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"Once upon a time… a beach sand grain": a bed-time story and scientific outreach activity for young children to increase sediment literacy

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Abstract

Purpose Learning science in early years can cultivate children's curiosity and enjoyment in exploring the world around them, laying the foundation for the progression of science learning and ultimately increasing science literacy. Here, we present an example of a tailored preschool scientific activity designed to enhance literacy about sediments and illustrate their importance to both humans and nature.

Methods The activity centres around a captivating story detailing the journey of a sand grain from the mountains to the sea. This storytelling experience is enriched with hands-on observation of various sand grains, informative cards on key topics, and culminates in a creative colouring activity.

Results To date, the activity has been repeated five times, engaging 110 children (from 2 to 10 years). It has yielded positive outcomes with both preschool and primary school students, as they were actively engaged in the story and delighted in handling and observing the magnified sand grains.

Conclusions The activity was successfully implemented for preschool and primary school students, fostering engagement with the story and the sand samples. However, while the immediate engagement was evident, the impact on sediment literacy remains to be measured. Future structured evaluations are needed to assess the long-term effectiveness of such initiatives in enhancing sediment literacy among young learners.

Keywords Erosion · Sediment transport · Sediment sink · Sediment source · Toddlers · Preschoolers · Knowledge transfer · STEM

1 Introduction

Scientific literacy is the ability to use scientific knowledge to identify questions and draw evidence-based conclusions to understand and make informed decisions about the natural world (Laugksch 2000; Howell and Brossard 2021; Li and Guo 2021). Learning science in early childhood can foster children's curiosity and enjoyment in exploring the world around them and lay the foundation for progression of science learning (Gottfried et al. 2016; Bonnette et al. 2019; Henriksson et al. 2023; Wu et al. 2024). Eshach and Fried (2005) further support the inclusion of science as part of the curriculum in both kindergarten and the first years of primary school, giving six main reasons: 1) children naturally enjoy observing and thinking about nature; 2) exposing students to science develops positive attitudes towards science; 3) early exposure to scientific phenomena leads to better understanding of the scientific concepts studied later in a formal way; 4) the use of scientifically informed language at an early age influences the eventual development of scientific concepts; 5) children can understand scientific concepts and reason scientifically; and 6) science is an efficient means for developing scientific thinking.

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Joint book reading by an adult and small child is one of the most recommended practices for building vocabulary and emergent literacy competencies in preschool children (National Research Council 1998; Leung 2008). Thus, incorporating science picture books in kindergarten activities can enhance children's cognitive and affective engagement with both literacy and science (Mantzicopoulos and Patrick 2011). Regarding specifically the contact with geoscience concepts and topics, recent works have identified that storytelling is an effective way of communicating geoscience with small children (Matias et al. 2020; Kall et al. 2024; Peters 2024).

Sediments are ubiquitous in all environments, and there is a growing demand for tailored management practices to ensure their health and ecosystem service provision (Bergmann and Maass 2007; Brils 2020). However, scientific literacy concerning sediments-such as understanding sedimentary processes and related topics-remains a significant knowledge gap for many, from policymakers to the general public (Ausili et al. 2022). Scientists bear the responsibility of communicating their findings not only to their peers but also to non-experts, including children. To enhance public understanding, a stronger foundation in scientific literacy regarding sediments must be established (Pedrozo-Acuña et al. 2019).

A bottom-up approach to sediment literacy involves starting at the individual or community level and working upwards towards broader understanding and engagement with sediment-related concepts (Mondesir and Griffin 2020). This approach focuses on building knowledge, awareness, and skills from the ground level, targeting specific groups or communities.

Here, we present an example of a tailored preschool scientific activity that is aimed to increase literacy about sediments and closely related natural processes, thus showing how important they are to nature and humans. The activity comprises a bed-time story, the observation of different sand types, information cards and a colouring activity. The activity was specifically developed for preschoolers but is also adaptable for primary school students.

