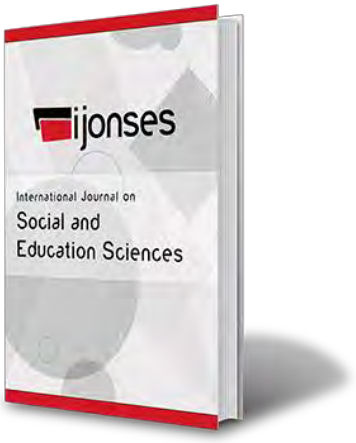

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Children's Literature: A Contribution to the Emergence of Science in the Early Years

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To cite this article:

Cruz, C., & Breda A. (2024). Children's literature: A contribution to the emergence of science in the early years. *International Journal on Social and Education Sciences (IJonSES), 6*(1), 1-19. https://doi.org/10.46328/ijonses.613

International Journal on Social and Education Sciences
2024, Vol. 6, No. 1, 1-19 https://doi.org/10.46328/ijonses.613

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Article Info

Article History

Received:
10 August 2023
Accepted:
21 December 2023

Keywords

Children's literature
Science
Divergent thinking
Basic education

Abstract

Children's natural curiosity by everything around them is a premise for discovery. Natural phenomena such as the alternation between day and night, elements of nature such as the tree's leaves and their shapes and colors, daily routines as sorting waste, raise many questions in children, stimulating them towards scientific literacy trough what is familiar to them and their personal life experiences. In the science children's books, the concepts' approach sometimes difficult its understanding by children, due to the used vocabulary, the lack of an appealing narrative, among other aspects. In turn, children's literature books without any intention of promoting or developing ideas of science can, through their narrative and illustrations, in a more meaningful context for children, motivate the inquiring and the concepts' exploration. This work results from a presentation session of the children's book "From the outside to inside and from the inside to outside" to children of a Portuguese school of the 1st Cycle of Basic Education, by the authors which are also the researchers, having as aim create an environment based on questioning activity, supported in the story narrative, and develop children's divergent thinking in a context involving scientific ideas.

Introduction

From its birth, children have an intrinsic motivation to know, displaying readiness to learn and explore, since they are active, and curious creatures (Ryan & Deci, 2000; Eshach & Fried, 2005). The informal knowledge that children acquire stems from an involvement with and from their curiosity in relation to what they see around them and in relation to what they experience. Although the scientific conceptions created by the human mind are related with how we observe and experience the world, science is more than a result of that experiences or senses. Science emerges from an 'unnatural' activity, being difficult, even for adults, the understanding of scientific concepts and its application real world situations (Eshach & Fried, 2005). Since children do not have cognitive maturity to interpret and apply certain scientific concepts, many questions arise, namely why it is essential to develop scientific literacy in children from an early age. Several "researchers have shown that ideas which take shape in early childhood do not readily disappear with age but prove to be disconcertingly robust" (Black & Harlen, 1993; Gardner, 1999, cited in Eshach & Fried, 2005, p.318).

Scientific language can be an obstacle in the teaching and learning process of science in the early years, in this

sense, according to Fang (2014), children's literature can support the development of scientific literacy through its narrative and illustrations, approximating itself from the children language and engaging them in scientific ideas through well-crafted stories with meaningful contexts, helping them to understand scientific ideas and its progresses. In addition, children's literature also promotes positive attitudes, imagination, and creativity. The use of children's literature into science teaching and learning process has become a more common teaching method (Erumit & Akerson, 2022). The presence of stylistic figures in children's literature, such as metaphors, also contributes to the understanding of the ideas to be conveyed as well as to the stimulation of new ideas, in fact, several scientific discoveries were supported in metaphors (Dreisdadt, 1968).

The contexts narrated in children's literature stimulate creativity and sometimes provoke divergent thinking, especially when they portray situations that differ from what is understood as normal. The creativity has been considered a crucial human characteristic with respect to academic, social, and emotional achievement (Weiss et al., 2021). The term "divergent" is frequently associated with creativity and refers to the mind capability of produce ideas beyond that is expectable (Khatri & Dutta, 2018). The divergent thinking is stimulated in inquiry learning environments involving contexts for creativity and open-ended questions (Ritchie et. al, 2011).

This work focuses on a study resulting from the children's book presentation "From outside to inside and from inside to outside" to children of a Portuguese school of the 1st Cycle of Basic Education. During the book's presentation, was established a dialogue between the authors, which are also the researchers of this work, and children based on questioning activity through open-ended questions emerging from the narrative, in a context involving scientific notions. This study has as research problem: Can children's literature contribute to the emergence and development of scientific knowledge, in particular mathematical knowledge, in students of the 1st Cycle of Basic Education?

Theoretical Background

Science in the early Ages

Children are, from a very early age, awake to the perception of their surroundings. The understanding of what surrounds them occurs naturally in their daily routines, when they face new experiences, when they are encouraged to think about situations or concepts in contexts that are meaningful to them. In one of his reflections, Einstein (1936) said "The whole of science is nothing more than a refinement of everyday thinking." (Zimmerman & Klahr, 2018, p.2), reinforcing the proximity between innate characteristics of children and scientists, namely, the natural curiosity about the surroundings and the constant inquiry.

