpretation of the N-Gain Criteria

Skor N-Gain	Kategori
$1.0 \geq g \geq 0.7$	Tinggi
$0.7 > g \geq 0.3$	Sedang
$0.3 > g$	Rendah

RESULTS AND DISCUSSION

The effectiveness of the PJBL learning model integrated with STEM through a water filtration project was analyzed by processing data from knowledge and cognitive tests, as well as attitude questionnaires administered to 31 seventh-grade junior high school students over the course of three sessions. The instruments developed for this study were validated by science subject-matter expert teachers before field testing. The results of the validation were analyzed to determine the average score for each research instrument. Based on the instrument validation results, the average score for the observation sheet was 94%. The validation results for the questionnaire and test questions yielded an average of 92%. The average validation scores for the teaching module and student worksheets were 95% and 97%, respectively. In addition, empirical statistical analysis confirmed the construct validity and reliability of the test instrument. Based on Pearson's product-moment correlation analysis ($N=31$, $r_{\text{hitung}}=0.355$), items 1, 4, 5, 8, 9, and 10 demonstrated significant validity with correlation coefficients ranging from 0.378 to 0.861 ($p < 0.05$). Items 8, 9, and 10 consistently showed strong correlations in both the pretest ($r_{\text{hitung}} = 0.767, 0.814, 0.761$) and posttest ($r_{\text{hitung}} = 0.840, 0.861, 0.746$) assessments. Reliability analysis yielded a Cronbach's alpha coefficient of 0.613 for the pretest and 0.784 for the posttest (for valid items), indicating moderate to high internal consistency.

After receiving validation results from subject-matter experts in science, the PJBL STEM teaching module which integrates environmental literacy was implemented. Prior to implementing the PJBL STEM module, a pretest was

conducted to assess students' initial environmental literacy skills. The PJBL STEM module was applied to the topic of humanity's role in preserving the local environment. The implementation involved a structured learning process where students investigated water pollution, designed, built, and tested simple water filtration devices using local recycled materials. In the design phase, students were required to select and sequence materials (gravel, coarse sand, fine sand, activated charcoal, and cotton) based on their understanding of physical filtration and adsorption mechanisms. During the testing phase, students systematically tested polluted water samples, observing and comparing clarity, odor, and flow rate before and after filtration.

When initial prototypes failed to achieve clear water, students conducted iterative re-engineering by adjusting layer thickness and material proportions. This hands-on process of designing, testing, and troubleshooting directly connected abstract scientific concepts with contextual problem-solving, driving the improvement in students' cognitive and ecological competencies. While working on the project, students divided tasks to complete the provided worksheets. The project results were presented in class using a "gallery walk" format. Throughout the project activities up to the presentation, observational assessments were conducted to evaluate students' attitudes and behaviors, in addition to the provided questionnaire. After completing the project, a posttest was administered to assess students' final understanding following the implementation of the integrated PJBL STEM model with environmental literacy. The PJBL STEM learning syntax used during the instructional process aligned

with environmental literacy indicators such as ecological knowledge, cognitive skills, and a caring attitude is outlined in Table 2.

Table 2 PJBL STEM Syntax with Environmental Literacy Indicators

STEM PjBL Syntax	Teacher Activities	Student Activities	Environmental Literacy Indicators (McBeth)	Instrument
Syntax 1: Reflection	The teacher presents the comic “The Mystery of Microplastic Rain.” Students reflect on how “Apin’s” behavior (littering) affects his own health.	Students examine the content of the story provided and reflect on how plastic waste can pollute the environment and harm living things.	Knowledge: Understanding the concept of the pollution chain and the interactions among ecosystem components.	Preliminary Test / Oral Questions
Syntax 2: Research	The teacher asked the students to conduct a literature review using books and the internet to answer the questions provided in the worksheet.	Students conducted a literature review to find out how plastic breaks down into microplastics and how the filtration process works to purify water	Cognitive Skill Analyzing scientific information related to environmental degradation and technological solutions.	Student Worksheet
Syntax 3: Discovery	The teacher asks and guides the students to design a simple filtration device to observe the clarity of the water	Working in groups, the students design a simple filtration system. They determine the order of gravel, sand, cotton, and charcoal to produce clear water.	Cognitive Skills: Developing technical designs as solutions to environmental problems.	Device Design Diagram (worksheet)
Syntax 4: Applications	The teacher monitors and guides the students as they assemble a simple filtration device	Students assemble the apparatus and conduct experiments. Students measure the volume, clarity, and color of the water before and after the filtration process.	Cognitive Skills: Evaluating the effectiveness of solutions based on numerical data	Observation Table
Syntax 5: Communication	The teacher asked the students to give a presentation explaining the	Students present their findings and engage in moral reflection. Students	Attitude: Demonstrating concern and a sense of moral	Reflection Journal