2 Educational approach

2.1 Scientific contents

The activity was designed to introduce and convey concepts and processes related to the topic of sediments, tailored for children aged 2 to 9 years old. The activity was structured into four distinct segments, introducing various scientific concepts and allowing different experiences:

1. Segment 1: A storytelling session, where a bedtime story about a sand grain is shared with the children. This is the main activity.
2. Segment 2: Presentation of information cards providing additional details (this step can be omitted for very young children).
3. Segment 3: Hands-on exploration of different types of sand grains.
4. Segment 4: Engaging colouring activity.

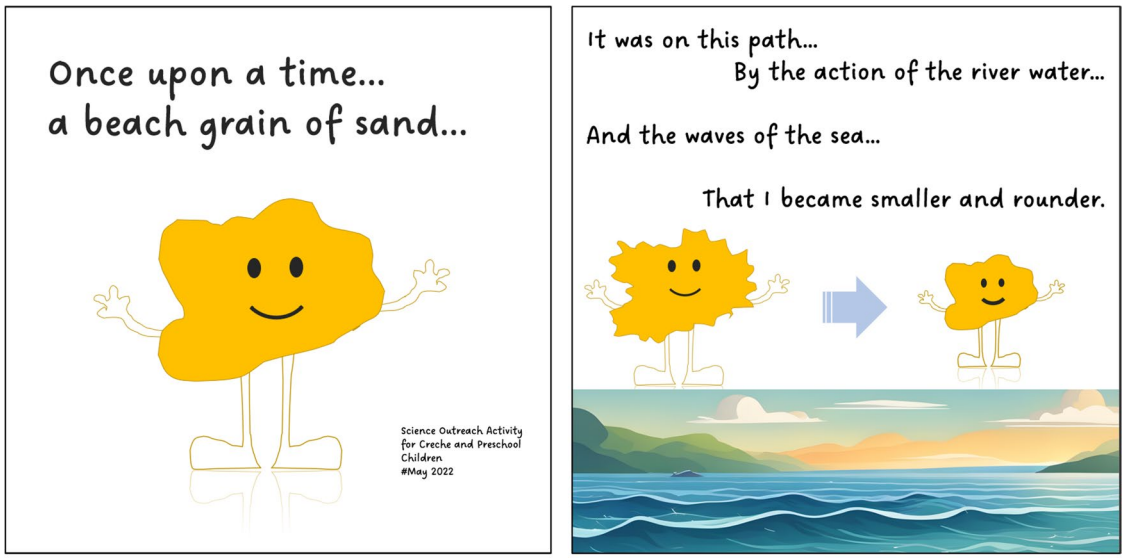
The key processes and concepts related to sediments being communicated in the different activities were: (i) the erosion process, including erosion agents; (ii) the concept of source-to-sink transfers (Laceby et al. 2019; Mahoney et al. 2019); and (iii) different textural and composition characteristics of the sand grains (Dixit et al. 2024).

Erosion is one of the key concepts to grasp when talking about sediments. The erosion process and erosion agents are responsible for creating sediments and facilitate the transport of sedimentary particles along different environments. The notion of source-to-sink is important to recognise sediment pathways, sediment connectivity and sediment continuum from the catchment to the open sea (Owens 2007). Lastly, the concept that there are different characteristics of the sedimentary particles, like shape, size and colour (Lira and Pina 2009, 2011; Deal et al. 2023; Haddad et al. 2023), is also important to convey the notions of different sediment sources and textural/compositional characteristics.

2.2 Creation of the bed-time story (Segment 1)

The bed-time story, in picture book format, was created using as the main character a grain of sand named Sandy and its journey from the mountains, where it was "born", to the bottom of the sea. The story develops over 12 pages, with short sentences in a simplified language, accompanied with colourful cartoon images (Fig. 1). The story revolves around the following sediment related scientific topics:

1. Erosion – the grain of sand is born larger, with more angular edges, and becomes smaller and rounder with time, distance of travel and the effect of flowing water and waves (erosion agents). This is the opposite of people, who are born smaller and grow up with time.
2. Source to sink – the grain of sand is born on the mountains (source), and travels through rivers until it reaches the beach and the sea. Later, it will be deposited at the bottom of the ocean (sink). During this path, the grain of sand changes its characteristics as an effect of the different environments it passes through.
3. Different types of sand – the story also talks about different grain types, presenting many colours, that are the grain siblings. Different grains are related to different



a) b)

Fig. 1 Bed-time story: **a** book cover; **b** page 8, as an example: this page introduces the concepts of grain erosion and erosion agents

sediment compositions. Information about this topic is also provided in the information cards.