In early childhood, science education is relevant in terms of cognitive development, providing children with knowledge and skills about phenomena that they encounter in everyday life, but also in their social development, since science and technology influence the human culture (Sackes et al., 2009; Eshach & Fried, 2005). Nowadays, in a scientifically and technologically advanced society, the citizens must be scientifically literate (Zimmerman & Klahr, 2018). According to Eshach and Fried (2005), small children should be exposed to science because: "they naturally enjoy observing and thinking about nature; exposing students to science develops positive attitudes

towards science; early exposure to scientific phenomena leads to better understanding of the scientific concepts studied later in a formal way; the use of scientifically informed language at an early age influences the eventual development of scientific concepts; children can understand scientific concepts and reason scientifically; Science is an efficient means for developing scientific thinking." (p. 321). The term "science" may comprise two types of knowledge, namely, domain-general, and domain-specific knowledge (Zimmerman & Klahr, 2018), in which domain-specific knowledge refers to the knowledge of concepts in the different domains of science, such as natural sciences, chemistry, physics, mathematics, among others, and domain-general knowledge refers to general reasoning processes and skills involved in experimental studies design and evidence evaluation.

Children's Literature in the Scientific Literacy Development

The use of children's literature in the development of scientific knowledge is not new (Sackes et al., 2009; Clyne & Griffiths, 1991; Doig, 1987, 1989). Literature supports young children's development in scientific concepts and provides information in understandable language, based in their interests, promoting the children's curiosity and opportunities for inquiry (Zeece, 1999; Sackes et al., 2009). In fact, from children's literature the ideas emerge in a narrative which helps children understand difficult science concepts, since the concepts and skills are involved in a context that is more meaningful for them (Morrow et al., 1997). In addition, children's literature allows develop scientific literacy, in an interdisciplinary context, also improving language literacy (Akerson et al., 2019). The use of storytelling in teaching and learning processes can stimulate students' interest and motivation, reduce their anxiety, engage them in the educational process through meaningful and memorable ways (Van den Heuvel-Panhuizen et al., 2009; Lemonidis & Kaiafa, 2019).

Children's literature involves a narrative and, usually, everyday situations related with students' experiences, providing meaningful ways to illustrate concepts and stimulate problem solving as well as investigations, turning students from passive learners into active learners (Skoumpourdi & Mpakopoulou, 2011; Lemonidis & Kaiafa, 2019; Erumit & Akerson, 2021). On the other hand, the emergent contexts from children's literature can engage students in an approach involving imagination and creativity, stimulating good emotions, and promoting the development of cognitive, social, and emotional skills. There is a mutual influence between the cognitive, emotional, and social domains, so it is important that educators and teachers create environments in which children can express their emotions, reduce their anxiety about educational environments and academic knowledge to acquire (Furner, 2018; Tucker et al., 2010). The use of *bibliotherapy* (the approach to concepts, formulation and problem solving, based on the reading of pre-selected books) envisions changes in children's attitudes towards different curricular areas, contributes to the articulation between the cognitive, social, and emotional domains, reduces possible behaviors of anxiety, and stimulates positive attitudes (Furner, 2018).

The use of literature allows children relate their informal ideas to scientific concepts (sometimes abstract), serving the narrative and illustrations as cognitive "hooks" for children (Tucker et al., 2010; Van den Heuvel-Panhuizen et al., 2009). Children's literature can influence positively the academic performance since promotes communication, different representations, and the use of metaphors (Furner, 2018; Van den Heuvel-Panhuizen, 2009). One of the characteristics of literature in general, and children's literature in particular, is the use of

metaphors.

Metaphors, in addition to being figures of style of a linguistic nature, are also a basis for thinking and conceptions, that is, they make thoughts perceptible, structure perceptions and foster the understanding of concepts or ideas (Lakoff and Johnson, 1980/2005, cited in Çekirdekci, 2020). Kirby (1997) presents the Aristotle's view of metaphors as a transference from one point to another, where "the transfer seems to be that of a name from one item - the ordinary item for which that name is the "literal" term - to a new (and unaccustomed) one, where its applicability may be highly figurative." (p.532). Metaphors, in addition to helping to understand concepts or phenomena, bringing them closer to what is simpler or more familiar, triggering connections between what is known and what is unknown, can also be levers for ideas or scientific discoveries.

Bruner (1962) highlighted the influence of metaphors on science stating that "It is true that the product of science is not metaphoric, but the process of science is shot through with metaphor at rather critical points in the history of science." (Porter, 1969, p.41). Several scientists have credited their discoveries in metaphor, Dreisdadt (1968) from the biographical analysis of scientific discoveries have found that a great number of scientists have supported their discoveries in metaphor, being Einstein one of them with his imaginary elevator, falling in the shaft, which led to the Principle of Equivalence of Gravitation and Inertia (Porter, 1969). Since in the early years, scientific concepts can be constructed and acquired with meaning through metaphors, the children's literature is a promising resource in this regard.

Several researchers have pointed out limitations in the children's books that are used in early childhood classrooms, namely: misconceptions embedded in texts; inaccurate illustrations; fantasy; and anthropomorphism (Sackes et al., 2009; Trundle & Troland, 2005; Broemmel & Rearden, 2006; Gomez-Zweip & Straits, 2006). However, according to McLean et al. (2015), the problem is not the misrepresentations of science in children's literature but the low levels of teachers' background knowledge which can influence their ability in using children's literature as an invitation to science inquiry, promoting discussions from those misrepresentations. That is, "One way of addressing this concern is to consider pedagogical approaches that use children's literature not as a source of scientific concepts, but rather, as a springboard into potential science inquiry learning" (McLean et al., 2015, p.50). According to Akerson et al. (2019) the effective use of children's literature in educational context to improve science knowledge implies an appropriated evaluation of the books and a constant questioning from teacher.

Martson (2014) identifies three different types of 'mathematical' picture books to assist educators and teachers in selecting and evaluating of books for promoting quality mathematics learning, namely: perceived (books written principally to entertain; the mathematical concepts are unintentional and incidental); explicit (books written in picture book format to specifically teach or develop one or more mathematical concepts; these include counting books and 'trade' books); embedded (quality picture books written principally to entertain but with mathematical language and concepts purposefully embedded within them) (p.15). Although Martson categorizes books according to specifically to mathematical content, in our perspective this classification could be extended to the presence or evidence of science content.

