gc-2019-21

Reply to reviewers and editor comments on "Engaging children in geosciences through storytelling and creative dance" by Ana Matias, A. Rita Carrasco, Ana A. Ramos, Rita Borges

"*Reviewer/editor comments*" and authors' reply. All line numbering refers to the revised version of the manuscript.

Reviewer#1

"Figure 1: From reading the text as well as looking at Fig. 2, my understanding was that Geology, Art, and Storytelling came together in the Science Communication activity. If this is the case, I might like to see Fig. 1 rearranged accordingly, with Science Communication at the center as the result of interdisciplinary research."

Reply: The reviewer suggestion makes sense. Figure 1 was changed accordingly.

"References: It might be useful to add a couple of references regarding coastal geology scientific concepts"

Reply: A paragraph will basic scientific concepts on coastal geology was added (Lines 163-182).

"Line 180: What is psychomotricity equipment? Could you give an example?"

Reply: A brief explanation and examples were added (Lines 225-234).

"The first paragraph of Section 3.1 is very important, as it provides the rationale for the activity development. I suggest moving it to the introduction."

Reply: The paragraph was moved to the introduction (Lines 130-138).

"Lines 353 and 390: The existence of "kinaesthetic learners" has been long dismissed as a myth. Please remove this."

Reply: Removed.

"Line 363: This is currently unsubstantiated. Please provide evidence or avoid speculation."

Reply: Removed.

"Line 405: Those are fantastic examples. Are those your ideas (in which case you should explicitly mention that's the case) or have those been carried out before (if so, please provide references)."

Reply: These examples are our ideas, except the example of plate tectonics/sculpture, which is referred to the artist that developed it. To avoid misinterpretation, the sentence was rearranged (Lines 518-526).

Reviewer#2

"*While I admire the approach to activity development I find it problematic to separate the learning activity from the communication of the science as stated in text beginning on lines 55 and 395. If the goal is to raise science capital rather than geoscience literacy, more evidence would need to be presented regarding the positive linking of the physical activity to the understanding, familiarity, and comfort with the science, or any science, being communicated. Without this, the evidence is only convincing in demonstrating an increase in social capital, at best cultural capital.*"

Reply: In line 55 of previously submitted version we stated: "here (…) engagement is a loosely term referring to behaviours that demonstrate interest in, or interaction with science-related activity or experience". In line 395 of previously submitted version we stated: "Regarding the activity impacts, inquiry results showed that all children enjoyed themselves. Nevertheless, the improvement of geoscience literacy was not measured." Our point is that the physical activity contributed to the familiarity and comfort with science. We are not sure if we understand entirely the reviewer's point; nevertheless, we added in lines 412-415 that we have qualitative evidence of increased familiarity and comfort with geosciences, which is the result of both the brief explanation in the beginning of the section, reinforced by the physical exercises. In future works, effects should be evaluated separately. In lines 507-513 we elaborate on how we think science capital may have increased.

"The manuscript would be greatly improved with some simple changes to the evaluation including, 1) Pre-activity data on knowledge of coastal morphodynamics – this need not have detracted from the activity as could have been included interactively in the introductory section by asking for experiences of waves/shorelines. 2) Pre-activity data on how pupils prefer to learn science: this would have greatly strengthened assertions that the activity was a preferred method rather than relying on feedback post event collected by those delivering, which has a strong likelihood to create audience bias through wanting to please the activity deliverers. 3) Follow up data on the pupils' understanding and retention of the principles being communicated at 14 days or other time period as deemed suitable post event. 4) Pre and post data on science capital of the teachers and pupils. 5) Evaluation of any impact on the researchers and creative partners. 6) Follow up with teachers on the impact of the activity on team building, etc, would be a useful metric as well. I do however appreciate there are difficulties in collecting some of this data. It might have helped to have more teacher involvement in developing the activity to support follow up evaluation."

Reply: The reviewer suggestion is pertinent and we acknowledge the concern. We were not sure, at the beginning, about the feasibility and receptivity of students and teachers to this activity. The activity implementation, rendered in this manuscript, demonstrated that coastal geosciences are suitable for this type of Science & Art approach and age group; and this was our main drive for trying to disseminate it within the science communication community. On the discussion (Lines 387-388) and final remarks (Lines 514-517) sections of the manuscript, we reinforced that evaluation was a shortcoming of the work that needs to be acknowledged in future studies and that the step forward to scientifically demonstrate impacts (at least on the short- to medium-term) is to implement an evaluation plan, which followed the reviewer suggestion (Lines 461-475). We gratefully thank the reviewer's generosity in taking the effort to propose a plan.

"I also appreciate and fully agree with the authors' insight into the limitations of this study (text starting line 315, and 369) and believe that careful evaluation planning integrated into the delivery would have in fact provided the data required to greatly strengthen the manuscript. The data collected could be considered a baseline for further delivery at, for example, European Researchers' Night 2020."

Reply: We are totally in agreement with the reviewer. The proposed plan (reviewer previous comment) was included on the discussion section (Lines 461-475) as an issue to move this (and similar) activities further.

"Finally, I fully agree with the authors' point, starting line 385, that more analysis on the emotional connection with learning is a factor that should be recognized and measured more in science communication."

Reply: We thank this remark. Furthermore, we added information about emotional connection on the manuscript (Lines 410-415, 436-438, 467-468), besides references already in the previous version (Lines 488-493).

"Line 180: what is 'psychomotricty? Please define."

Reply: We added a brief explanation and examples (Lines 225-234).

"Line 215: I would like to see a reference for both Laban's theory of movement and the adaptations from Anne Green Gilbert."

Reply: We added a brief reference to Laban's theory of movement and referred adaptations (Lines 272-287).

"Line 248: A reference or link to the EVREST project would be useful."

Reply: The reference was added (Lines 132-135).

“Line 272: typo: ‘brief’ should be ‘briefed’”

Reply: Correct (Line 340).

“Line 321: typo: ‘trough’ should be ‘through’”

Reply: Correct (Line 391).

“Line 322: Please rephrase ‘it seems to promote ocean literacy’ (perhaps to it ‘may have the capacity to promote. . .’), or present evidence that this is the case, qualitative or quantitative from pupils directly or from teachers.”

Reply: Changed as suggested (Line 392).

“Line 337: please provide your evidence, even if it is observation based, on how you assessed the presence of the ‘positive emotions’.”

Reply: These elements were added (Lines 410-415).