The story is brought to life with illustrations of Sandy and his siblings, accompanied by whimsical cartoon depictions of the diverse environments Sandy encounters along his journey - from mountains and rivers, to beaches and the sea. Sandy and his sister, Saya, were designed by the first author, while the charming environmental cartoon images were created using AI technology (https://www.freepik.com/).

Sandy was designed as a round grain of sand, like the grains of sand found in the beach environment. Its design is simple but appealing to young children, with a bright yellow colour. The cartoon images accompanying the text are also attractive to children and are intended to symbolize the idea of the different environments that children might already have experienced (e.g., a blue sea with small waves).

2.3 Complementary activities (Segments 2 to 4)

The bedtime story serves as the central activity, around which additional enriching experiences are designed to reinforce learning and encourage interaction among children with various sand samples. In addition to the bedtime story, these complementary activities include:

1. Cards that communicate information about different environments where sand can be found (e.g., beaches, deserts) and the importance of sand as a resource (e.g., for construction, for leisure).
2. The observation of different types of sands (handling different sand samples), including the observation of different grains using a geology hand lens.
3. A drawing of the Sandy character that the children can colour and take home. This gives them the opportunity to tell their parents about the activity, allowing them to revisit, and further cement the information.

2.4 Implementation of the activity

The activity commences with segment 1, when the children seated on the floor prepare to listen to the story, ensuring everyone has a clear view of the picture book. The scientist leading the storytelling session engages the children by asking them about their experiences at the beach and what they enjoy most about it. This interactive moment sets the stage for the story about to unfold. Throughout the storytelling, a larger drawing is presented depicting Sandy in various poses, enhancing the narrative. For instance, when Sandy tumbles over a mountain and finds himself near a river, there is an illustration of Sandy upside down, synchronized with the events in the storybook.

Once the story concludes, the session transitions to presenting information cards, tailored to the age group of the children. This second segment allows time for any questions the children may have about the story, the information on the cards, or even their personal experiences related to the topic at hand.

Following this segment, a hands-on activity unfolds, inviting children to explore various sand samples. Most of the sand samples are in plastic tubes or bags, while a larger

sample is in a tin, allowing the sand to be manipulated, and providing an opportunity for children to touch, feel, and examine the sand using geology magnifying lenses. This tactile experience aims to deepen their understanding of the diverse textures and compositions of different sand grains (Fig. 2b, d). Here, the scientists elucidate the distinctions between sand grains from various environments. For example, they explain that sand grains from rivers are typically less rounded compared to those from beach environments.

The last segment involves giving each child a drawing of Sandy to colour as they please. This personalized artwork allows them to express their creativity and take home a memento from the experience. They are also encouraged to share their drawings and tell their parents about the experiment, fostering a discussion at home about the fun and educational activities they participated in.

2.5 Creation of the website Sandy Story

To engage a broader audience, the team decided to establish a dedicated website. This platform intends to serve as a centralized hub to present and share the activity's objectives and materials, facilitating dissemination to a wider community. With this goal in mind, we developed the website (https://sandy-story.com) in English to ensure accessibility to as many people as possible. While the website is still under development, and some resources are not yet fully available, visitors can already access the storybook in the available languages, some resources related with the activity (e.g. Sandy drawing-activity sheet) and news about the project. Future additions will include various resources, such as a comprehensive teacher's manual designed to facilitate the implementation of the activity in kindergartens and schools.

