International Journal of Professional Development, Learners and Learning
2023, 5(2), ep2312
ISSN 2754-0618 (Online)
https://www.ijpdll.com/
Research Article
OPEN ACCESS

A teaching intervention for magnetism using STEM in kindergarten

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Citation: Samara, V., & Kotsis, K. T. (2023). A teaching intervention for magnetism using STEM in kindergarten. *International Journal of Professional Development, Learners and Learning*, 5(2), ep2312. https://doi.org/10.30935/ijpdll/13667

ABSTRACT

STEM education should begin in kindergarten, as pre-school children's engagement with science and other fields, such as technology, raises their awareness and interest in science (Mantzicopoulos et al., 2009). In addition, it provides kindergarten children with the necessary opportunities to cultivate their talents (Chesloff, 2013) and contributes to their later development (Kermani& Aldemir, 2015). Pre-school children are capable and ready to learn with a STEM approach, as they can ask investigative questions, justify their opinions, and formulate interpretations about how the world around them works (NSF, 2012). Given the importance of the universal introduction of STEM in pre-school education, this work aims to design a teaching intervention in kindergarten using STEM on the topic of magnetism. First, reference is made to the use of STEM in kindergarten and the usual learning theories on which it is based. Then, the basic methods of its application are briefly presented. Furthermore, the theoretical framework regarding children's misconceptions about magnetism is presented. Subsequently, the research questions are formulated on which the design of the educational intervention will be based, as well as the research hypotheses arising from the bibliographic review. Then, the goals of the teaching intervention are developed in harmony with the goals of the Greek curriculum for kindergarten, and the choice of methods, means, actions, and applications is justified. Finally, interdisciplinary activities using STEM and the involvement of new technologies are proposed.

Keywords: STEM, kindergarten, magnetism, project

Received: 02 Aug. 2023 ◆ Accepted: 07 Sep. 2023

INTRODUCTION

STEM education seems to be an approach that improves the knowledge and experience of individuals (Gunsen et al., 2017), predisposes them to solve problems by making interdisciplinary connections for situations they face in their daily lives (Tosmur et al., 2018) and enhances their creativity (Tozlu et al., 2019). Learning about magnetism is an important component of science education (Van Hook & Huziak-Clark, 2007). Students' understanding of magnets has been studied extensively over the past 20 years, covering a wide range of age groups, from elementary to university level.

LITERATURE REVIEW

STEM in Kindergarten

STEM education begins in kindergarten. Pre-schoolers have an innate curiosity for inquiry, like experimenting and using various tools, solving problems and puzzles, comparing phenomena, and objects (Sharapan, 2012), and investigating facts, patterns, and rules.

In addition, early childhood brain development through STEM education can contribute to later life children's development (Kermani & Aldemir, 2015) and minimizes possible poor performance in their later education, enhancing the success of admission to higher education but also in their later work career (Chesloff, 2013).

Furthermore, research has shown that including STEM in primary education motivates students and improves learning speed (Scaradozzi et al., 2015).

STEM is a seed for cultivating critical-thinking citizens for a digital tomorrow, and early childhood appears to be the perfect "seed time" (McClure et al., 2017). Children are born scientists, and every child wonders about the objects that surround him and about the events that happened (Akturk, 2019; Alan, 2020).

In conclusion, pre-school children appear ready and able to engage in STEM activities. Therefore, they should be introduced to STEM approaches from early childhood. In pre-school classrooms, where STEM activities are conducted, children build and internalize scientific and mathematical concepts through experimentation and exploring various materials. In this way, STEM education provides meaningful learning and can lead to positive future educational experiences (Moomav & Davis, 2010).

Theories of Learning

STEM education is based on the following learning theories:

1. **In Piaget's constructivism:** A theory argues that students build new knowledge on top of pre-existing knowledge. The teacher's role is to guide and aims to provide the student with the appropriate stimuli to discover knowledge on his own (Mödritscher, 2006).
2. **In Papert's constructivism:** This theory is based on Piaget's Constructivism. Still, the emphasis is placed on the "construction of knowledge", which is constructed by the students themselves, based on their previous knowledge, to build new knowledge. Thus, knowledge is constructed and not transmitted (Chatzidimitriou, 2015).
3. **In Bruner's discovery learning:** A theory on constructivism claims that students discover knowledge on their own, starting from internal motivations, the main of which are curiosity, the need to interact with other students to achieve common goals, and the desire for recognition (Raptis & Raptis, 2004).