“Line 339: While the association of pleasant memories to science seems probable, I can’t see the evidence presented that this is the case. Please make it clear if this is evidence based or a supposition.”

Reply: Changed to clarify that it is a supposition (Line 415).

“Line 356: While social benefits again seem probable, I can’t see the evidence presented that this is the case. Please make it clear if this is evidence based or a supposition.”

Reply: Changed to clarify that it is a supposition (Line 433).

“Line: 367: word omission: please place ‘of’ between ‘identification’ and ‘whether’.”

Reply: Correct (Line 446).

Editor

“Thank you for submitting your manuscript to Geoscience Communication, and for engaging so thoroughly in the peer-review process. The activity that you report on and the context that you provide is very useful to the wider geoscience community, and would be very well suited for publication in Geoscience Communication.

I am recommended that this manuscript requires major revisions before publication, because whilst I think most of the issues can be addressed in a relatively straightforward manner, I am in strong agreement with Reviewer 2 that you need to carefully reconsider your evaluation *strategy. Whilst it is obviously not possible to get pre-workshop data now that the activity has taken place, it should still be possible to follow up with the participants to see if there has been any long-term learning as a result of your intervention. If this is not possible, then you will have to better explain limitations of your study and use this to reframe the paper. For example, are you really raising science capital, and if so then how?"*

Reply: We appreciate the editor's decision regarding our manuscript. The editor concern, referring to Reviewer #2 comment, is pertinent. As we refer above on our reply to Reviewer #2, the manuscript intention was to demonstrate that coastal geosciences are suitable for this type of Science (Coastal geoscience) & Art (Dance) approach and age group. This was our main drive to submit it to *Geoscience Communication* journal. However, we do agree that evaluation is a key topic, and that asking for students' opinion at the end of the activity is not enough. Thus, on the discussion (Lines 387-388) and final remarks (Lines 514-517) sections of the manuscript, we reinforced that evaluation was a shortcoming of the work that needs to be acknowledged in future studies and we suggest an evaluation plan, which followed the reviewer suggestion (Lines 461-475).

"Furthermore, in Section 5 you state that the activity was 'qualitatively evaluated', but I see no real evidence of this. Figure 5 shows that the participants enjoyed the session, but this is a basic quantitative evaluation. Do you have any comments or opinions from the participants, or could you get these now? If so then these would form the basis of a very useful qualitative evaluation."

Reply: As stated above, we agree that the qualitative evaluation of students' enjoyment and engagement, reinforced on the manuscript (Lines 410-415, 436-438, 467-468) was insufficient. Accordingly, an evaluation plan for future activities was proposed following Reviewer #2 suggestions (Lines 461-475).

Finally, please conduct a very thorough proofread of the manuscript, as there are several typographical and grammatical errors that need correcting, some of which have been picked up by the reviewers.

Reply: A thorough revision was conducted, hopefully picking all typos. The ones identified by reviewers are pinpointed above.

Engaging children in geosciences through storytelling and creative dance

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Abstract. Natural sciences have traditionally been disseminated in outreach activities as formal one-way presentations. Nevertheless, innovative strategies are being increasingly developed using arts, gamming, sketching, amongst others. This work aimed at testing an alternative and innovative way to engage non-expert audiences in ocean and coastal geology, through a combination of scientific concepts explanation with creative dancing. An informal education activity focusing on ocean dynamics was designed for 10-year-old students. It combines coastal science concepts (wind, waves, currents, and sand), storytelling techniques (narrative arc), and creative dance techniques (movement, imaginative play, and sensory engagement). A sequence of six exercises was proposed starting in the generation of offshore ocean waves and ending with sediment transport on the beach, during storm/fair-weather conditions. Scientific concepts were then translated into structured creative movements, within imaginary scenarios, and accompanied by sounds or music. The activity was performed six times summing 112 students. It was an inclusive activity given that all students in the class participated, including children with several mild types of cognitive and neurological impairment. The Science & Art activity aroused emotions of enjoyment and pleasure, and allowed an effective communication between scientists and school public. Moreover, the results provide evidence of the activity effectiveness to engage children and to develop their willingness to further participate in similar activities.

Keywords: coastal science; ocean literacy; storytelling; science engagement; geoscience communication; creative dance.

1. Introduction

The act of dissemination (and communication) is part and parcel of doing research. The main vehicle of scientific information relies within the scientific community, through peer-reviewed periodicals, generally focused on specific research areas and directed at well-circumscribed, specialized audiences (e.g., Gravina et al., 2017). Nevertheless, there is still a gap in the effectiveness of such communication to the general public, with scientists often seen as being trapped in the ivory tower (e.g. Baron, 2010) and commonly using scientific jargon hard to understand by the common citizen. There are a vast range of approaches to engaging public audiences with scientific concepts (Bultitude, 2011); Mesure (2007) identified over 1500 active initiatives within the UK alone. There are three main forms of media used in science communication to the general public: traditional journalism; live or face-to-face events, and online interactions. According to Bultitude (2011), live events have the advantages of being more personal, scientists are able to better control the content, engenders two-way communication, and can involve partnering with other external organizations with complementary expertise. The disadvantages are limited audience reach, resource intensive, leading to low sustainability of activities, and can be criticised for only attracting audiences with a pre-existing interest.

According to Kim (2012), effective communication of science lies in the processes of public engagement with a problem or an issue relative to science; the processes of engagement ~~develop~~develops from the acts of exposing and focusing attention to the act of cognizing. Science journalism and classroom instruction seem to hold strongly to the traditional learning-theory paradigm that mere exposure to scientific knowledge would lead to scientific literacy and public understanding (Kim, 2012). In this work, engagement will not be used in the same sense as Public Engagement with Science, which has a specific meaning that refers to activities, events, or interactions characterized by mutual learning among people of varied backgrounds, scientific expertise, and life experiences who articulate and discuss their perspectives, ideas, knowledge, and values in response to scientific questions or science-related controversies (McCallie et al., 2009). Here, in terms of informal science education, engagement is a loosely defined term referring to behaviours that demonstrate interest in, or interaction with science-related activity or experience.