The outline of the website is as follows:

1. **Home** – front page of the website
2. **The project** – a short introduction about the project and its objectives.
3. **The bed-time story** – the storybook can be accessed in a digital Issuu flipbook format (www.issuu.com) in different languages.
4. **Activity Resources** – download related resources (e.g., Sandy drawing, information cards) in multiple languages to facilitate independent implementation of the activity.
5. **News** – stay updated with the latest news and activities related to the project.
6. **The team** – here you can access information about the project team.
7. **Related Resources** – some sediment literacy resources can be found here, without an exhaustive list of what can be found online.
8. **Contact** – details on how to further engage with the team.

The website was created as a resource for scientists and educators interested in knowing more about the project and/or implementing the activity, in collaboration with the project team or on their own. Nevertheless, the website, as is, might also be used to read the story to the children, in a digital format, or present a live animation of the Sandy character to the children.

3 Pathway to impact

Studies about scientific activities development and importance in education are relatively recent, particularly in early childhood, as most studies are implemented for elementary, middle, and high schoolers (Impedovo et al. 2017; Convertini 2021). There is a growing demand to begin science education as early as possible and develop actions targeting preschool children (Impedovo et al. 2017; Weng and Li 2020; Wu and Huang 2023). However, many countries still lack science education in formal preschool curricula (Léna 2009; Impedovo et al. 2017; Wu et al. 2024) and limited activities are available for teachers.

The science outreach activity "Once upon a time… a beach sand grain" project was established in May 2022 and has worked since as a proof of concept. The goal was to develop an activity and test it in the real-world using-small scale actions with very young children. According to the hierarchical model of STEM literacy for kindergarten children developed by Wu et al. (2024), this activity might be considered as incorporated in the category of STEM knowledge, sub-category Science knowledge - Geosciences, as the activity intends to introduce some simple, yet fundamental, sediment concepts (see Sect. 2.1).

3.1 School activities

The Sandy story was first developed with the primary goal of providing simple scientific concepts about sediments to toddlers and preschool children. Until now, the activity was repeated five times in Portugal, reaching 110 children (Table 1).

The initial session was designed for toddlers aged 2 to 3 years and was hosted at a private kindergarten. Due to the success in engaging such young children and encouraged by the teachers, we planned to expand the age range to primary school kids. The second and third sessions took place in homes, where two different families with preschool and primary school children incorporated the Sandy story into their bedtime routine. These sessions were opportunistic, as fellow colleagues wanted to tell the story to their own children. The fourth session targeted both preschool and primary school students from a public school, ranging in age from 4 to 10 years old. The last (5th) activity was again

Fig. 2 Examples of the activities targeting toddlers (panels **a** and **d**) and pre- and primary children (panels **b**, **c** and **e**). Panels **a** and **c** show the storytelling activity, and panels **b**, **d** and **e** show the hands-on activity involving the observation of different sand grain

Table 1 List of the activities carried out for years 2022 to 2024. The socio-economic context was evaluated considering factors such as average income, education, occupation of the average population for municipalities/neighbourhoods where the activities took place (data source: INE—https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_main)

Place of the Activity	Type of school	Socio-economic context	Date	Children age (years)	Number of children
Portugal, Lisbon, Creche	Private school	Moderate to high	June 2022	2—3	20
Portugal, Lisbon, at home (2 different families)	-	Moderate to high	2023	4—9	4
Portugal, Sintra, Pre and Basic School	Public school	Low to medium	February 2024	2—10	65
Portugal, Lisbon, Kindergarten	Private school	Moderate to high	June 2024	4–5	21

conducted at a private kindergarten and targeted children from 4 to 5 years old. In the activities that took place at schools, all students present in the classroom participated. Teachers were present during the activities, primarily to assist in managing the students through the various stages of the activity. Their role was limited to providing support and guidance as needed, allowing the children to actively engage with the materials and explore the learning experience. There was no presentation of the activity to the teachers prior to the sessions and no guidelines were provided of how children should behave.

