

Using narrative to enhance STEM identity, increase environmental awareness and encourage biodiversity literacy

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Abstract

The demand for qualified STEM workers, especially in fields relating to environmental science and engineering research far exceeds the current workforce supply. Inspiring students to consider a career in these fields requires innovative educational intervention, to maximize student interest and engagement in these fields. Imaginative education, through the combination of a storyline based approach, infused with specific learning content, and supplemental concept-reinforcing activities, has the potential to elicit deep student engagement in various STEM subjects. This approach also has the ability to generate and enhance student TEM identity. In this study, we provided 250 elementary school students, and their teachers, in 6 high needs districts across the US with a book and activity intervention, focused on wildlife conservation and adverse human environmental activities. Schools were provided with a choice of three adventure/mystery books, focused on different endangered species in various regions of the world. Pre and post-intervention surveys were developed with an outside consultant, and completed by 103 students. The results of these surveys indicated a strong positive change in STEM engagement (58.25%), career knowledge (36.17%), career interest (22.67%) as well as STEM identity (32.36%). The results of this study demonstrate that the environmental-themed storyline approach had highly positive learning effects on the student participant population. Teacher feedback confirmed that the book and STEM literacy approach, being different from regular forms of instruction, was welcomed and

had positive overall effects on the learning environment. Students were deeply engaged in the narrative, and were able to use their imaginations to engage in activities to extend the lessons learned from the content within the books. Beyond environmental STEM content, students were also exposed to concepts involving cultural diversity, geography, environmental policy and more.

Keywords: biodiversity; narrative; literacy, STEM education

Introduction

In recent years, much attention within the STEM education research community has focused on interventions targeting elementary and middle school aged children. This is in large part because it has been shown that there is mounting evidence demonstrating a relative decline in interest in STEM fields, and overall decrease in STEM identity prior to high school years, particularly among girls and other under-represented groups (Petroff, 2017; Modi et al., 2012). In addition to identity, it has been shown that other measures such as interest and engagement also drop significantly from elementary through high school years (Tai et al, in preparation). These trends are observed both in boys and girls, in formal and informal learning settings. While there is mixed evidence with regard to STEM content knowledge gain/loss in this same period of learning, we contend that the greater priority in STEM is attracting and maintaining youth interest and engagement in STEM fields; inversely, a STEM content foundation is less relevant, if students choose not to pursue STEM fields in later life. As such, there is a great need to enhance and improve STEM interventions in this age bracket, to rebuild/salvage the STEM interest levels seen in younger students. Through a broader array of STEM interventions that are more targeted and engaging, young students may have a higher likelihood of developing and maintaining lifelong interest in STEM fields. Given the shortage of a properly qualified STEM workforce today, and significant equity gaps with regard to gender and diversity, it is critical to develop innovative interventions that target students in the upper elementary and middle school age range, in particular within diverse communities.

Throughout time, children have been drawn to new subjects of interest through the power of story. Fictional narrative has been used as a tool for engaging students in STEM learning, as well as other subjects, for many decades (Lauritzen, 1997). It has been demonstrated that quality STEM based books have the ability to generate greater scientific and engineering literacy as well as potentially greater overall success in STEM fields (Popov, 2017). This is further evidenced by the fact that numerous Nobel Prize winners and other top scientists often recall reading STEM books as children, thus sparking their deep level of interest in science and engineering fields (*What Did the Nobel Prize Laureates Read When They Were Young?*, n.d.). Numerous studies have indicated positive changes in STEM identity, knowledge and other measures, following storyline-based interventions (Kelemen, 2018; McGinnis-Cavanaugh, 2010; Carino, 2019). Research has also confirmed that interventions which incorporate a variety of informal STEM activities, that reflect one's personal identity, are particularly useful tools to enhance STEM identity and potential career pathways among diverse groups of students (Kang et al., 2018).

A storyline approach permits young students to immerse themselves in a new world and insert their imaginations into the context of an engaging plot. Through the titles selected for this study, students visit distant lands and are introduced to fascinating animals, who have become endangered due to human activity. Students can experience, through imagination, worlds that they might not otherwise ever have an opportunity to visit in the real world. This is especially true in socioeconomically disadvantaged school districts, such as those selected for this study. Through engaging story, students can be exposed to a multitude of educational concepts (math, logic, language, critical thinking skills, social studies, civics, etc.) in addition to the core content knowledge (for instance, environmental science, engineering, biodiversity, animal biology).