Recent work indicates that storytelling and narrative can help communicate science to non-experts, within the wider context of "framing" as an important feature of public outreach (Martinez-Conde and Macknik, 2017). Furthermore, strategies fusing arts and science (e.g. using games, poetry, music, painting, sketching) are becoming a favoured medium for conveying science to the public (e.g., Cachapuz (2014), Von Roten and Moeschler (2007), Gabrys and Yusoff (2012)). Collaborative projects between artists and Science, Technology, Engineering, and Mathematics (STEM) fields are not new, with renewed interest over the last decades (Heras and Tàbara, 2014), hence Science, Technology, Engineering, Arts and Mathematics - STEAM is increasingly replacing the traditional STEM designation. A maturing body of work indicates that the arts can deeply engage people by focusing on the affective domain of learning (i.e., engagement, attitude, or emotion) rather than on the cognitive domain (i.e., understanding, comprehension, or application), which is often emphasized in science education (Friedman, 2013). Therefore, science communication through art brings science to the public in ways that are engaging, instructive, artistic and, always, content-driven (Schwartz, 2014). Examples of "Science and Art" projects include theatre as a way of communicating coastal risk (Brown et al., 2017), hip-hop dance as a way of learning ecology (Wigfall, 2015), or art installations inspired in neuroscience laboratories (Lopes, 2015). Varelas et al. (2010) observed that while participating in a play representing STEM concepts, students engaged in understanding science from multiple perspectives. Embodied exercises situate abstract concepts in a concrete context, thus relating intangible ideas with corporeal information, and so rich multimodal distributed neural representations are forged (Hayes and Kraemer, 2017). Chang (2015) compiled an environmental science artwork database that consisted of 252 artworks, but only 4% included artistic mediums like poetry, dance and performances; the majority was from the visual arts domain. Good examples of STEM education through creative dance can be found in Landalf (1997) approaching earth sciences and in Abbott (2013) approaching mathematics. Creative dance is thus one mode for learning that involves using the body and the senses to gather information, communicate, and demonstrate conceptual understanding (Cone and Cone, 2012).

In Portugal, Afonso et al. (2013) reported that science teaching appeals to memorization of data and lacks abstract conceptual understanding. Geology education in particular is mostly associated to memorization (e.g. minerals and rocks), which drives students away from the geosciences. Moreover, science communication to the general public only occasionally ~~cover~~covers geosciences, in comparison to other sciences such as astronomy, health, or biology, as can be deducted from an analysis of most newspapers records (consultation to the science section records of the Portuguese newspaper "Público"), although good examples can be found in science communication literature (e.g., Pedrozo-Acuña et al., 2019).

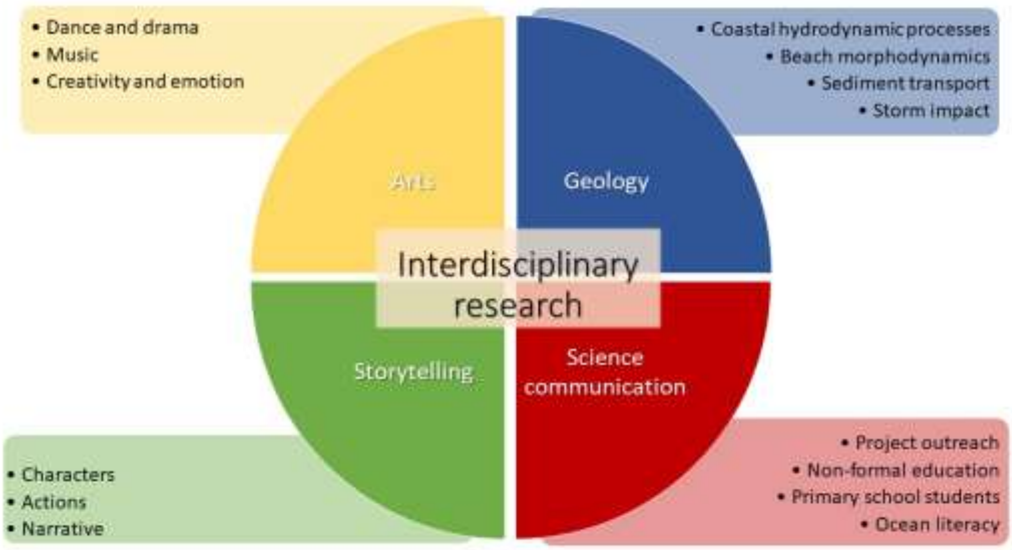
Coastal and marine geology have traditionally been disseminated in science outreach activities in the form of formal one-way presentations or, at best, field trips or lab experiences. The success of outreach actions and education programs requires knowing and understanding different audiences and strategizing how to reach them. So, efforts are kept now in the improvement of marine science literacy with accurate and appealing techniques that strengthen the learner's emotional connection to the ocean. The Intergovernmental Oceanographic Commission (IOC) of UNESCO stands that only through Ocean Literacy it will be possible to create an educated society capable of making informed decisions and caring for the preservation of Ocean's health (~~Francesca et al., 2017). In this context, effective geoscience communication activities addressing Principle 2 of Ocean literacy defined by Intergovernmental Oceanographic Commission~~Santoro et al., 2017). In this context, effective geoscience communication activities addressing Principle 2 of Ocean literacy defined by the IOCommission: "The ocean and life in the ocean shape the features of the Earth" are in great need and aligned with UNESCO

Sustainable Development Goal (SDG) 14: “Conserve and sustainably use the oceans, seas and marine resources for sustainable development”, are in great need.

Aligned with SDG 14 and IOC Principle 2 of Ocean literacy, the objective of this work was to develop an alternative and innovative activity to engage children in geosciences, borrowing from creative dance teaching. Moreover, this work intended to provide additional arguments about the importance of arts (dance) and communication techniques (storytelling) in engagement and effectiveness of geoscience programmes and develop their willingness to participate in similar activities.

2. Development of the activity “The Sea Rolls the Sand”

An interdisciplinary activity was developed by merging techniques and tools from arts, science, science communication and storytelling (Figure 1). The three main components were the scientific content (the message to be communicated); the storytelling and metaphors (the verbal way of communicating the message); and creative dance structure (the sensorial way of communicating the message).



Aligned with SDG 14 and IOC Principle 2 of Ocean literacy, the objective of this work was to develop an alternative and innovative activity to engage children in geosciences, by combining scientific concepts transmission with creative dance. Moreover, this work intended to provide additional arguments about the importance of arts (dance) and communication techniques (storytelling) in engagement and effectiveness of geoscience programmes and develop their willingness to participate in similar activities. Described activities were performed within the framework of the outreach task of a research project devoted to the evolution and resilience of barrier island systems (the EVREST project). EVREST project (more information in https://evrest.cvtavira.pt/) identified natural and human processes that contributed to Ria Formosa (south of Portugal) barrier island evolution (Kombiadou et al., 2019b) and developed a framework to quantify barrier island resilience (Kombiadou et al., 2019a, 2018). The project, led by a research centre (CIMA – Universidade do Algarve) also included Tavira Ciência Viva Science Centre (devoted to disseminating science to the general public), the partner responsible for facilitating the bridge between researchers and primary schools' students.