Overall, the activity seemed to provide good results both with pre-school and primary school students, as they were engaged in the story and enjoyed handling the sand samples, seeing the magnified grains and asking questions during the story and observation/manipulation of the sand grains. Regarding the observation and handling of sand samples, the older children (4 to 10 years old) particularly enjoyed a sample of river sand, with a large compositional percentage of platy mica particles (mainly muscovite). Mica particles, being flat, have a remarkable ability to reflect sunlight, creating a sparkling effect, similar to glitter. This glitter-like sparkle can make science visually appealing to young children, potentially triggering early interest in STEM subjects. By engaging all children in creative and interactive ways, we can contribute to closing the gender gap in STEM fields and encourage more diverse participation in the future.

In terms of the scientific content, children were able to connect with the concept of erosion through the idea that a sand grain evolves in the opposite direction to that of a human. People are born smaller and grow larger over time, while sand grains are born larger and become smaller with erosion. This comparison resonates well with children, as they are familiar with the idea of growing up and can easily relate to the concept of changes in size over time.

Regarding the follow up of the information conveyed in the activity by asking children about Sandy, the youngest children could remember the story and relate it to nature up to 6 months. After that, the youngest children forgot the story. This is expected because to effectively build science understanding, young children need opportunities for sustained engagement with materials and conversations that focus on the same set of ideas over weeks, months, and years (Matias et al. 2020). Primary schoolers remembered the information and the story longer and more precisely.

Additional activities are currently being prepared to reach more schools in Portugal and at other European countries. The authors are particularly focused on maintaining the target audience of young children (aged 2 to 6) for the activity. Increasing the engagement of other scientists and educators have also been identified as key to enhance the relevance and effectiveness of the project. In Portugal, several science outreach and educational activities are already available for various K-12 levels at universities, science centres, and museums (e.g. https://lousal.cienciaviva.pt/en/schools/, https://www.ccvestremoz.com/en/escola-ciencia-viva-ano1). However, most geoscience activities target grades 6–12, with only a few STEM activities available for pre-K levels.

3.2 Engaging the scientific community and the public

3.2.1 Translation of Sandy Story

The story was created in Portuguese, as the activity was primarily implemented in Portugal. However, due to the growing interest from the scientific community (see Sect. 3.2.2), the story has been translated into English, German and Dutch. These translations aim to enhance the project's visibility and facilitate broader dissemination among scientists interested in implementing the activity themselves. Additionally, it aims to contribute to the development of related activities. Furthermore, since the activity targets young children, translating the story into other native languages is crucial for reaching this audience. Another important goal of the project is to not only increase the project's globalization but also to accommodate students' diverse cultural and linguistic ranges (e.g., multilingual classrooms) (Wawire et al. 2023; Ganesan and Morales 2024). The project team is actively working on these translations to enable broader engagement from both scientists and the general public.

3.2.2 Presentation of the project results in science forums

The preliminary results of the activity were showcased at the 13th International SedNet Conference during a special session on Sediment Literacy (https://sednet.org/events/sednet-conference-2023/). The presentation received a positive reception from the expert audience in sediment studies. In fact, several researchers volunteered to translate the story into their home country languages such as Italian and Dutch, indicating the broad interest and potential impact of the project. Others suggested the story could be part of a series, where other sediment-related topics could be introduced to children (e.g., clay particles, contaminated sediments). Building on the valuable discussion during this scientific session, the project team is presently working closely with the SedNet network (https://sednet.org/) to expand the Sandy story into a series of stories. Different characters are being developed to introduce other sedimentary types of particles (e.g., silt, clay) together with benefits and challenges related with sediments (e.g., dredging, mineral resources, soil erosion, contamination).

3.2.3 Adapting Sandy Story activity for other age groups

Science activities targeting young children often take the form of one-time events that, although popular, are realistically limited in achieving long-lasting effects (Archer et al. 2021). As identified by Archer et al. (2021), the next logical step would be to deliver a series of activities following the Sandy Story intervention. One possible way to further engage children with the sedimentary world would be to provide them with a series of storybooks, based on the Sandy character. This idea is already taking shape (see Sect. 3.2.2, for more details).