In this study, we have developed an intervention that combines an upper elementary / middle school level scientific adventure book series with activities, discussion guides and video presentations from experts on a variety of environmental topics. Our underlying goal with this narrative-centric multi-media approach was to generate greater understanding among students with regard to human impacts on animal habitats. The book series of choice addresses biodiversity, wildlife conservation and the plight of endangered species in modern industrial times. Through NGSS standards-aligned curricula and choice boards, combined with a book and/or other form of narrative, students can be engaged in STEM content, and through the use of a cast of young characters from different backgrounds, it is thought that students may be able to better identify with the heroes of the story. Through this alignment of identity, students may potentially be able to envision themselves as the protagonists in their own stories of life. It is our thesis that embedding educational STEM content into narrative formats will “hook” more students both into potential STEM pathways (for instance, independent PBL/science fairs, courses chosen in high school, or college majors/minors), enhance knowledge about possible careers in environmental fields, and will also increase their understanding of the natural world around them. Through the utility of a book series, students enhance reading skills and are also exposed to diverse characters, from different cultures and regions of the world. It is thought that through the inclusion of diverse role models/mentors more students from diverse backgrounds will be enticed to think of themselves as potential future members of the global STEM community.

Project Aims

Project intervention and evaluation aims were to: distribute books from the “ResQ: Saving One Animal at a Time”: adventure novel series, viz. ResQ and the Baby Orangutan, ResQ Takes On The Takhi and ResQ In Panamá: Can We Save The Frogs? to high needs schools and libraries; utilize books to deliver cross-disciplinary programs and expand student knowledge of science and social studies relevant to conservation biology in general through the specific context of the

chosen book; enhance reading comprehension; increase STEM identity; and improve approaches to instruction through narrative-based engagement.

Intervention

In early summer of 2021, ten schools were selected that met demographic objectives, situated in economically disadvantaged/underserved communities as follow — Hazelton, PA (2), Houston, TX (2), New York City (2), Philadelphia, PA (1), Scranton, PA (2) and Tunkhannock, PA (1). Schools were polled to determine which of the book titles were of greatest interest to their community. Books were selected by school contact/teachers primarily on the basis of the main endangered animal species theme and geographic setting of the book (orangutans in Indonesia, wild horses in Mongolia, frogs in Panama). Classroom sets of the chosen books were delivered to all schools. Twenty-five copies of the chosen title were provided, and were utilized as the main subject of learning in the classroom, in addition to digital curricular materials, some basic professional development as well as instruction with regard to conducting pre- and post-intervention surveys. Activities and lessons were aligned with specific themes within a given book plot. Additionally, two copies of each of the other titles were provided to all associated school libraries.

Digital curricular materials included study guides in the form of Choice Boards for each book, as well as book discussion guides and other materials. These digital tools provided the teacher/student with lessons in the form of videos, appealing text and inquiry-based activities that address and aligned with the Next Generation Science Standards including Ecosystem Dynamics, Earth and Human Activity and Engineering Design. The relevant Choice Boards and other supplemental materials were made available for teachers to use along with their selected book. Readings and associated activities were administered by teachers, after minimal virtual professional development from the research team (less than one hour). After students read the selected book, author and biology expert Dr. Pell met with the classes for a one-hour virtual author visit. The lectures included lively, interactive exchanges with the students. Visits began with providing the students with her personal story from early days as a first generation

American and first-generation college “goer” to her professional development as a professor, plant research scientist, and US federal science policy maker at the Smithsonian. Students were engaged in thinking about endangered species through interactive quizzes / polls, administered primarily online due to Covid pandemic-related restrictions for in-person guest lectures (with several lessons in-person). Lessons were administered for an average of 3 hours per week, throughout the length of the program, which varied based on school availability, with most students receiving approximately 1 month of treatment, and up to ~2 months.