2. Development of the activity "The Sea Rolls the Sand"

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Figure 1 - Scheme summarising the elements from each component to develop the interdisciplinary research.

2.1. Scientific contents

The activity was developed to communicate concepts and processes related to marine and coastal morphodynamics to 10 years old students, attending the 4th grade. In Portugal, the geosciences are an academic discipline of the official primary school curricula. Nevertheless, geoscience contents are included in the generic discipline of "environmental studies", which includes basic knowledge of science such as the human body, solar system, monarchy history, earth surface morphology, water cycle, and protection of the environment. Within this discipline, there is a unit devoted to the sea – land interface.

The activity was composed by a series of six exercises (Figure 2) that were preceded by a simplified but accurate scientific explanation, adapted to the average expected pedagogical level, starting with an introduction, followed by basic geoscience concepts explanation, and enforcing the message with a resume at the end. The key geosciences concepts were wave, wave size, breaking waves, sand grain, sediment transport, beach dynamics, and seasonality. Waves form when the water surface is disturbed, for example, by wind, earthquakes or planetary gravitational forces. During such disturbances energy and momentum are transferred to the water mass and transmitted in the direction of the impelling force (e.g., Carter, 1988). At the shoreline, part of the incoming wave energy is reflected and is propagated back to the open sea, very much the way light bounces off a mirror; most of the incoming wave energy, however, is transformed to generate nearshore currents and sediment transport, and is ultimately the driving force behind morphological change at the coast (e.g., Masselink and Hughes, 2003). The portion of the coast most familiar to most people is the beach. The beach includes the adjacent seabed bellow shallow marine waters, generally called the nearshore environment until the highest high tide line. The beach is composed of nearly anything that can be transported by waves (e.g., Davis, 1996), predominantly sand but also gravel, mineral as well as organic, that come from river discharge, cliff erosion, glacier melting, organic shells production, volcanic activity, and ocean continental shelf, amongst others (e.g. Anthony, 2014). The exchange of beach sediment between submerged and sub-aerial portions of the beach is accomplished by onshore-offshore transport, mainly by waves, but aided sometimes by wind (e.g. Carter, 1988). Beach morphology thus responds to changing wave conditions, and has a cyclic behaviour. In many occasions, the cycles are seasonal; wave conditions during winter storms shifts sand offshore, whilst calm conditions during the summer induce landward migration of sediments back to upper parts of the beach (e.g., Komar, 1976).

Important associations from this activity are the connection between atmosphere, ocean and the coast, and the insight between casual observations that the students make, i.e., their empirical knowledge of the coast, for example, breaking waves, beach width, sand grains, and the science behind it.

The scientific content was divided into three major hydrodynamic and morphodynamics situations: wave generation and propagation, sediment transport and storm/fair-weather conditions. Wind blowing on ocean surface and wave generation were explained not only to elucidate how waves are generated but also to demonstrate the connection between separate environments (atmosphere and the oceans). Wave propagation was used to illustrate energy transference across the ocean surface, opposite to mass transference and to make the transition from the ocean to the coastal environment, until waves break at the shore (Figure 3). The generation of onshore currents under the presence of waves from the submerged to the sub-aerial part of the beach was then introduced. Sediment transport by onshore currents was explained as a straightforward effect, in the presence of grains in the bottom (lower block-diagram and pink arrow on Figure 4). Here sediment variability, including shape, size and composition, were introduced in relation to possible sources, such as volcanic rocks or coral reefs.

	Geology 	Storytelling 	Dance/movement 	Example
1	Introduction to coastal geology	Exposition Action: preparing for the beach trip/applying sunscreen	Warmup	
2	Coastal & oceanic environments	Exposition Action: trip to the coast and dive into the ocean	Jumping Swimming movements	
3	Wind & wave generation Wave propagation	Rising action Action: making waves	Cadence Improvisation	
4	Wave induced currents Sediment transport	Rising action Action: currents moving grains, and breaking waves	Direction Improvisation Ball passage	
5	Storm waves Off/onshore currents Erosion/accretion	Climax Action: currents moving grains	Direction change Improvisation Ball passage	
6	Resume	Falling action Action: sunbathing	Relaxation	

Figure 2 - Activity outline: list of scenes (from 1 to 6), related scientific contents, associated storytelling moment and type of dance movements.