To engage older audiences (middle and high schoolers), more detailed scientific explanations and context about sediment and geology have to be incorporated, together with an upgraded version of Sandy story (e.g., a graphic novel version). To further involve older children, data analysis exercises, aligned with school curricula, or interactive games and mobile apps where students can engage with Sandy's world, could also be a possibility to build-up on the primary activity.

In sum, by diversifying how Sandy's story is presented through more complex and interactive content, one might maintain the interest and deepen the understanding of further sedimentary preconcepts with older children. The project team is enthusiastically also considering different ideas on how to adapt the original activity to older audiences, including university students, and a collaboration between the project and the SedNet working group on Education-Science-Policy Interfacing & Sediment Management Concepts is already in place to co-create solutions.

4 Discussion and final remarks

A science outreach activity aimed at preschool children was developed with the primary goal of enhancing sediment literacy. The activity employed an innovative approach by integrating storytelling with traditional science activities.

The first segment of the activity – the story of Sandy - is the main activity and was designed specifically for preschool children. The story is short (12 pages) with simple sentences and large drawings. Although simple, several key messages about sediments are conveyed, so the story can also be used with primary school children.

Segments 2 and 3 should be adapted for each child's age group. For toddlers (2 to 3 years old), segment 2 (presentation of the information cards) should be skipped and segment 3 should be mainly about presenting the difference between sand and other sedimentary particles (pebbles for instance), allowing for the children to experience both materials and understand the differences. For preschool children (3 to 5 years old) the information cards can be used, but the information should be simplified. For primary school children (6 to 10 years old) both segments can be used to convey more information about the topic, e.g., why sands are so different in colour and texture. Using the three school activities already completed as a guide, the viewing and handling of the sand grains proved to be the most appreciated activity by the children in the older age group (primary school), as they asked more questions, took more time discerning the differences among sand grains and sand samples. The last segment (segment 4) is the colouring of the Sandy character, which can be used regardless of children's age, as all would easily engage in the activity without much adaptation.

The authors would like to reinforce that this is not a study about teaching strategies or is targeting a teachers-oriented audience. The main goal is to present a new science communication activity about sediment concepts that can be used with young children. As such, the authors consider that the objective has been achieved, as a successful proof-of-concept. However, there is a need to undertake a formal evaluation of the science communication activity.

One notable shortcoming was the lack of a formal science communication evaluation to measure its impact on cognitive and emotional levels, which would have enabled validation and comparison of the activity's impact. There is a recognized need for tailored inquiries to follow up on the activity's outcomes (Ziegler et al. 2021). The second shortcoming is that the improvement in sediment literacy could not be quantitatively measured. Nonetheless, the authors are confident that the students were actively engaged, enjoyed the activity, and posed questions indicating the integration of knowledge.

Surveying children can be challenging, as different survey techniques must be emplaced to ensure all children participate regardless of their age. Also, the engagement of both the schoolteachers and the children's parents is essential to allow for a true sampling of the activity impact. The outreach activities here described were opportunistic and not tailored to assess how the provided learning concepts were received, perceived or cemented by the children.

Authors are also aware that different economic backgrounds of the children will impact how children respond to the activity and how they will appropriate knowledge. Regarding the participating schools, the selection was opportunistic; it was not the goal of this activity to represent a variety of children's socio-economic contexts and how they may impact the activity outcome. Nevertheless, the sample is somewhat diverse (private and public schools, different municipalities), but biased towards a moderate to high economic status (Table 1).

Acknowledging these shortcomings future work involves designing short questionnaires for teachers and students to collect data on the activities impact and limitations. As such, the activity will comprise a last segment – segment 5 – evaluation of the activity.

Furthermore, recognizing the areas for improvement, the authors suggest that a multidisciplinary collaboration between geoscientists and experts in education and the science communication team could be beneficial. This collaboration could help devise a comprehensive approach to fully assess the impact of such activities in the future, ensuring a more robust understanding of their effectiveness in enhancing sediment literacy among young learners.

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Declarations

Consent to participant The schools involved informed the parents about the activities and gave their consent to take pictures of the children as long as no visible identification of their identity could be made from it.

Conflict of interest The authors declare no conflict of interests.

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