At the end of each session, students were invited to submit questions and engage in group discussions. Students addressed Dr. Pell, as well as the entire class with their individual questions, which were far ranging. Examples of questions included: What inspired the characters in the story? Is it based on a true story? How long did the story take to write? Are you going to write more stories like this one? What species will the next book be about? Where did your parents come from? The questions allowed Dr. Pell to expand on the story with interesting facts about the science in the stories, interactions with people from the respective countries where the stories are set, as well as conservation challenges the students could all respond to. Students additionally participated in a number of hands-on activities including drawing an imaginary, conceptual vehicle, capable of travelling in the air, sea and land, designed to aid in the conservation work conducted by the fictional scientific heroes in the ResQ endangered animal series.

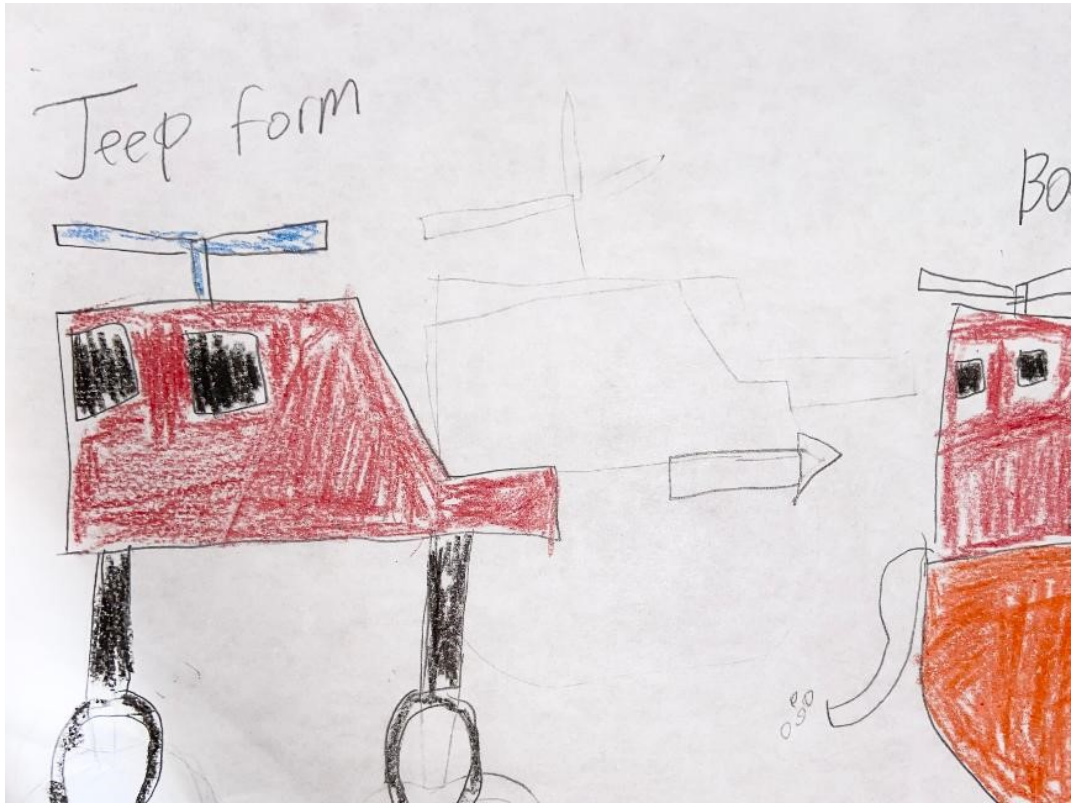


Figure 1. Students from an underserved community in the Philadelphia, PA region engaged in an activity to envision and draw their own conception of a “HeliBoaJee” – an imaginary vehicle used by heroes in the ResQ stories, to help save endangered wildlife.

Teacher feedback was solicited, and the results of this inquiry aligned with project objectives. Teachers were receptive and welcoming of a classroom activity based on the combination of fictional narrative and STEM literacy, and relayed the student enthusiasm for the opportunity to read the books. Below is a response from an elementary school teacher in one of the rural schools in Hazelton, PA:

Many students, especially this year, have not read a chapter book in years or have never read one. When I told my students we would be reading a chapter book, most were ecstatic (some were not, of course, but they warmed up to it). I even had one kid come up to me and say thank you for letting him read a book. After day one of reading this book, students began bringing in books of their own because it sparked their interest in reading. Beyond getting students to be more excited about reading, this book contained so many topics and materials to discuss. There was math, science, social studies, and reading material that could be pulled out and examined. As a math, science, and social studies teacher, it was extremely helpful to be able to cover so much in just one book. We discussed different currency and how conversions work, we talked about time zones and where Indonesia is in the world, we were able to talk about the various idioms in the book and what the characters meant, w11.5e even were able to talk about feelings and how they would feel if they were there. I could go on and on about the amount of valuable information (and standard based information) that came from this book that we were able to discuss meaningfully as a class. This program has inspired me to teach through chapter books more because of the incredible experience I had with this one.