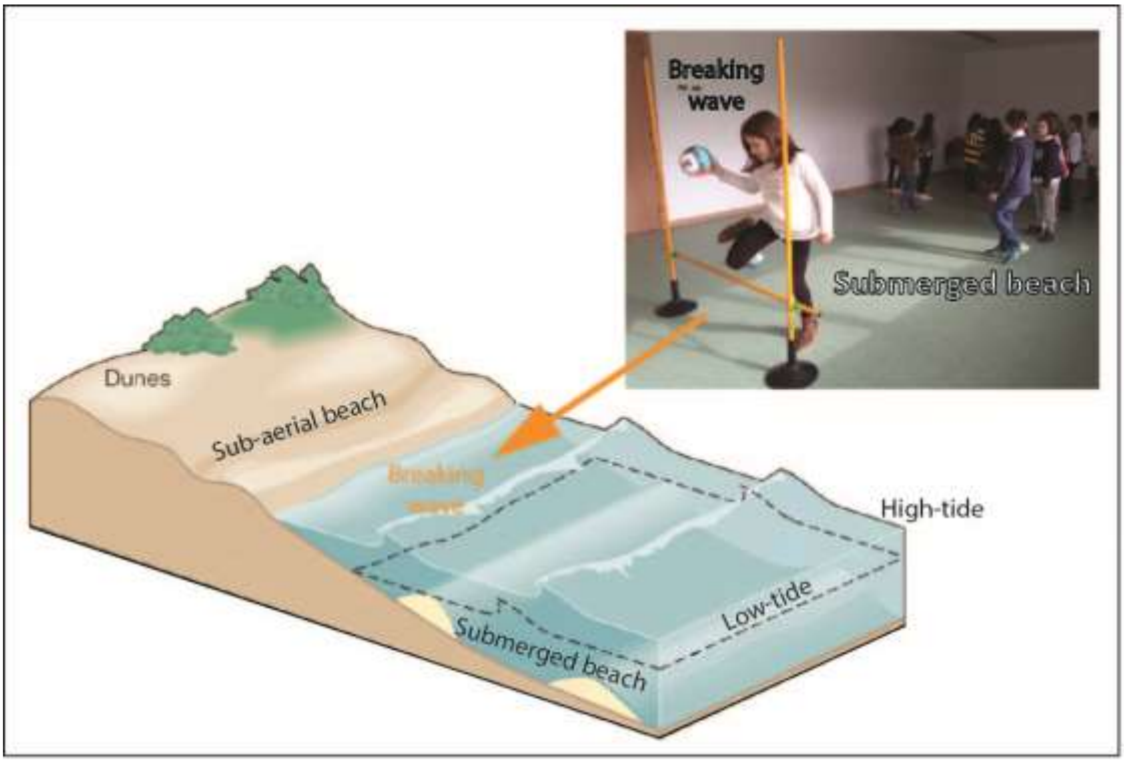

Figure 3 - Coastal environments: dunes, sub-aerial beach and submerged beach. The photograph shows a "breaking wave" with a jump over the yellow horizontal bar, representing the position that separates the sub-aerial from the submerged beach (towards the right hand-side, where children are in two rows "propagating waves").

Wave height variations throughout the year ~~was~~were explained, by introducing the concept of storm waves and induced sediment transport pattern (upper block-diagram and pink arrow on Figure 4). Because onshore currents generated by fair-weather were explained, offshore currents ~~during~~ and consequently beach erosion did not need an elaborated explanation. The alternation between erosion and accretion, i.e., seasonality of waves and beach morphology depending on wave height was reinforced, both as natural occurrences on a natural beach.

2.2. Storytelling and metaphors

As in any story, the activity had a theme, settings, scenes, characters, actions, and a narrative arc. In broad terms, the narrative arc is the sequence of action shaped by the exposition, rising action, crisis, climax and falling action (e.g. Hart, 2011). The theme of coastal dynamics is immediately set in the introduction, when the scientific topic is addressed. ~~The settings, i.e., the natural environments were built with psychomotricity equipment, but mostly appealing to imagination.~~The settings, i.e., the natural environments, were built with psychomotricity equipment, but mostly appealing to imagination. Psychomotricity is a holistic type of intervention by means of movement and play, oriented towards humanism and respecting a child's development stage (cf., for example, Vetter, 2019). It refers to psychomotor educational interventions (e.g., Perrotta, 2011) but also to therapeutic practices (e.g., Ayres, 2005; Ingwersen et al., 2019), where there is a relation between the psyche (mental processes) and motoric (physical activities). Typical psychomotor equipment (cf., European Forum of Psychomotricity, 2016) for children includes colourful hoops, balls, cones, mates, bags, blocks, and poles, that can be used isolated or as frames, tunnels, tracks, climbing sets or balancing courses.

There were three main settings: the deep ocean, the beach under water and the sub-aerial beach (Figure 3). The limit of the sub-aerial and submerged beach, i.e., the wave breaking position was marked with two poles and a horizontal bar, while sediment balls of different sizes, colours, shapes and textures represented sediments (Figure 3). The settings/scenario of the action (marine and coastal environments) were also suggested by specific actions such as ~~dive~~diving into the ocean (jump over the horizontal bar), imaginary application of sunscreen, and sunbathing (relaxation, Figure 4). Characters performed by students were beach users (scenes 1, 2 and 6, Figure 2) and water particles (scenes 3 to 5, Figure 2).

Figure 4 - Coastal environments, coastal processes and metaphors. The image illustrates waves approaching the coast, coming from the right side (blue arrow). The direction of sediment transport (pink arrows on top of photographs) was embodied by the direction of the hand-to-hand balls (representing sediment grains) passage during storms (top right) and fair-weather (bottom right). The wave breaking position is represented in the room by two yellow vertical poles + horizontal bar, with the sub-aerial beach towards the left hand-side (where children are resting on the middle photograph).

The narrative consisted of a set of six practical actions (exercises) that were plotted in a predefined sequence of increasing complexity and excitement (at the beginning of the activity), with a sharp decline to relaxation (at the end of the activity), following the narrative arc (Figure 2). During scenes 1 and 2, an exposition to the theme and settings was conducted, obtained by the verbal explanation of the beach topic and by suggesting a sequence of actions that mimic a trip to the beach, finishing with the dive into the ocean; students (actors) embodied beach users. From scenes 3 to 4 settings were kept, but characters were changed, and actors embodied water particles, instead of beach users. The actions involved exercises of increasing complexity, reflecting a rise in action, as they impersonated water particles of the sea surface and then water particles as a current that transported grains to the shore. In scene 5, the climax was attained when storm waves reached the coast in several moments, and sediments could move in opposite directions. During scene 6, characters returned to beach users again; actors came out of the ocean and sunbathe, in a falling action (Figure 2 and 4).

2.3 Creative dance structure

According to Gilbert (2015), creative dance is a dance form that combines the mastery of movement with the artistry of expression. ~~The basic movement concepts used here derive from Laban's theory of movement, with adaptations from Anne Green Gilbert. The creative dance unit focused the effort concepts of time (fast/slow), space (direction), and flow (bond/free). A typical session of creative dance is composed of: 1) warming up, 2) Exploring the concept,~~In creative dance, children generate, vary, and manipulate movement by using the elements of dance through the process of improvisation (Cone and Cone, 2012). The basic movement concepts used here derive from Laban Movement Analysis. Rudolf Laban's (1897-1958) philosophy was based on the belief that the human body and mind are one and inseparably fused (e.g., Newlove and Dalby, 2004). It was Laban's firm belief that it is the birth right of every man to dance – not just trained dancers or folk dancers and the like, but all human beings (Newlove and Dalby, 2004). Laban Movement Analysis is a method to describe and analyse human movement and to establish a notation system with precision and clarity (cf., Laban, 1963). Laban's ideas have been picked up, reinterpreted, evolved and ramified, for example, to Dance Movement Psychotherapy (e.g., Best, 2008), programmes for individuals affected by complex needs (e.g., Price, 2008) and creative dance (e.g., Gilbert (2015). Structure and elements used here were also based in techniques described by several dance educators (Landalf, 1997; Carline, 2011; Cone and Cone, 2012; Abbott, 2013; Gilbert, 2015). The creative dance unit focused the effort concepts of time (fast/slow), space (direction), and flow (bond/free). A typical session of creative dance is composed of: 1) warming up; 2) Exploring the concept; 3) Developing skills; 4) Creating; and 5) Cooling down (Gilbert, 2015).
During the first exercise (scene 1), applying sunscreen, there was a warm up of muscles and mobilization of articulations through light aerobic movements, such as bending, twisting and curling (see dance/movement on Figure 2). During the second exercise (scene 2), students jumped over the obstacle (~~dive~~diving into the sea, Figure 3), in turns, and made swimming free movements across the space. In the third exercise (scene 3), students stand in two lines facing each-other, consisted in reproducing several waves with the body curling up, with arms up, in a cadence. The movement was repeated in a cadence of dance improvisation. During the fourth exercise/scene, the two rows of students performed dance improvisation while passing different balls (representing sediment transport) in the direction of the obstacle (the sub-aerial beach, Figure 4), jumping to mimic breaking waves. In the fifth exercise/scene, students applied the