STEM Application Methods

STEM application methods are, as follows.

Project method

This method is very popular in applying STEM education. The project method is a group learning process, where the whole group participates actively, regulatory, and decisively (Frey, 1991). Matsangouras defines projects as "collective, interdisciplinary work plans of multiple intelligences" (Matsangouras, 2003). Using the project method, the students independently implement "complex work plans, thus developing their critical thinking and collaborative skills" by interacting with their classmates, teacher, and social environment (Matsangouras, 2003). The process of the method is divided into four phases, starting with a temporal gradient view and the characterization of the initial, middle, and final phases in the life of a project (Katz & Chard, 2004). These four phases are, as follows:

1. Problematization
2. Planning the teaching activities
3. Conduct of activities
4. Evaluation.

This separation is not binding but is necessary for a presentation of the activity in a more systematic way.

Problem-solving method

According to the literature (La Force et al., 2017), problem-solving contributes to increasing students' interest in STEM education. Also, students develop their creativity, critical thinking, and problem-solving skills while at the same time learning to collaborate and improve their communication skills. In addition, students' self-confidence regarding STEM fields is strengthened, and the likelihood of them engaging in them in the future increases.

Exploratory method

The application of the exploratory method strengthens children's interest in science (Zakariah et al., 2016). The exploratory method is appropriate for STEM education (Crippen & Archambault, 2012), as students follow a series of steps to gather evidence to find the answers they need to a problem in their everyday life that interests them. Furthermore, the analysis of these elements and the presentation of the results of their research in the form of various representations, such as tables, diagrams, etc. This is followed by evaluating their effort and thoroughly presenting their findings.

Engineering design process

Engineering design process includes the construction of a final product resulting from the utilization of children's knowledge in mathematics and engineering to involve them mainly in the whole process (Mann et al., 2011) in the search for possible solutions and not so much in successful manufacturing of the product.

Planning Teaching Intervention

Children's perceptions of magnetism

A review of the research literature reveals that there are only a limited number of studies on children's perceptions of magnetism, even though children are quite familiar with related phenomena, which are usually included in the curriculum of physical activities in kindergarten. In some research that has been done on children's understanding of the concept of gravity, it has been found that children tend to associate magnetism with gravity since they sometimes explain the existence of gravity in terms of a magnetic force that tends to pull objects towards earth (Driver et al., 1998).

Many researchers report that pre-school children generate theories about objects or situations through their intuition (Bonawitz et al., 2019; Gopnik, 2012). Young children tend to make spontaneous operations, which they have never classified or organized conceptually (Ravanis, 1994).

According to Bagno and Eylon (1997), several studies conclude that students need help understanding the phenomenon of magnetism. Children's science misconceptions appear to be quite persistent and particularly resistant to change (Driver et al., 1994).

Some studies conducted have shown that children explain the attraction behavior of the magnet as an "invisible force" (Selman et al., 1982) and use the expression "sticking" (Piaget & Chollet, 1973).

According to Barrow (2000), children mostly only have perceptions of the attractive behavior of magnets and think that the attractive force of magnets will increase with their size. The fact that children state that the magnet has "miraculous" characteristics, and the use of incorrect conceptual expressions show us that invisible situations must be explained correctly and clearly for pre-school children to understand the nature of science (Kalogiannakis et al., 2018).

A study by Bailey et al. (1987) investigated whether or not elementary school students use their alternative ideas about magnetism to predict how magnets interact. The research was conducted on 119 elementary school students. The students came to the following conclusions:

(a) that in every interaction, the more recent it is the medium, the greater effect it has, and

(b) that the larger the medium, the greater effect it has.

Many students thought that the older the magnet would be, the less its magnetic strength, which is inconsistent with the scientific data. They also considered, in their majority, that a magnet half the length of the magnetic strip would have a less magnetic effect than a magnet twice the size (Bailey et al., 1987).