What follows is a response from a teacher in an urban school in Philadelphia:

There was a really cool teachable moment for the students while we were reading. One student asked me why the Mongolian characters weren't using articles (a, an, the) in their dialogue. And I explained to them that many times, people who are speaking a second language don't always have to follow each and every convention of the language (especially as it pertains to people who speak English as a second language, due to its many rules). I have several students who are interested in STEM programs. They really enjoyed all aspects of the book, the Sci-Fi aspects in particular. We all love the book! We discussed the "HeliBoaJee", and what it would take to design one. Many of them drew illustrations. I will be returning to teach 4th grade again, and I will be using the book as a part of my curriculum.

Analysis

Prior to the start of the intervention, students were asked to provide demographic information, on a voluntary basis, and most students responded, with results as follows.

Of the students who participated in demographic questionnaires, 58% were boys, 33% girls and 10% did not answer. Virtually all who responded (96%) were in 4th grade, with most aged 9 (45%) or 10 (40%). 16% identified as African American, 14% Caucasian, 11% Hispanic, 11% Multi-Racial, 7% Asian American, 2% American Indian, and 39% preferred not to answer, or their ethnicity was not listed. For 39% of students, English was their primary language, while for 53%, English was not a primary language, and 9% preferred not to answer.

In all, the survey, books and associated program materials were provided to 10 schools in 6 US cities, however, not all schools that participated in the program completed their required surveys. As such, as of the time of this publication, pre- and post- data has been collected from 103 students out of approximately 250 participants. Despite the incomplete survey participation, we consider the 41% response rate to be a success, and the volume of responses

received provides us with a sufficient sample size, large enough to ascertain the success of the program.

Survey questions were developed in conjunction with, and vetted by, PEAR (Partnerships in Education and Resilience). Formerly a part of Harvard University and Harvard-affiliated mental health center, McLean Hospital ISRY (The Institute for the Study of Resilience in Youth), PEAR is an independent educational research organization, focused on social emotional learning/development (SEL / SED) research. Their approach has been normalized through incorporation into large volume of federal and privately funded educational research programs, throughout the country, most notably in the fields of STEM education and STEM identity. PEAR provided our project with both resulting raw data as well as fully analyzed results of the pre- and post- intervention surveys conducted by our participant schools.

Students were surveyed with queries that can be bundled into five categories: STEM engagement; STEM career interest; STEM career knowledge; STEM activities (students are or would like to be involved in); and STEM identity.

Surveys were administered electronically, at participant sites. A four-point Likert scale was utilized, with no neutral option. Following the intervention, students were asked to rate their agreement with a battery of statements relating to the project, as well as about their perceptions of STEM in general.

Standardized survey questions were selected from PEAR's CIS-S (Common Instrument Suite – Student) database of previously tested survey questions regarding STEM interest/engagement, along with a number of custom questions, specifically designed for the endangered animal book series based intervention (Sneider and Noam, 2019).

Sample Project-Specific Survey Statements:

- I would like to visit a zoo or aquarium.

- I am interested in learning more about endangered animals.
- I would like to be an inventor.
- I like to read about science adventures
- I am interested in learning more about engineering.
- I think stories are a good way to learn about the world.