same type of movements than in the fourth exercise/scene, but listening a different soundtrack; music changed in intensity and the balls moved to the obstacle when the music's intensity was lighter and move in the opposite direction when the music was louder and more intense to represent fair-weather waves and storm waves, respectively. During the sixth exercise/scene, students spread thorough the available space and rested on the floor, while relaxing, and sensory stimulation was induced by speech, appealing to sensations felt while sunbathing (sea smell, warm on the skin, wind sensation, sand grains below the body).

~~Sound-tracks~~Soundtracks included music/sounds with lyrics allusive to the sea (exercises 1, 2 and 6), soundtracks of animation movies (exercise 2), sounds from nature (wind on exercise 3 and waves on exercise 6), a Portuguese traditional theme (exercise 1), classical music (exercise 5), and pop music (exercise 4). The activity was called “The Sea Rolls the Sand”, which is the name of ~~the~~a Portuguese traditional song. All musical themes had easy rhythmical and melody compositions.

3. “The Sea Rolls the Sand” activity implementation

3.1. Performing opportunities and institutional framework

~~The activity was performed within the framework of the outreach task of a research project devoted to the evolution and resilience of barrier island systems (the EVREST project). The project, led by a research centre (CIMA – Universidade do Algarve) also included Tavira Centro Ciência Viva (Science Centre devoted to dissemination to the general public) who facilitated the bridge between researchers and primary schools' students.~~

The activity was performed six times, within national and international initiatives. During the first two times, the sessions were included in the activity of the “European Researcher Night”, in September, 29th, 2017. These sessions took place in the educational laboratory of the Tavira Ciência Viva science centre, which was emptied as much as possible to create space for physical activities. The other four sessions were included in a national initiative “Science and Technology Week”, in November 23th and 24th, 2017. These sessions took place ~~in~~at three ~~schools, including (~~private and public) schools, ~~on~~in the classrooms and in the gym.

Overall 112 students participated in the activity, divided in school classes, varying between 15 and 22 students per session. Two classes in small schools in rural areas ~~include~~included students from different grades; 1st and 4th, in one case, 3rd and 4th in another case. Tavira municipality had 323 students attending 4th grade classes or mix classes, divided in 16 classes (with 13 to 26 students/class). Therefore, about 35% of all 4th grade students of the municipality participated in the activity.

All students in the class participated, including children with cognitive impairment, attention deficit disorder, amblyopia, light autism, hyperactivity and dyslexia.

Teachers assisted all sessions and had no intervention on the scientific topics or session alignment; however, occasional teacher's interference occurred to assist behaviour control of the class. In one of the sessions, a teacher assigned for cognitive impairment students was also present, but no interference took place. There was no discussion or presentation in advance with the teachers about the sessions' specific methods and contents. Teachers volunteered to participate solely based on the information of the general topic. They were ~~brief~~briefed about the need of an empty room and that children should be wearing clothes appropriate for physical activity.

3.2. Activity evaluation by participants

At the end of the activity, with children still laying over the room floor, small inquiries were distributed to obtain an anonymous evaluation. Questions concerned: 1) if they enjoyed the activity~~,~~; 2) if they liked the movements; 3) if they liked the music; 4) how do they prefer to learn science; 5) if they think they learnt something new; and 6) if they would like to repeat it, and if so with another person or in another place.

From the 112 students that responded the inquiries, there was an even distribution of boys and girls (51% were girls). Results showed that all children enjoyed themselves, and 80% enjoyed a lot (Figure 5A). About 75% liked the movements a lot and only 1% was not sure about this.

Only one student did not like the music selection. After anonymously filling the inquiry, the student stated: "I hate classical music".

According to the inquiry's responses, these children prefer to learn science through movement and games, although field trips and laboratory experiments were also frequently selected (20/112, Figure 5B). When questioned about how much they learned with the activity, 35% answered they learned something new, and 60% answered they learned a lot, with 5% stating they already knew everything. 99% of children want to repeat the activity, but 20% of the students from one of the schools referred they preferred to do it elsewhere (Figure 5C).

The time constraints and the lack of personnel to assure children's supervision did not allow a proper quantitative assessment of the schoolteacher's opinions. Nevertheless, teachers expressed that "the activity was very nice and good for children this age". Additionally, some teachers were concerned about some children's inability to follow entirely the scientific content, or not having an appropriate behaviour all the time.

The researcher conducting and researchers assisting the activity observed that these children, living in coastal areas, although having limited scientific background on coastal geology, have plenty of empirical experience on the coast.