Inquiry and Divergent Thinking

The OECD Learning Framework 2030 refers the need to apply students' knowledge in unknown and evolving circumstances, highlighting a range of skills, including cognitive and meta-cognitive skills such as creative thinking (OECD, 2018). According to Runco (2008), divergent thinking, popularized by Guilford (1950,1959), is one of the multiple facets of creativity, being defined as the ability to identify different directions when faced with a problem or open-ended tasks (Guilford, 1959; Acar, 2022). The term "divergent", frequently associated with creativity, refers to the tendency to identify a different direction and describes the capability of the mind to produce ideas beyond the agreed expectations and rote thinking, that is, in simple terms, it is "thinking outside the box" (Khatri & Dutta, 2018).

Divergent thinking, was defined by Guilford and Merrifield (1960) as "generation of information from given information having as characteristic "jumping from one class of information to another" (Porter, 1969, p.42). This type of thinking is often viewed as a good metaphor for cognition – type leading to creation of original ideas. This thinking stands strikingly apart from convergent thinking, which characteristically produces predictable and "correct" thoughts and explanations instead of imaginative or unusual alternatives (Guilford, 1959; Khatri & Dutta, 2018). However, Brophy (2001) defended that divergent and convergent thinking are complementary and, theoretically, interact between them.

Guilford (1957) identify in divergent thinking three components: fluency, flexibility, and originality. Posteriorly, Guilford (1960) and Torrance (1963) characterized divergent thinking as a mental process following main attributes such as fluency, flexibility, originality, and elaboration (Porter, 1969), characterized as: fluency is the ability to rapidly identifying many varied solutions to an issue or problem; flexibility is the capability to change effortlessly according to the situation, focusing itself on the ability to approach a problem from varied viewpoints or perspectives; originality is the ability to discover unique, novel, divergent or fresh ideas, focusing itself on creating or inventing a work which is novel or unique differentiating itself from forgeries, clones, reproductions or derivative works; elaboration is the ability to actualize each and every element of ideas and see their role towards a bigger solution, referring itself to the process of accumulating more information to already available, and forward information to craft a more multi – faceted, evolving whole (Khatri & Dutta, 2018, pp.1005-1006).

Many educators and teachers, recognizing the pertinence of divergent thinking in the development of skills in the cognitive, emotional, and social domains, are faced with questions such as: How to promote this type of thinking? What strategies or methodologies can contribute to its development? Khatri and Dutta (2018) present several strategies for develop divergent thinking, pointed out by several researchers, namely: reverse the question / answer concept (rather than posing a question, ask students to craft or construct the problem); let us celebrate the differences (students freely express their thoughts and opinions not being judged by their peers, expressing or sharing our divergent thoughts and ideas); inquiry – based feedback (a value based feedback should be replaced by an inquiry based feedback); encourage play and handle failure (a failure is seeing as a situation wherein students get time to introspect and draft new strategies); seek wild ideas – brainstorming (help in the generation of wild ideas and although such wild ideas may not work directly, moving away from the line of conventional thinking

helps in embarking on an idea which is "out of the box"); alternate uses task (in this exercise, given an object the task is to produce or list out as many possible uses of that particular object); play devil's advocate (when someone plays devil's advocate, the person inspires and promotes divergent thinking, since stimulate the finding of solutions for its questions); *establish a tolerant environment* (divergent thinking flourishes in environments which allows failure, approves varied expression and ideas, and encourages risk); embrace creative constraint (when someone faces paucity of resources, is stimulated to unearth unusual means to use the existing resources available); *collaboration* (we are more prone to involve in divergent thinking when we are faced with different and unusual viewpoints, and collaboration may contribute in this sense).

The open-end problems or tasks are essential in the promotion and development of the divergent thinking, since stimulate students to build up their own answers rather than offering tasks to develop routine processes and memorization (Guilford, 1959; Runco, 2020; Khatri & Dutta, 2018). Also, the questioning activity and the type of questions involved in it play an essential role in stimulating creative, alternative, and innovative thinking. In questioning activity, a teacher or educator asks questions either orally or in written form (Aziza, 2021), being oral questions considered by Cotton more effective for stimulating learning and teaching activities than written questions, since through oral questions, teachers motivate students to involve actively in the discussions verbalizing and defending their ideas. The questions are categorized as closed questions, when have only one correct answer and require memory-driven responses, and as open-ended questions when assume more than one acceptable answer and involve more than known facts (Aziza, 2021).

Several research studies have concluded that teachers rarely ask open-ended questions, although recognize it as important tools in developing student understanding, and in situations in which ask open-ended questions, usually all the students' answers are not accepted (Svanes & Andersson-Bakken, 2023). In the questioning activity involving open-ended questions, several features must be considered having in view the achievement of the benefits that this type of questioning can trigger in the cognitive, emotional and social development of students: teacher/educator/person is not only concerned with the correctness of the answer, but also in the reasons behind the thinking, solution methods, and misconceptions (Aziza, 2021; Klavir & Hershkovitz, 2008; Franke et al., 2009); the incorrect answers are important since can stimulate students' explanations and justifications (Aziza, 2021; Hoffman et al., 2009; Tofade et al., 2013); teacher/educator/person can ask follow-up questions, for both correct and incorrect answers, to develop students' critical thinking, students' creative thinking, students' curiosity and inquiry, guiding student in problem solving skills (Aziza, 2021; Moyer & Milewicz, 2002).