According to Smolleck and Hershberger (2011), three-eight year-old children had the misconception that magnets attract all materials and thought that magnets attract all metals. In addition, children reported that magnets are different “colors,” “shapes,” and “sizes,” and reported that they “have a north pole and a south pole” and that they have “different forces. “Most children also reported that the magnets “stick”. Some other children’s perceptions were that magnets are ‘magic’, ‘hard’, ‘stick to all metals’, ‘stick to silver’, the ‘size of the magnet’ affects its magnetic field, the poles ‘do not attract equally’, the magnet will not attract objects that are “heavier” than the magnet itself. Magnets will not attract objects that are “harder”, “thicker”, “stronger,” and “bigger” than the magnet.

Similarly, research has concluded that children under the age of seven have difficulty distinguishing objects/materials that are attracted to magnets from those that are not, i.e., they cannot explain magnetic attraction (Finley, 1986; Ravanis, 1994). Gunes (2017) explained the reasons for misconceptions in the form of “magnets only attract” and “magnets repel nonmetals” among students in his book.

The literature also points to students’ need to be more accurate about understanding the effect of the magnetic force produced by magnets. “Bigger magnets are stronger than smaller magnets” is a popular misconception among students of all grades (Gulcicek, 2004; Lemmer et al., 2018; Smolleck & Hershberger, 2011; Tanel & Erol, 2005). The opinion that “the magnet must touch a material to attract it” was found among students aged nine-18 years (Bar et al., 1997). Studies have also revealed misconceptions about how far magnets can attract materials among students at all grade levels (Bar & Zinn, 1998; Bar et al., 1997; Hickey & Schibeci, 1999).

Implementing planned activities, enriched with various pedagogical means, can help younger children overcome wrong alternative ideas regarding magnetism (Samara & Kotsis, 2023). In a study by Christidou et al. (2009), three different approaches to teaching magnetic attraction were applied to pre-school children to investigate their degree of effectiveness. In the first approach, emphasis was placed on the children’s alternative understandings regarding magnets and magnetic forces and on the interactions that appeared among the children in the classroom. In the second approach, emphasis was placed on children’s perceptions combined with specially designed activities that used pedagogical tools such as storytelling, experiments, and dramatization. The third approach was purely teacher-centered regarding magnetic attraction. This research concluded that children who participated in the first two approaches showed a better understanding of magnetic attraction, while the third approach did not seem to affect changing their initial incorrect alternative ideas (Christidou et al., 2009).

In research conducted on the teaching of magnetism in kindergarten with the alternative approach of reading related picture stories, before the teaching intervention, it appeared that the children had little knowledge about magnets and their properties. They also needed clarification on magnets’ definition, utility, material, and origin. They also did not know the property of the magnet to repel, only to attract. The kids thought the magnets could attract because there was glue on the magnets, a material they often use at their age. They still needed to sort out which materials cause the magnetic attraction, but they understood that magnets attract other materials besides magnets. After the teaching intervention, the children were able to create an adequate definition of magnets. In addition, they could correctly identify the material from magnets. They understood that a magnet has the property of attraction and repulsion and that this “invisible force” is responsible for these properties. Furthermore, most children understood the magnet’s property to attract only iron objects but needed to identify its origin and utility before or after the teaching intervention (Kalogiannakis et al., 2018).

In research conducted by Dimitriou (2015), the development of the skill of sorting objects based on their interaction with the magnet and the cultivation of the skill of sequencing magnets based on their strength were investigated before and after the implementation of appropriate activities designed with the application of the didactic learning sequence. After the instruction, it was observed that the children could sort the objects according to their property of being attracted to the magnets and rank them according to their strength. The classification of objects based on their property of being attracted by magnets contradicts other research, such as the research by Temertzidou et al. (2014), where even after the assessment, children managed to group them into magnetic and non-magnetic materials without error. Before instruction, children could not name any magnetic object or only mentioned one. Only two children (out of 32) showed the ability to identify two or three objects attracted by the magnet but also make incorrect identifications at the same time (“nail, paper clip, coin, and glass ornament” or (“coin, paper clip and plastic cup”). Also, before the teaching, 18 children out of the 32 who participated in the research, managed to put the magnets in order, recognizing that the big one is the strongest, followed by the medium one and the small one respectively (Dimitriou, 2015).

Ravanis (1994) argued for the necessity of playing with and manipulating magnets for pre-schoolers to discover the reciprocal forces of interaction.