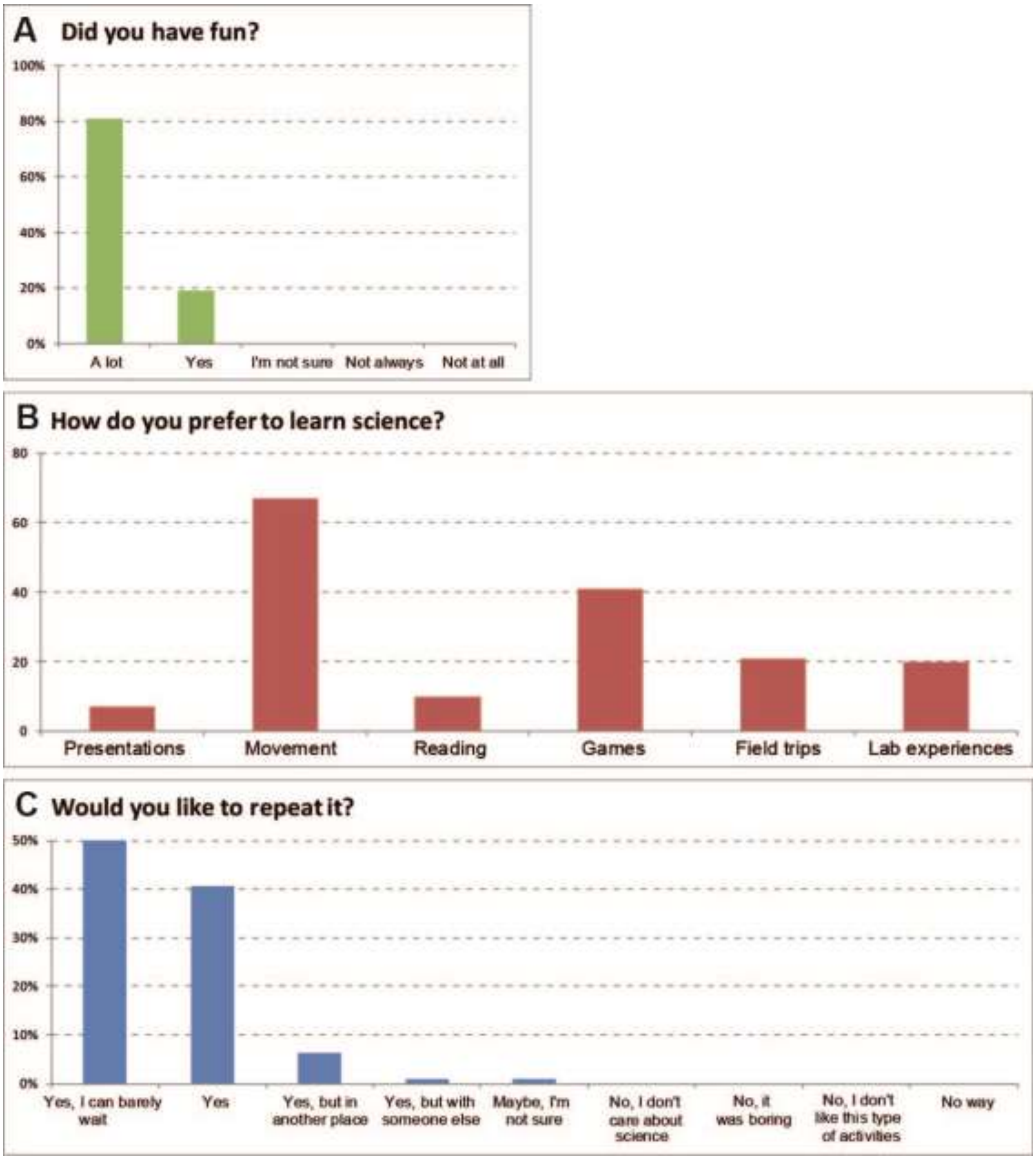

Figure 5 - Results of inquiries for some of the questions.
Note: for the question about how they prefer to lean about science, multiple responses were allowed, and the vertical axis is the number of responses, not a percentage.

4. Innovation, insights, and limitations of the interdisciplinary fusion

The observations made throughout the activities showed that the developed and performed activity has pros and cons in relation to more traditional forms of informal education.

The main hypothetical risks associated with the methodology application are: the detachment of children of the activity; the disinterest of children in the scientific subject; the lack of understanding of children about the message; shame feeling during the dance exercises; and the little time for reflection they had to consolidate the scientific contents. Some of these risks could not be directly observed and measured with the results of inquiries. The size of the sample (six sessions, 112 students) was considered sufficient for a pilot test, attesting its feasibility, age adequacy, content relevance, ~~students teachers~~ teachers' interest and acceptance. However, the sample size and composition were insufficient to analyze other factors. Comprehensive analysis and conclusions would require a comparison between the impact of this activity and another science communication format covering the same scientific topics and age group. The lack of an evaluation plan was the main shortcoming of this work.

The main opportunity associated with the methodology application is the engagement of children about science concepts, by focusing attention (demonstrated by Kim (2012) as the first step towards engagement) on the affective domain of learning, showing emotions ~~trough~~through movement. Furthermore, it ~~seems~~may have the capacity to promote ocean literacy~~, although this requires~~. Nevertheless, a measurable assessment in future implementations and studies will be crucial in order to validate the impact of such methods. The innovation of the presented activity is the enlargement of the science communication strategies, whereby scientists ~~communicates though~~communicate also through creative ~~dance~~dancing.

Insights from the activity development and performance can be summarized as follows:

- The interdisciplinary solution ~~is~~seems to be adequate as a general approach to solving complex issues; the complex issue here being a generalized disconnection between students and geosciences. The appeal to conceptual understanding, rather than memorization in geosciences (e.g. names of minerals and rocks, types of volcanism and their location, names of geomorphological features) aligns with the most necessary improvements in curricular guidelines identified by Afonso et al. (2013) for Portuguese education of sciences. The storytelling technique of contents sequencing versus a plain sequence of contents look as a successful technique of engagement with the activity.
- The emotional involvement in the presence of music seems to effectively encourage engagement, participation and willingness to take part in different experiences. Several positive emotions and feelings were promoted during the activity, evolving from anticipation, pleasure, surprise, enjoyment, to excitement, and then serenity and relaxation. ~~The~~The assessment of emotional states was based on local observations by the persons conducting and assisting/observing, both directly and by revising photos and videos. Observation notes included the record of facial expressions, silence/talk/laugh, and body language (heads follow/not follow the person explaining, readiness/delayed movement, take a peek/indifference, jumping and frenzy in

anticipation/apathy, inertia or yawn). It seems fair to suppose that the pleasant memories of the playful visits to the beach evoked during the activity (vacations, playing, and freedom) became also associated to science and learning. The movement and improvisation is effective in creativity stimulation, self-expression and stress release, thus ~~aligns~~being aligned with the 21st-century educational orientations (as demonstrated by Cone and Cone (2012)). Moreover, the activity is innovative, yet not supported by screens. During the early stages of the activity, shyer children tended to be reluctant to participate, very self-conscious and consequently their movements are small. As the activity advanced, they became more open and engaged ~~on~~with the proposed exercises.