The combined data from all schools, demonstrated an overall positive response, across all key instrument categories. The following data represents a net positive increase in all categories; percentage of all students showing a positive change as a result of our engagement:

STEM Engagement: 58.25%

STEM Career Knowledge: 36.17%

STEM Career Interest: 22.67%

STEM Identity: 32.26%

Program - Percent Positive Change 103

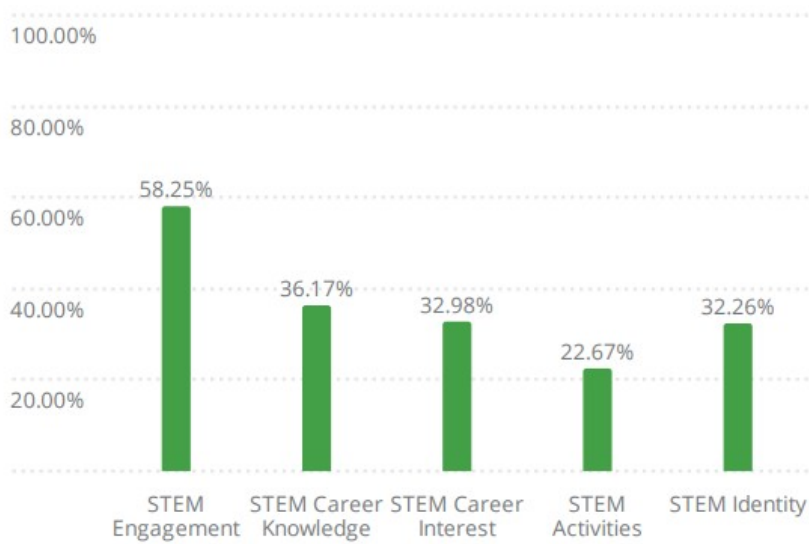


Figure 2. Percent positive change, demonstrating impact in specified STEM sentiment survey question categories, showing the difference between pre- and post-intervention surveys, developed by an external analysis firm.

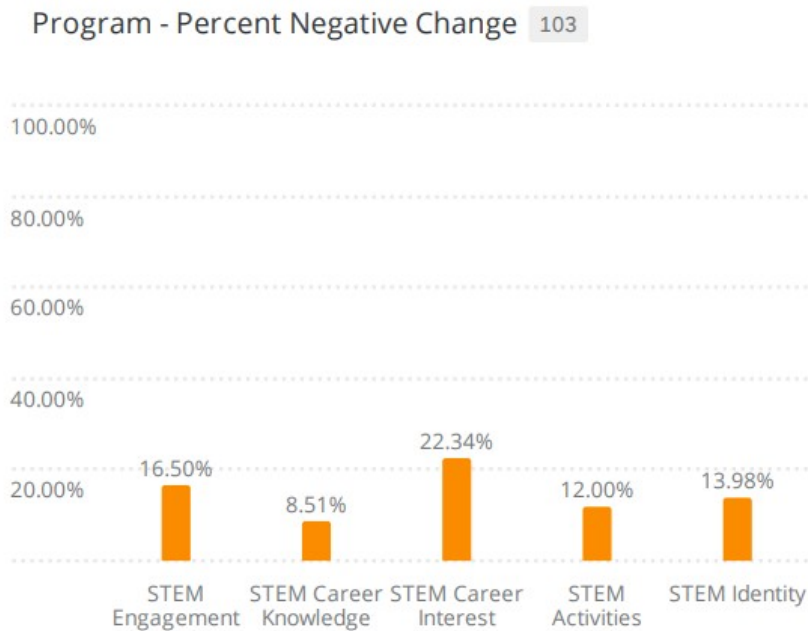


Figure 3. Percent negative change, demonstrating changes in sentiment within specified STEM sentiment question categories, showing the difference between pre- and post-intervention surveys, developed by an external analysis firm.

Negative changes in student sentiment toward STEM related measures were also observed, which is typical of most STEM education program evaluations. While some negative effects were observed, particularly in the category of STEM career interest, the net change in student attitudes toward STEM demonstrated that overall, students felt that the experience was positive.

This data demonstrates that a narrative and discussion based approach yielded the intended effect on students, especially with regard to STEM Engagement (58.25% increase) as well as STEM Career Knowledge (36.17% increase). Moreover it suggests that the wildlife

conservation content was of genuine interest to the students, and led some of them to consider a career in this field, and reinforced STEM identity.