Also, in research conducted, it was shown that the alternative teaching method that includes the interaction of children, who participate actively and experientially in the entire educational process, can help them understand the concept of magnetism (Rendom et al., 2022).

Systematic design is necessary if one wishes to create a framework of analysis for comparing communication practices and for its role in the construction of kindergarten activities on the concepts of magnets and magnetic attraction (Poimenidou & Christidou 2010).

For Constantinou (2013), the children’s chronological age, and not their cognitive maturation, in relation to a structured teaching intervention played an important role in the performance by two groups of children aged four-six years of two operational definitions of a magnet (Constantinou et al., 2013).

The results from the above studies suggest that pre-school children should be given the opportunity to try and sort different objects that are attracted and not attracted to magnets, such as cardboard, plastic, and metal objects (some should be iron or steel, but others should be materials such as aluminum). In this way, children will learn that many materials are not attracted to magnets: those that are attracted to magnets are all metals, but not all metals are attracted to magnets.

Research Questions

1. Effectiveness in learning that magnet has push and pull behaviors due to its positive and negative poles.
2. Effectiveness in learning that magnets attract and repel certain materials.
3. Effectiveness in learning that magnets have different shapes and sizes.

4. Do STEM activities increase children's mathematical talk in the reflection/expression lesson on the characteristics of magnets?
5. Is using technology in STEM activities effective in teaching the concept of magnets to pre-school children?

Research Cases

1. Children will struggle to define the concept of magnetism for which they draw their explanations from everyday life and attribute magnetic attraction to some 'electricity', 'air pressure' or 'some kind of gravity' (Barrow, 2000).
2. Children will not know the property of the magnet to repel, only to attract (Kalogiannakis et al., 2018).
3. Children will assume that magnets attract all metals and include in their answers about which materials magnets attract and other materials that are not attracted to magnets, a perception that is consistent with other studies (Finley, 1986; Karabacak, 2014; Ravanis, 1994; Smolleck & Hershberger, 2011).
4. Activities using STEM will increase children's mathematical talk in the reflecting/expressing the characteristics of magnets lesson, which agrees with the literature review (Cambell & Speldewinde, 2022).
5. Children will understand that magnets have different shapes, sizes, and colors, as mentioned in the literature review (Smolleck & Hershberger, 2011).
6. Children will consider bigger magnets to be stronger than smaller ones, as mentioned in the literature review (Gulcicek, 2004; Lemmer et al., 2018; Smolleck & Hershberger, 2011; Tanel & Erol, 2005).
7. Children will consider that the distance of the magnet from the object will affect its magnetic attraction to it since even nine-18 year olds have expressed the opinion that "the magnet has to touch a material to attract it" (Bar et al., 1997).

DESIGN & DESCRIPTION OF ACTIVITIES: METHOD, APPLICATIONS, OBJECTIVES, MEANS-MATERIALS, & PEDAGOGICAL MANAGEMENT

Method

It is recommended to use the project method, where children can retrieve their previous ideas, visualize their perceptions and plan, implement, and present their actions. The teaching approach will be interdisciplinary, that is, more than one learning area will be involved in each activity, as is consistent with the new kindergarten curriculum (Educational Policy Institute, 2014) and the needs and abilities of pre-school children.

Applications

StoryJumper

StoryJumper is a web 2.0 tool for creating illustrated e-books (https://www.storyjumper.com/book/read/16476072/StoryJumper). The user is given two possibilities: either to develop a descriptive story or narrative easily and quickly by choosing one of the available ready-made templates or to start from scratch. To illustrate the story, one can use ready-made scenes and various objects but also upload photos of one's choice from one's own computer. The application is free, requires registration, and supports the Greek language. It is easy to use and simple, so it is ideal for young children.

Kidspiration

It is a concept mapping software aimed at young children (https://learningworksforkids.com/apps/kidspiration/).

Nvivo

It is a software package for processing qualitative data, which enables the visualization of the participants' responses in a survey, thus helping to conclude (https://lumivero.com/products/nvivo/).

BeeBot

Beebot, the "smart bee," is a programmable floor robot specially made for pre-schoolers and first graders (https://grobotronics.com/bee-bot.html).

ScratchJr

It is an introductory programming language that enables children aged five and up to create their own interactive stories and games (https://www.scratchjr.org/).