results of their make concrete responsibility
 project to build a commitments to toward
 simple filtration change their environmental
 device. The behavior in order to sustainability.
 teacher also guided protect the
 the students in a environment in their
 group reflection daily lives.
 session.

Based on Table 2, the PJBL STEM learning model integrated with environmental literacy indicators was implemented over three sessions, with 2–3 JP per session. This intervention began with a pretest and an attitude questionnaire. Next, the PJBL STEM model was applied through the design of a water filtration project. Here, students worked in groups to share tasks in designing a simple water filtration device. In addition, students completed a worksheet containing problem-solving questions and the results of the water filtration project they created. During the process of constructing the water filtration device, observations were made for each group to measure the implementation of the environmental literacy indicator, specifically attitude. This project was carried out over one session with a time allocation of 3 JP. In the following session, students gave presentations, engaged in reflection, and took a posttest to determine whether the PJBL STEM learning had an effect on students' environmental literacy skills before and after the intervention.

From the implementation of these treatments, data were obtained and analyzed using SPSS 16.0 statistical tests to assess the effectiveness of the interventions administered to seventh-grade junior high school students. The results of the pretest-posttest and the attitude questionnaire were then analyzed using several tests, including

the normality test, the paired t-test, and the N-Gain test. The normality test was conducted to assess the assumption of a normal distribution for the obtained data (Ahadi et al., 2023). Data are considered normally distributed if the statistical p-value is > 0.05 . The data from the pretest and attitude questionnaire yielded values of 0.9 and 0.8, respectively, based on the Shapiro-Wilk normality test, indicating that the data are normally distributed. Hypothesis testing was conducted after the data were confirmed to be normally distributed through the normality test. This hypothesis test used a simple paired t-test because the data being tested were paired (Waluyo et al., 2024). The results of the simple paired t-test for the pretest and posttest are shown in Table 3.

Table 3. Pretest and Posttest Results

Score	N	Mean
Pretest	31	73.48
Posttest	31	89.81

Based on Table 3, the results of the simple paired t-test showed a pretest mean score of 73.48, and after the intervention of PJBL STEM learning through a water filtration project the posttest mean score was 89.81. The pretest results – posttest results indicate that $\square_1$ is accepted due to a significant difference between the pretest and posttest scores, meaning that the PJBL STEM learning model has an effect on students' environmental literacy. After

determining the results of the hypothesis test, if a difference is found, an N-Gain test is conducted for each indicator to assess the effectiveness of the PJBL STEM learning model used (Muhammad & Subekti 2023). The results of the N-Gain test showed an average score for all environmental literacy indicators of 0.49, indicating a moderate level of effectiveness. The N-Gain results for each measured environmental literacy indicator are presented in Table 4.

Table 4. N-Gain Results by Environmental Indicator

Indicator	N-Gain	Category
Ecological knowledge	0.58	Moderate
Cognitive ability	0.44	Moderate
Attitude	0.47	Moderate
Average	0.49	Moderate

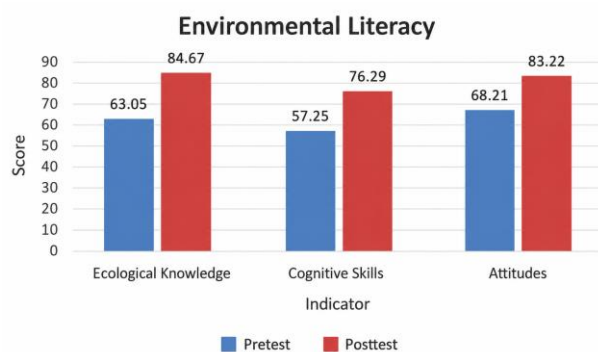


Figure 1. Posttest Scores for Environmental Literacy Indicators

According to McBeth et al. (2011), ecological knowledge within the realm of environmental literacy encompasses an understanding of ecology, natural resources, pollution, and environmental issues ranging from local to global. In this learning process, indicators are honed by providing stimuli in the form of problems that students can solve. The questions tested basic ecological understanding related to water pollution and human