Method

This study was motivated by the presentation of the children's book "From the outside to inside and from the inside to outside" (Figure 1) realized by the authors, which are investigators in this study, in a Portuguese school of the 1st Cycle of Basic Education. In this book, of perceived content (Martson, 2014), mysterious "journeys" experienced by João (the character) are described. These journeys do not require the traditional transports, being mind-blowing journeys in which emotions are a constant presence as well as the improbable situations, or even impossible, that João is faced with. In this story, from fascinating and intriguing places many questions raise!

Figure 1. Children's Book

The book presentation took place in the school library, in a non-formal education environment, and involved three sessions for the 2nd, 3rd and 4th grades, respectively. The presentation consisted of the reading of some excerpts from the book, accompanied by the projection of illustrations (Figure 2), followed by excerpts' emerging questions, mainly open-ended questions, asked to the children to promote dialogue and reflection about convergent or divergent ideas.

Figure 2. Book's Illustration

The richness of the discussions triggered by the excerpts from the book and by the questions posed, many of them having as intention provoking the minds of children with improbable or impossible situations, having in view the divergent thinking development, is the basis of this study, which has as research problem: *Can children's literature contribute to the emergence and development of scientific knowledge, in particular mathematical knowledge, in students of the 1st Cycle of Basic Education?*. This research has as main objectives: to create an environment for discussion and questioning, considering some strategies to develop divergent thinking, by reading excerpts from the children's book; to identify evidence of learning development, in particular the emergence of divergent thinking, through the analysis of dialogue and questioning established between researchers and students, from a context involving scientific ideas.

To promote discussion and questioning from children's book excerpts having in view divergent thinking development, some strategies, according to Khatri and Dutta (2018), were considered during the sessions, namely: inquiry-based feedback; seek wild ideas; establish a tolerant environment; celebrate differences. According to Chin (2006), Lee and Kinzie (2012), and Tofade et al. (2013), to enrich the inquiry during the discussions and reflections with children, were privileged open-ended questions and considered several aspects such as: not be only concerned with the answer's correctness, but also in the reasons behind the thinking, solutions, and misconceptions (Aziza, 2021; Klavir & Hershkovitz, 2008; Franke et al., 2009); consider as important both correct

and incorrect answers (Tofade et al., 2013), since the incorrect answers can stimulate students' explanations and justifications (Hoffman et al., 2009); promote questions to develop critical thinking (Moyer & Milewicz, 2002), children's curiosity and inquiry, as well as guiding children in problem solving skills (Gall, 1970).

To develop the study, a qualitative, descriptive, and interpretative research methodology was followed (Bogdan & Biklen, 1994). In this sense, the data was collected during the sessions by audio recording, from which the transcripts were made being these the focus of the content analysis. The content analysis focused on children's thoughts and answers to the questions or statements made by researchers or their peers, considering scientific knowledge, mathematical concepts, children's conceptions and misconceptions, and attributes of divergent thinking (Guilford, 1960; Torrance, 1963) involved. Since the academic area of the authors and researchers of this study is Mathematics, data analysis focused on this field of science.

Results

In the book, João is faced with many imaginary and unreal situations on which he reflects and asks many questions, creating opportunities for the emergence of divergent thoughts and opening space for investigative and creative paths, which fostered and stimulated a dialogue between children and researchers in which the questioning activity was constantly present. In this section, are presented some excerpts from the dialogue established with the children and its analysis considering emerging mathematical concepts, students' conceptions and misconceptions, and characteristics of divergent thoughts. In the presented dialogues, "Inv" refers to the researchers' statements. The children's statements are identified using only the word "Child", even if they refer to different children.

Excerpt 1

In the book, João experiences different emotions, which are expressed physically by the beating of his heart. To confront children with this possible relationship between emotions and heartbeats, some questions raised:

Inv.: Why when we are in love the heart beats in a different way?

Child: It beats fast when we are in love.

(…)

Inv.: How are you feeling today?

Child: Good!

Inv.: You feel good. What is this about feeling good?

Child: When the heart is beating a lot.

Inv.: When we feel good, do we feel that way because our heart beats a lot? Is that? When you are happy or excited, do you feel that your heart is beating a lot?

Children: Yes.

Child: More or less.

Child: No.

(…)

Child: Because it's getting desperate.

Inv.: So, you think yours when it hits too much is a sign that you're desperate... So, what about when you're fine? How does your heartbeat? When you're fine...
Child: Slowly.

Mathematical concept(s):

In this excerpt, the idea of pattern emerges with two distinct meanings, on the one hand as rhythmic patterns associated with different heartbeats and, on the other hand, as the recognition of an eventual pattern or regularity in the association of a given heartbeat with a given emotion.

Conception(s) or misconception(s):

Children are aware that the emotional state influences the heart rate. Although there is no explicit reference, by the children, to the idea of a rhythmic pattern, they express its perception through expressions such as “it beats fast”, “is beating a lot” and “it beats slowly”.

Attributes of divergent thinking:

In the dialogue, the presence of one of the characteristics of divergent thinking stands out, the flexibility, allowing the exploration and confrontation of different points of view, reinforcing, in this specific context, that we are different and that our differences are also manifested in terms of emotions. For example, about the heartbeat when they are happy, the children were asked if it beats a lot, and different answers emerged.

Excerpt 2

In the story, when dreaming, João finds himself inside his heart, which makes him very confused! Following this passage, children are challenged with the hypothesis that something small can contain something much bigger inside:
Inv.: When we look around us, can you give me an example of something that, being very small, keeps within itself something else that is very big?
Child: The brain! The brain can store memories and we have a lot of memories, but it is smaller than us…
(…)
Inv.: If we thought of a very small box, and if we thought of gradually placing a thread that goes on wrapping, wrapping, wrapping, at some point we would be seeing that a thread of enormous length could be fitted into such a small box…
Child: If you wrap it, it's still the same size, but the shape is different, and it might fit.