Activities: A & B Phase of the Project

Problematization and planning of the activities

Learning areas: New technologies–Language.

Objectives from the kindergarten curriculum (Educational Policy Institute, 2014). The children:

- to develop their oral language
- to build new knowledge about magnetism on top of the old, that is, on what they know
- to express their opinion and their cases

Materials–media: Kidspiration software.

Pedagogical management: Work in small groups.

Activity description: Creating histograms highlighting children's previous ideas through the Kidspiration application (**Figure 1**). Thus, young children visualize their knowledge and are helped to structure and process it to plan the next actions to discover new knowledge and to overcome their false alternative ideas "represent knowledge that cannot be expressed measurably" (Komis & Raptis, 2002).

Activities: C Phase of the Project–Implementation

Learning areas: Natural sciences–Mathematics.

Objectives from the kindergarten curriculum (Educational Policy Institute, 2014). The children:

- to express their ideas about the natural phenomenon of magnetism and discuss them with others.
- to adopt or formulate relevant questions for investigation
- to formulate answers to the questions they investigate and utilize the results of their investigations in new situations

Materials–media: Variety of materials: plastic, metal, magnets of various sizes, & A3 paper.

Pedagogical management: Children work in small groups.

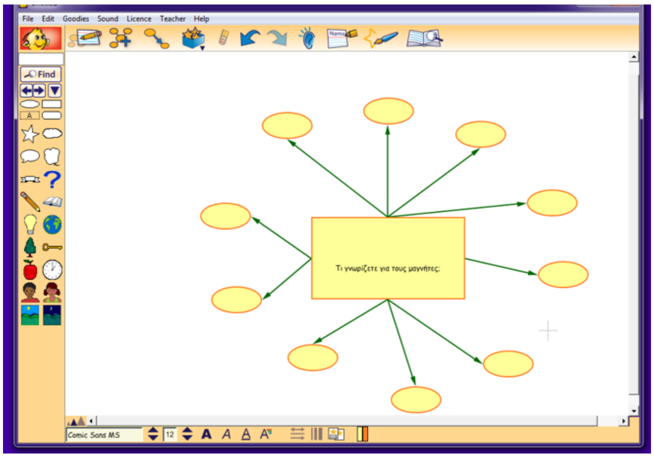

Figure 1. Kidspiration application: What do you know about the magnets? (https://learningworksforkids.com/apps/kidspiration/)

Activities' Description

Activity 1

Children are given a variety of materials, plastic, metal, small and large, as well as magnets of various sizes with which they experiment and form their perceptions of which materials are attracted or not. A child is designated as the representative of each group, who will present the conclusions of his group's action at the end of the activity.

Activity 2

The conclusions will be recorded using the painting technique: the children will divide the A3 paper into two parts: objects attracted by a magnet and objects not attracted by a magnet.

Activity 3

With the help of phonological awareness, the children write the names of these two groups and the names of the objects that are attracted or not by the magnet.

Activity 4

Children in groups test magnets of different sizes, new and old, for how well they attract different objects, record their answers about how many objects each magnet attracted, discuss with each other the results of their actions and the representative of each group presents to the other groups the conclusions of his group.

Learning area: Mathematics.

Objectives from the kindergarten curriculum (Educational Policy Institute, 2014). The children:

- to think about and investigate various situations, rely on previous knowledge and experiences, make simple assumptions, and come to relevant conclusions.
- to "interpret" general elements of the world around them through processes of observation and description, comparison, classification, matching, sequencing, and symbolic representation.

Materials–media: magnets of various sizes, various materials: plastic & metal.

Pedagogical management: Work in small groups.