Discussion

Learning about environmental science and engineering concepts through an imaginative, narrative based vehicle allows students to immerse themselves in STEM learning, using a format that they enjoy. While not all students will be drawn to the academic content, more students will be drawn to the narrative plot, into which STEM content knowledge is embedded. At the same time, students gain reading skills and learn about culture, policy, environmental stewardship and more. Simply exposing children to these concepts at a critical time in the formation of their self identities, can inspire a habit of mind to learn more about the world around them and to consider STEM-related futures. Stories about animals, in particular exotic animals, as well as stories about other young people, tend to draw interest among young children. STEM knowledge can be reinforced by combining learning goals and story elements with an adventure/mystery themed plot, and correlated hands-on activities/lessons. As evidenced by feedback from teachers and administrators, many of the students in participating schools had not read books since the beginning of the pandemic. Providing students with opportunities to imagine themselves in new worlds, full of scientific possibility, promotes not just imagination, but also promotes specific fields of STEM. In this case, our focus on biodiversity and wildlife issues clearly resonated with the participants, as the measure of positive change in subject matter specific career knowledge related measures was 36.17% (with 8.51% negative change) which is quite substantial. Moreover, positive change in measures relating to STEM engagement increased by 58%, affirming that the storyline approach achieved its intended effect. The results of this intervention clearly showed that a narrative-centric pedagogical approach has the ability to enhance student literacy regarding ecology and biodiversity issues, as well as increase general interest in STEM fields.

By exposing readers to plots inclusive of characters from different backgrounds with a range of individual talents, students may be drawn to embrace diversity, and potentially envision themselves as the protagonists in their own life stories. Because of today's diversity gap in the STEM workforce, and the lack of sufficient mentor roles that reflect one's personal identity, some students may have the perception that they do not belong, or will not succeed, in STEM. Exposure to stories with examples of diverse heroes likely helps students to overcome perceptions of alienation within certain fields of study, and ideally, attain a sense of self-efficacy. STEM-embedded narrative learning complements more traditional modes of education. The combination of ELA and STEM further allows for the collaboration of teachers in otherwise disconnected disciplines.

Future Directions

Since the development of human language, storytelling has been an essential tradition in education, passed down through the generations. For centuries, books have been the primary mode of narrative content available to the masses. In the digital age, narrative has evolved substantially and includes video/social video (both short form like Tiktok or long-form like Youtube), immersive video game series, fan fiction blogs, and more. With the advent of ChatGPT and other Natural Language Processing related AI, narrative technology will surely evolve rapidly, especially as we now enter a new phase of social computing in meta-world virtual realities, and in highly interconnected Web 3.0 learning environments. Regardless of the format, learning through story is essential to maximally engage students, to help form and reinforce STEM identity, and inspire them to imagine a future in which scientists and engineers use their knowledge to solve global problems.

A modular, menu-based approach to format, allowing students to experience a combination of narrative based trans-media is thought to be ideal, in order to reach more students and educators,

with the mode of their own choosing. While this intervention focuses on a more traditional printed book-based narrative, future research activities could incorporate a variety of narrative choices for students, including physical and/or digital interactive books, combined with optional video and other media content, along with instructor-guided lessons and both digital and physical project-based learning activities. In particular, students would benefit from data science lessons that incorporate math/statistics as well as visualization of datasets correlating endangered species populations to habitat destruction and other environmental factors. In subsequent research, we intend to incorporate a greater variety of media options for students to self-discover, through their own preferred narrative vehicle, and with greater freedom of choice.

Furthermore, we anticipate that greater employment of narrative based education will likely include the use of dynamic, AI-generated texts, with common underlying themes and content, specifically customized to the cultural/gender identities, learning levels and other personal requirements of individual students. It is thought that this approach will deepen the engagement of students, improve learning progression, and further enhance individual STEM identity. This is an area which the authors are currently exploring and which we intend to incorporate into future studies.

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Supplemental Resources:

Sample Choice Boards

<https://tumblehomebooks.org/wp-content/uploads/2022/07/Sample-Choice-Board-ResQ-and-the-Baby-Orangutan.pptx>

Curricular Materials (Free download available):

Mongolian horses:

<https://www.teacherspayteachers.com/Product/Endangered-Animals-Reading-Writing-and-Projects-about-wild-Mongolian-horses-8780780>

Orangutans:

<https://www.teacherspayteachers.com/Product/Endangered-Animals-Reading-Writing-and-Projects-all-about-orangutans-8802096>

Panama frogs:

<https://www.teacherspayteachers.com/Product/Endangered-Animals-Reading-Writing-and-Projects-related-to-a-story-about-frogs-8780844>

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