Mathematical concept(s):

In this dialogue, the notions of volume, length and measure are present.

Conception(s) or misconception(s):

Children compare elements of different natures, physical and non-physical, such as the volume of the brain and the amount of memories "it keeps", revealing, in a way, some lack of knowledge about comparing measurable characteristics, that is, which this is only possible when they correspond to the same measurable characteristic. However, when faced with the situation in which a very long thread is placed inside a small box, that is, a situation in which apparently the length of the thread and the volume of the box are being compared, one of the children, despite not making it explicitly, when saying " *it's still the same size, but the shape is different, and it might fit* ", reveals that understands that the length of the thread is not being compared with the volume of the box, but the volume that the thread occupies.

Attributes of divergent thinking:

Despite being faced with a question that goes against what is usual, there were children who quickly pointed out what would be, for themselves, a possible answer, revealing fluency in their thoughts. In one of the answers presented, in which the volume of the brain is compared with the number of memories, the child reveals creativity in the example presented and, although it is not a correct comparison from the point of view of mathematics, it turns out to be an interesting example in the figurative sense, demonstrating originality.

Excerpt 3

In one of his reflections, João questions whether the Universe will have a shape. The same question was posed to the children:

Inv.: Does the Universe have shape? What shape do you think the Universe has?

Child: Circular, a spherical shape. Because if we talk about the world, about the entire Planet Earth, we will always end up in the same place.

Child: The Universe is round.

Child: I thought Earth's was the same.

Child: I think the Universe has no shape because it is infinite.

Child: We don't know if it's infinite because it's the way we think. We never travel...

Child: It may have an unknown shape.

Child: No…

Inv.: And why not?

Child: Because stay away from us…

Child: We can't see the shape of the Universe because you will never get too far to see the shape… When you go to the Moon, you can see the Earth because you're too far away, but because you're small you can't go too *far* because you're not tall.

Child: No… Because we are so far away from him that afterwards he looks like a tiny dot…

Child: There is no border, the Universe is infinite.

Inv.: The Universe is infinite…at least that's what it seems to us, isn't it?

Child: Every day it grows more.

Mathematical concept(s):

Through the discussion generated by the question posed, several mathematical concepts emerged, namely geometric shapes, distance and measure, the notion of infinity and mathematical skills such as visual perception and spatial thinking.

Conception(s) or misconception(s):

In this dialogue, some misconceptions are identified, some examples are the confusion between the Earth and the Universe ("*The Universe is round; I thought Earth's was the same.*"), the distinction between two-dimensional and three-dimensional geometric shapes ("*Circular, a spherical shape.*"), the idea that what is infinite is not limited by a border ("*I think the Universe has no shape because it is infinite; There is no border, the Universe is infinite."*), and a perception of the Universe as something that is external to us, that is, as if we were not part of it ("*Because stay away from us…; Because we are so far away from him that afterwards he looks like a tiny dot…*"). Some of these misconceptions come from the levels of cognitive development these children are at. For example, at these ages, the notion of infinity is addressed in informal contexts, in which the idea that "what is infinite has no end" is addressed, being associated with something that our vision cannot reach. As such, when confronted with statements such as "a triangle is composed of an infinity of points", these seem to contradict the perception that children have of infinity. Some children show a keen visual perception ability, in particular they establish relationships between the dimensions of objects and the distance they must be from them to perceive them as a whole ("We can't see the shape of the Universe because you will never get too far to see the shape; When you go to the Moon, you can see the Earth because you're too far away .").

Attributes of divergent thinking:

From the dialogue it is possible to recognize the four characteristics of divergent thinking. The ability shown by the children to answer, or justify their answers, with some speed, reveals their fluency in approaching the question posed to them. The successive interventions were, in a certain way, conditioned by the answers presented before, by the children. The existence of different points of view was also considered in the reformulation of ideas, revealing by the children the capacity for flexibility and elaboration. Some answers presented show openness to other ideas not yet explored, namely when they refer to " We don't know if it's infinite because it's the way we think. We never travel...; It may have an unknown shape; Every day it grows more."

Excerpt 4

In one of his dreams, João begins to grow in height, in such a way that he starts to see different countries, continents and oceans, and the shape of the Earth. From this excerpt of the story, and from a previous discussion about the im(possibility) of pointing out a shape for the Universe, the following dialogue emerged:

Inv.: But, if I ask you what shape the Earth has, can you tell me?
Child: Yes!
Child: Sphere!
Child: It was thought to be flat, and they thought that if they reached the bottom, they would fall.
(…)
Inv.: For example, just now you said that the Earth has a spherical shape, but when we are here, inside in this room, can we visualize the Earth's shape?
Children: No!
Inv.: If I asked you "look, we are here on the Earth, what is its shape?", what would you say?
Child: It's a sphere.
Inv.: But could you see that, in fact, the Earth has a spherical shape, as you said a moment ago?
Children: No!
Inv.: So, how do we can visualize the Earth's shape?
Child: Going to the Moon.

Mathematical concept(s):

According to the question posed, geometric shapes naturally appear in this dialog. In addition, in this excerpt is involved the notions of distance and measure as well as mathematical skills such as visual perception and spatial thinking.