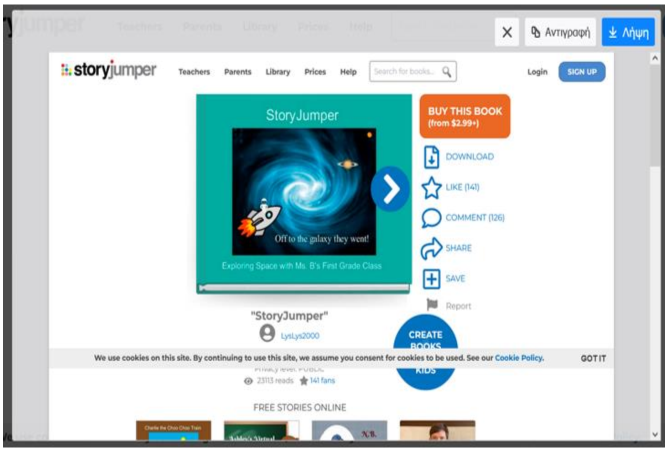

Figure 2. StoryJumper program (https://www.storyjumper.com/book/read/16476072/StoryJumper)

Activity Description

The children put the magnets in order, from the smallest to the largest magnet, and vice versa. They also make groupings of the objects, based on the materials that are attracted and the materials that are repelled by the magnets.

Learning areas: New technologies–Language.

Objectives from the kindergarten curriculum (Educational Policy Institute, 2014). The children:

- to cooperate in groups to produce a project and respect the opinions and work of others.
- to develop their oral language.

Materials–media: StoryJumper application & photos of the children's activities.

Pedagogical management: Work in small groups.

Activity description: Create an electronic book with photos of the children's actions from their interaction with the magnets, as well as create comments under each photo that will concern their conclusions for each action, with StoryJumper program (**Figure 2**).

Learning areas: Robotics–Art.

1. **Bee-Bot**

Objectives from the kindergarten curriculum (Educational Policy Institute, 2014). The children:

- to familiarize themselves with the correct use of simple robots

Materials–media: Bee-bot robot, tape measure, markers, and other painting materials.

Pedagogical management: Work in small groups.

Activity description: Children use simple materials to create a floor path for their robot Bee-Bot and program it to only move towards the area, where there are magnetic objects.

2. **Scratch Jr**

Objectives from the kindergarten curriculum (Educational Policy Institute, 2014). The children:

- to investigate, experiment, model, and discover knowledge
- to develop the ability to judge and make decisions and solve problems

Materials–media: ScratchJr.

Figure 3. ScratchJr software (https://www.scratchjr.org/)

Pedagogical management: Work in small groups.

Activity description: Through ScratchJr program, children can give their hero, which can be, for example, their well-known bee Bee-Bot, which in our case, will attract and be attracted by magnetic objects, simple commands, such as to move only in the area, where metal objects are present, to reach its destination (**Figure 3**).

D Phase of the Project–Evaluation

Learning areas: New technologies–Robotics.

Objectives from the kindergarten curriculum (Educational Policy Institute, 2014). The children:

- to compare their initial alternative perceptions and their perceptions after implementing the activities using appropriate applications of new technologies
- to develop their oral language

Means: NVivo application.

Pedagogical management: work alone

Activity description: Transcribing the children's answers and entering this data into the qualitative analysis software NVivo (https://lumivero.com/products/nvivo/) through two-dimensional expansive graphs, stereoscopic analysis, text search query to visualize the answers of the children, before and after the teaching intervention, as a means of evaluating it for the kindergarten teacher and the children. Also, new data may emerge in this way, leading to an extension of the teaching intervention. NVivo can also be used as a concept mapping tool at the initial stage of the project when the histogram of the children's ideas is created.

CONCLUSIONS

Various attempts have been made occasionally to teach primary education concepts of sciences, such as the concept of magnetism. From the evaluation of these efforts, it follows that the teaching of natural concepts to children is much more effective when it is enriched with tools such as the telling of related stories, experiments, theatre, storytelling, tools that are also STEM tools, as long as it is used the appropriate technological equipment.

STEM is not difficult for teachers to apply to children since no specialized technological knowledge is required, but the active participation of children throughout the educational process is required for the tasks to arise from the students themselves, and the teacher to it has only an encouraging, facilitating and mediating role both between the students and between the students and the technological tools.

In the present work, a project is developed, based on STEM education, since, as evidenced by the literature review, STEM can help children change their wrong alternative ideas about the properties of magnetism and thus understand the specific concept better. The results and conclusions from implementing the project in a kindergarten served by the researcher will be presented in subsequent work.

Author contributions: Both authors were involved in concept, design, collection of data, interpretation, writing, and critically revising the article. Both authors approved the final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Ethics declaration: The authors declared that the study does not require ethical approval since it is based on existing literature.

Declaration of interest: Authors declare no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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