activities that cause environmental damage. The average pretest score for the ecological knowledge indicator was 63.05, while the average posttest score was 84.67. These results indicate an improvement in the ecological knowledge indicator of environmental literacy. Additionally, the effectiveness was rated as moderate, with an N-Gain of 0.58. Students' basic ecological knowledge is developed when they gain a fundamental understanding of ecological concepts, theories, and principles, as well as an understanding of how nature functions and interacts with social systems.

Cognitive skills in environmental literacy refer to an individual's ability to think critically in order to analyze environmental issues, evaluate information, and make decisions based on scientific evidence (McBeth et al., 2011). In this assessment, students are presented with a problem related to the impacts and consequences of human activities on the environment; they then identify, analyze, and plan solutions to that problem. The average pretest score for the cognitive indicator was 57.25, while the average posttest score was 76.29. Based on these pretest and posttest results, there was an improvement in the cognitive ability indicator for environmental literacy. In addition, the N-Gain test yielded a value of 0.44, which falls within the "moderate" category. Students' cognitive abilities can be honed through activities that require them to think critically to solve problems. According to Mauludah et al. (2018), problem-based learning can enhance students' ability to identify and analyze environmental problems.

According to McBeth et al. (2011), attitudes toward environmental literacy refer to an individual's tendency to care

about, value, and have the intention to act in order to protect the environment. To measure students' attitudes toward the environment, a questionnaire was administered, and observational assessments were conducted throughout the learning process. As a result, the average score on the pre-test was 68.22, while the average score on the post-test was 83.22. These results indicate an improvement in students' attitude scores following the questionnaire. In addition, an N-Gain test was conducted to assess the effectiveness of the learning model, yielding an N-Gain value of 0.47. This result was further supported by observational data showing that, on average, students demonstrated a sufficiently caring attitude toward their surrounding environment. This caring attitude can be fostered through students' small daily habits, such as disposing of trash properly, turning off unused water faucets, and cleaning their desks after use. Through these habits, a sense of caring for, loving, and valuing the environment can grow a conscious effort stemming from the students' conscience.

The integration of STEM elements directly supported students' environmental literacy development. Science and technology were applied as students investigated water pollution and configured filtration media to improve ecological knowledge. Engineering and mathematics were integrated through designing, testing, measuring water characteristics (clarity, odor, volume), and re-engineering prototypes, which heavily cultivated cognitive problem-solving skills. Finally, evaluating project outcomes and presenting findings during gallery walks reinforced environmental attitudes and personal conservation responsibility. These findings align with international research

demonstrating the efficacy of PjBL-STEM in environmental education. For instance, recent global studies on STEM-integrated environmental projects show that contextual, hands-on engineering tasks significantly enhance students' problem-solving abilities and ecological awareness compared to traditional instruction (e.g., Georgiou et al., 2021; Winarni et al., 2022). The consistent gain in environmental attitudes observed in this water filtration project further corroborates international literature emphasizing that active participation in real-world environmental remediation builds long-term conservation ethics and civic responsibility among secondary students.

CONCLUSION

The implementation of the PjBL-STEM model through a water filtration project improved seventh-grade students' environmental literacy on water pollution. This was shown by a significant difference between pretest and posttest scores ($p < 0.05$) and a moderate overall N-Gain of 0.49 across ecological knowledge, cognitive skills, and environmental attitudes. However, since this study used a one-group pretest-posttest design without a control group, the results should be interpreted carefully. Other factors, such as students' learning experiences and natural development, may also have contributed to the improvement. In addition to improving students' scores, this study shows how hands-on projects can help students understand environmental concepts through practical activities and problem-solving. For science teachers who want to apply this model, small-group activities, structured worksheets, and easily available recycled materials are important to support students in designing, testing, and

improving their filtration devices. Overall, the PjBL-STEM model can be used as an alternative approach to teaching environmental literacy in secondary science classrooms, especially when students receive appropriate guidance throughout the learning process.

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