Conception(s) or misconception(s):

In addition to revealing that they know the Earth's shape, one child reveals know another shape Earth's theory, previously defended, that it would be flat, pointing out an argument that refutes this theory (*It was thought to be flat, and they thought that if they reached the bottom, they would fall.*). In this excerpt, considering the global view of an object, the children establish relationships between its size and the distance of the observer in relation to it. This is verified when asked if they could see the Earth's shape from the place where they were, answered no and gave as a reference point the Moon in sense that from it, we would see the Earth's shape.

Attributes of divergent thinking:

When asked with other questions arising from the first question, children quickly internalize and interpret what is being asked, adjusting their thinking and manifesting flexibility and fluency in it.

Excerpt 5

During the conversation with the children, we verify that their idea about infinity is like something that is unlimited, something that our sight or imagination cannot even reach, as can be seen in a previous excerpt. Faced with these conceptions, the children were provoked with examples that, in a certain way, contradict their ideas:

Inv.: If something is infinite it doesn't mean that we don't know its shape... From zero to one, do you know how many numbers are in there?
Child: Thousands.
Inv.: An infinity of numbers!
Children: Oh…
Inv.: We have in a finite part (range of numbers) an infinite number of points.
Child: Are numbers also infinite? All?
Inv.: Look, between any two numbers there are an infinity of numbers.
Child: And from zero to 0.1?
Inv.: It has an infinity of numbers.
Child: So, what about one to one?
Inv.: No, not there. There you have the same number. It can't be the same!
Child: So, what about between zero and zero?
Inv.: It is equal, it is the same relation, they are two equal numbers. If they are equal numbers, there is only that one.

Mathematical concept(s):

In this conversation, in addition to the notion of infinity, the notion of interval of real numbers also emerged.

Conception(s) or misconception(s):

In Portugal, in the 1st Cycle of Basic Education, the rational numbers are worked with students, and they understand that between two natural numbers there are other numbers, however the mathematics curriculum does not include the approach to intervals of real numbers. As such, the idea of the existence of an infinity of numbers between two natural numbers is new to children in these ages, provoking astonishment reactions. As example, were stablished that between zero and one there are an infinity of real numbers, however the idea that between any other two different numbers, even if they are very close to each other, there exist also an infinity of numbers generated some curiosity in the children ("*And from zero to 0.1?*").

One of the children asked "So, what about one to one?", in this case, since was considered the same number, was told that there is only that number. Next, the child asked "So, what about between zero and zero?". From this second question it seems that the child is considering zero as the cardinality of an empty set, due to his curiosity into ask the same that he have asked before but considering the number zero.

Attributes of divergent thinking:

In this excerpt, characteristics of divergent thinking like flexibility and elaboration are highlighted. When confronted with new ideas regarding their conceptions of infinity and sets of numbers, children were receptive to what is being said to them, despite being surprised. Some questions asked by children reveal understanding of the

issue that is being approach with them. On the other hand, there are evidence about the establishment of relations between previous information (that they knew) and new information to develop their understanding of the subject and to expand their knowledge.

Excerpt 6

In the story, João likes to observe the sky at night from his window, asking some questions about the stars. Following this excerpt, some questions about the stars were asked to the children:

Inv.: Do we see the stars whenever we look up at the sky at night?

Child: No.

Inv.: Depends on what?

Child: During the day, we don't see them.

Child: I look at the sky and all I see is the Moon!

Inv.: The Moon because … We see better the Moon than the stars, why is it? Why we see better the Moon than the stars?

Child: Because the Moon is bigger.

Inv.: Could it be that the Moon is bigger?

Children: No…

Inv.: So?

Child: Because the Moon is brighter.

Inv.: Is it because the Moon is brighter?

Child: Yes.

Child: No.

Inv.: Ah, but… is the Moon bigger than the stars?

Child: No.

Inv.: So? Why do we see the Moon better?

Child: Because the Moon is closer to us.

(…)

Inv.: When we look at the stars, some of them are more luminous than others… Are they different from each other?

Children: Yes.

Inv.: Will they have different colors?

Children: Yes.

Children: No.

Inv.: Some of you say yes, other say no. Why do you think not?

Child: Stars don't change its color.

Inv.: Don't the stars change its color?

Child: No.

Child: Because some stars are closer to the Moon, they get more light.

Mathematical concept(s):

In the dialogue, the notions of measurement, distance, as well as visual perception skills are present.

Conception(s) or misconception(s):

Faced with some questions, the children identify some factors that make it impossible for us to see stars in the sky, namely sunlight, which during the day obscures the brightness of other stars ((“*During the day, we don't see them.”*), the distance at some stars stay from us (Inv: “*Why do we see the Moon better?;* Child: *Because the Moon is closer to us.”),* its dimensions (“*I look at the sky and all I see is the Moon!”… ” Because the Moon is bigger.”*) and its brightness (“*Because the Moon is brighter”*). In this excerpt, some misconceptions are presented, namely the Moon is bigger than the stars, the brightness of the stars remains unchanged (“*Stars don't change its color.*”), the Moon has its own brightness, and the brightness of stars depends on their proximity to the Moon (“*Because some stars are closer to the Moon, they get more light.*”). These misconceptions may come from some lack of scientific knowledge, but also from a lack of skills in terms of visual perception and spatial thinking.

Attributes of divergent thinking:

When faced with questions, children tend to respond quickly, equating various hypotheses, although some of them are not correct, revealing flexibility in their thinking.

Discussion

The book's narrative and illustrations, by themselves, invite the reader to reflect and question quite intriguing subjects, namely, questions about the environment that surrounds us, and which arouses so much curiosity. In the book’s presentation, the questions mediated by the researchers intended to provoke children with unlikely or even impossible contexts or situations involving scientific knowledge. Considering the ages and the cognitive maturity of the children, it was expected, as can be seen, incorrect answers and misconceptions. However, according to one of the objectives of this study, the main intention of these dialogues was to encourage the development of divergent thinking, creative ideas and stimulate children's thinking through open-ended questions. During the dialogue, the researchers were mainly interested into understand the reasons behind the children’s thinking and misconceptions (Aziza, 2021; Klavir & Hershkovitz, 2008; Franke et al., 2009), and develop, from correct and incorrect answers, students’ critical and criative thinking, and students’ curiosity (Aziza, 2021; Moyer & Milewicz, 2002; Gall, 1970).

During the dialogues, whenever appropriate, according to the children's receptivity and their ability to understand, some misconceptions were demystified and were presented some ideas that, in their minds, would be impossible. In the previous section, since children thought that somewhat infinite is unlimited, is presented one excerpt in which infinite’s notion are clarified, given as example the possibility to have an infinity of points in a limited interval of small amplitude. In a part of the discussion, which is not reported in the previous section because it

focuses mainly on an intervention by a researcher not being interesting in terms of analyzing of children's ideas, children are confronted with the existence of triangles with curved sides in a " hyperbolic world". Through the presented excerpts from the discussions, it is possible to verify that children, when faced with questions for which they did not have knowledge to answer, always tried to think about what was being questioned and find an answer, revealing, in many interventions, a critical and creative thinking. In general, the children remained participatory and enthusiastic, also bringing to the discussion some scientific subjects that also aroused their curiosity, such as the existence of black holes in the Universe.

Conclusion

The successive transformations which have been experienced in the 21st century, in several domains, have had implications in Education, in terms of knowledge, skills, attitudes and values, being essential prepare students to have a “positive impact on their surroundings, influence the future, understand others' intentions, actions and feelings, and anticipate the short and long-term consequences of what they do”, that is, to prepare them to be the future change agents (OECD, 2018). Scientific literacy endows students with knowledge and skills that allow them not only to interpret the phenomena that occur around them, but also to develop critical and creative thinking, essential in responding to the major questions that the society currently poses to them. Although, at an early age, scientific concepts and processes are difficult to understand (Eshach & Fried, 2005), Since a long time ago many researchers have defended that science should be integrated in elementary school curriculum (Spooner and Simpson, 1979). Actually, children characteristics such as curiosity, creativity, and aptitude to explore and learn are important premises for the development of their scientific knowledge.

Several resources and artifacts can be used to facilitate the understanding scientific concepts, namely the use of children’s literature. Children’s literature not only presents a language closer to the language of children, but also presents narratives and illustrations that, in addition to motivating and capturing children's attention, stimulate their imagination and creativity, essential characteristics of scientific thinking. The choice of the children’s book to develop this study had as main parameter the involvement of scientific concepts in the narrative and the constant inquiry about intrigant and curious phenomenon.

In this work, although science is present in its broadest sense, according to the academic training of the researchers, in the data analysis there was a more incisive look at children's conceptions and misconceptions regarding mathematical concepts. According to the presented data and its analysis, we conclude that from the created environment, stimulated by the children’s book, where questioning activity was always present, it was possible stimulate children divergent thinking and understand the reasoning behind their scientific conceptions and misconceptions. The children’s book “From the outside to inside and from the inside to outside” further to contributed to engage children, capturing their attention and motivating them, contributed significantly to the questioning activity provoking open-ended questions. In this sense, having the research question in view, we conclude that in this study children’s literature contributed to the emergence and development of scientific knowledge, in particular mathematical knowledge, and stimulate children divergent thinking.

Acknowledgements

This work was supported by the center for research and development in Mathematics and Applications (CIDMA) through the Portuguese Foundation for Science and Technology, references UIDB/04106/2020 and UIDP/04106/2020.

References

Akerson, V. L., Erumit, B. A., & Kaynak, N. E. (2019). Teaching Nature of Science through children's literature: an early childhood preservice teacher study. *International Journal of Science Education*, *41*(18), 2765-2787.

Acar, S., Ogurlu, U., & Zorychta, A. (2022). Exploration of discriminant validity in divergent thinking tasks: A meta-analysis. *Psychology of Aesthetics, Creativity, and the Arts*. Advance online publication. https://doi.org/10.1037/aca0000469

Bogdan, R., & Biklen, S. (1994). *Investigação qualitativa em educação: uma introdução à teoria e aos métodos*. Porto Editora.

Broemmmel, A. D., & Reasden, K. T. (2006). Should teachers use the teachers' choice in science classes? *The Reading Teacher*, *60*(3), 254-265.

Brophy, D. R. (2001). Comparing the attributes, activities, and performance of divergent, convergent, and combination thinkers. *Creativity Research Journal*, *13*, 439-455.

Çekirdekci, S. (2020). Metaphorical Perceptions of Fourth-Grade Primary Students towards Mathematics Lesson. *International Journal of Psychology and Educational Studies*, *7*(4), 114-131.

Chin, C. (2006). Classroom interaction in science: Teacher questioning and feedback to students' responses. *International journal of science education*, *28*(11), 1315-1346.

Clyne, M., & Griffiths, R. (1991). *Books you can count on: Linking Mathematics and literature*. Heinemann.

Erumit, B. A., & Akerson, V. L. (2022). Using Children's Literature in the Middle School Science Class to Teach Nature of Science - Preservice Teachers' Development of Sources. *Science & Education*, *31*, 713-737.

Doig, B. (1987). *Puffin Mathspack: Lower primary level, Teacher's notes*. Penguin.

Doig, B. (1989). *Links: A guide to maths in children's literature*. Thomas Nelson.

Eshach, H., & Fried, M. N. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology*, *14*(3), 315-336.

Fang, Z. (2014). Disciplinary literacy in science: Developing science literacy through trade books. *Journal of Adolescent & Adult Literacy*, *57*, 274-278.

Franke, M. L., Webb, N. M., Chan, A. G., Ing, M., Freund, D., & Battey, D. (2009). Teacher questioning to elicit students' mathematical thinking in elementary school classrooms. *Journal of Teacher Education*, *60*(4), 380-392.

Furner, J. M. (2018). Using Children's Literature to Teach Mathematics: An Effective Vehicle in a STEM World. *European Journal of STEM Education*, *3*(3), 1-12.

Gomez-Zweip, S., & Straits, W. (2006). Analyzing anthropomorphism. *Science and Children*, *44*(3), 26-29.

Guilford, J. P. (1950). Creativity. *American Psychologist*, *5*(9), 444-454.

Guilford, J. P. (1957). Creative abilities in the arts. *Psychological Review*, *64*(2), 110-118.

Guilford, J. P. (1959). Three faces of intellect. *American Psychologist*, *14*(8), 469–479.

Hoffman, B. L., Breyfogle, M. L., & Dressler, J. A. (2009). The Power of Incorrect Answers. *Mathematics Teaching in the Middle School*, *15*(4), 232-238.

Khatri, P., & Dutta, S. (2018). Divergent Thinking – It's Time to Change the Box! *International Journal of Multidisciplinary*, *3*(10), 1004-1011.

Kirby, J. T. (1997). Aristotle On Metaphor. *American Journal of Philology*, *118*(4), 517-554.

Klavir, R., & Hershkovitz, S. (2008). Teaching and evaluating 'open-ended' problems. *International Journal for Mathematics Teaching and Learning*, *20*(5), 23. https://www.cimt.org.uk/journal/index.htm

Lee, Y., & Kinzie, M. B. (2012). Teacher question and student response with regard to cognition and language use. *Instructional Science*, *40*(6), 857-874.

Lemonidis, C., & Kaiafa, I. (2019). The Effect of Using Storytelling Strategy on Students' Performance in Fractions School of Primary Education. *Journal of Education and Learning*, *8*(2), 165-175.

McLean, K., Jones, M., & Schaper, C. (2015). Children's literature as an invitation to science inquiry in early childhood education. *Australasian Journal of Early Childhood*, *40*(4), 49-56.

Morrow, L. M., Pressley, M., Smith, J. K., & Smith, M. (1997). The effect of a literature-based program integrated into literacy and science instruction with children from diverse backgrounds. *Reading Research Quarterly*, *32*, 54-76.

Moyer, P. S., & Milewicz, E. (2002). Learning to question: Categories of questioning used by preservice teachers during diagnostic mathematics interviews. *Journal of Mathematics Teacher Education*, *5*(4), 293-315.

OECD (2018). *The future of education and skills Education 2030*. https://www.oecd.org/education/2030-project/contact

Porter, C. M. (1969). *Figures of speech, divergent thinking, and activation theory* [Doctoral dissertation]. North Texas State University.

Ritchie, K. C., Shore, B. M., LaBanca, F., & Newman, A. J. (2011). The Impact of Emotions on Divergent Thinking Processes: A Consideration for Inquiry-Oriented Teachers. *LEARNing Landscapes*, *5*(1), 211-225.

Runco, M. A. (2008). Commentary: Divergent thinking is not synonymous with creativity. *Psychology of Aesthetics, Creativity, and the Arts, 2*(2), 93-96.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology, 25*, 54-67.

Sackes, M., Trundle, K., & Flevares, L. M. (2009). Using Children's Literature to Teach Standard-Based Science Concepts in Early Years. *Early Childhood Education Journal*, *36*, 415-422.

Shahrill, M. (2013). Review of teacher questioning in mathematics classrooms. *International Journal of Humanities and Social Science*, *3*(17), 224-231.

Spooner, W. E., & Simpson, R. D. (1979). The influence of a five-day teacher workshop on Attitudes of elementary school teachers toward science and science teaching. *School Science and Mathematics, 79*, 415-420.

Svanes, I. K., & Andersson-Bakken, E. (2023). Teachers' use of open questions: investigating the various functions of open questions as a mediating tool in early literacy education. *Education Inquiry*, *14*(2),

231-250.

Skoumpourdi, C., & Mpakopoulou, I. (2011). The Prints: A Picture Book for Pre-Formal Geometry. *Early Childhood Education Journal*, *39*, 197-206.

Tofade, T., Elsner, J., & Haines, S. T. (2013). Best practice strategies for effective use of questions as a teaching tool. *American journal of pharmaceutical education*, *77*(7), 1-9.

Trundle, K. C., Troland, T. H., & Pritchard, T. G. (2008). Representations of the moon in children's literature: An analysis of written and visual text. *Journal of Elementary Science Education*, *20*(1), 17-28.

Tucker, C., Boggan, M., & Harper, S. (2010). Using Children's Literature to Teach Measurement. *Reading Improvement*, *47*, 154-161.

Van den Heuvel-Panhuizen, M., Boogaard, S., & Doig, B. (2009). Picture Books Stimulate the Learning of Mathematics. *Australian Journal of Early Childhood*, *34*(3), 30-39.

Weiss, S., Steger, D., Kaur, Y., Hildebrandt, A., Schroeders, U., & Wilhelm, O. (2021). On the trail of creativity: dimensionality of divergent thinking and its relation with cognitive abilities, personality, and insight. *European Journal of Personality*, *35*(3), 291-314.

Zeece, P. D. (1999). Books for Children - Things of Nature and the Nature of Things: Natural Science-Based Literature for Young Children. *Early Childhood Education Journal*, *26*(3), 161-166.

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