- The activity ~~is~~was able to mitigate some student's exclusion factors. Inclusion of students with diverse and special needs in the classroom has been a major focus in education over the past 30 years (Villanueva et al., 2012). The children's layout in space (spread or in two lines facing each-other), participating in chain sequencing, allows students with some degree of impairment to engage in the activity. ~~The activity potentially improves the level of attention of kinaesthetic learners.~~ Additionally, the organization of the activity for school classes, rather than an activity for families, assures the presence of children that would not participate otherwise.
- The social benefits from this type of activity can potentially include team building and students learn self-discipline, gain an appreciation to other movement styles, and discover the value of individual differences through creative exploration and problem solving. Socially, children enjoy interacting with others through movement (Cone and Cone, 2012). They laugh and talk with each other while sharing an experience that is fun and rewarding. The use of free (not choreographed) movements and balls can break the stereotype of "dancing is for girls" thus promoting gender equality. These are values identified in creative dance (e.g., Landalf (1997), Carline (2011), Cone and Cone (2012)) that can be ~~taken~~incorporated into science ~~communications~~communication.
- ~~A single session is clearly insufficient as students take time to adapt to a completely different way of learning. Even if the second session would be about a different subject, students would know what to expect.~~
- A thorough evaluation of science communication initiatives is essential to enable the identification of whether long-term objectives are being met, it can help to make the iteration of science communication initiatives more efficient, and can also highlight areas that need further strengthening ~~(Illingworth, 2017).~~(Illingworth, 2017). There was anecdotal evidence of increased familiarity and comfort with geosciences (e.g., use of scientific terminology by students towards the end of the activity, processes introduced by researchers in the exposition scenes were translated to actions by students on the

climax scene), which may have been the result of the brief explanation in the beginning of the section, reinforced by the physical exercises. In this study, due to the sporadic nature of the event, within a major event, it would be difficult to establish a baseline of children's knowledge prior to the intervention. After this session, the same students were involved in a science club devoted to topics of coastal geosciences, where experiences and a field trip were made.

- In future ~~studies~~activities such as European Research Night 2020 and following, an improved programme ~~can~~should incorporate an assessment of the ~~student's~~students' interest and understanding of the scientific subject, in comparison to other methods. This entails the development and testing of a specific impact assessment design. A future evaluation plan can include: 1) Pre-activity data on knowledge of coastal morphodynamics, this may be done prior to the activity or be included interactively in the introductory section by asking for experiences of waves/shorelines; 2) Pre-activity data on how pupils prefer to learn science, and on how students with special needs interact with other students; 3) Pre- and post-data on science capital of the teachers and pupils; 4) Teachers' and outside observers' evaluation of emotional states during the activity; 5) Evaluation of impacts on the researchers and creative partners; 6) Follow up data on the students' understanding and retention of the principles being communicated at e.g. 14 days or other time period as deemed suitable post-event; 7) Follow up with teachers in order to assess the impact of the activity on team building, self-discipline, and appreciation for each other's differences. At first, qualitative methods may be used to identify what outcomes are emerging; later quantitative methods may be used to measure the strength of the outcome, or what proportion of participants experience the different outcomes (Grant, 2011).
- This activity was a first step towards the setting of transdisciplinary activities in geosciences, that can meet a rather difficult balance between scientific accuracy, stimulation of creativity, art & science bonding, integration of body-mind principles, and promotion of inclusion of students with special needs.

5. Final remarks

A science communication activity for primary-grade children, was described and qualitatively evaluated. It combines coastal science concepts, with storytelling ~~techniques~~, and creative dance techniques. The way scientific concepts were translated into the dance class structure were described thoroughly, to allow science communicators the chance to look behind-the-scenes of dance creative.

The dance ability to directly improve overall learning skills (which is at least questionable, according to Keinänen et al. (2000)) was not the purpose here. The proposal ~~is~~was to use art (dance to exemplify) as a means to promote science engagement through emotional involvement, creativity and sensory stimulation. The presence and acknowledgement of emotions is a further way that the practice of science communication can overflow expectations and models of it, and something else that it would be valuable to notice more in science communicators analysis (Davies and Horst, 2016).

The proposed activity had the ability to promote social inclusion of children with special needs, physical impairment, and kinaesthetic learners. The theme of social inclusion in the science communication field is not new; the political value of science communication was explicit in many cornerstones of the history of this field (Massarani and Merzagora, 2014). Nevertheless, the exclusion from science communication activities is not only a statistical fact, but also a neglected matter on communication research (Dawson, 2018).

Regarding the activity impacts, inquiry results showed that all children enjoyed themselves. Nevertheless, the improvement of geoscience literacy was not measured. Yet, science communication paradigms have shifted from science literacy (the ‘deficit model’) to “Science and Society” (e.g. Bauer (2008)). This activity is aligned with the most recent paradigms, where communication is interactive and constructive, with emphasis on dialogue, deliberation, participation, and empowerment (Davies and Horst, 2016). It ~~contributes~~may contribute to the students “science capital” (as defined by Archer et al. (2015)) on the dimensions~~ of science~~: Science-related attitudes, values and dispositions~~, knowing~~ - because science was approached in an enjoyable and engaging way, with potential to have increased openness to geosciences; Knowing people in science-related jobs~~, making~~ - because both people conducting the activity were researchers and were introduced that way at the beginning, Making science relevant to the everyday lives of students~~,~~ - because geoscience study objects are part of students’ lives as coastal inhabitants, very familiar with barrier islands; besides the potential for increased science literacy~~.~~ (evidenced by the use of scientific terminology towards the end of the activity).

~~Addressed~~Increased science capital or science literacy by this activity are suppositions based on qualitative observations and suppositions; an effort to a more evidence-based science communication approach (Jensen and Gerber, 2020) is needed and is a shortcoming of this pilot work.

The addressed geoscience topics and adopted art forms can be combined in a number of ways: for example, we can foresee as adequate, innovative and engaging, volcanology and music (e.g., types of volcanoes and volcanic rocks can be approached by percussion instruments and rhythms); climate change and drama (e.g., impacts of heat waves can inspire a play); and oceanography and poetry (e.g., waves and currents around the world can inspire poems~~),~~). An existing case of geoscience and art is the work of the artist Laura Moriarty (see http://www.lauramoriarty.com/) who combined plate tectonics and sculpture (~~e.g., ~~faults and bedding planes ~~can be ~~approached and appreciated as blocks of a sculpture~~, cf. artist Laura~~

Moriarty in http://www.lauramoriarty.com/).). This almost endless number of mishmashes, on top of the aesthetical value of earth-science objects, from a desert landscape, to a mineral, a geyser, satellite imagery, a canyon, a rocky shore, just to name a few, is an asset worthy of further exploration in science communication of STEAM.

Competing interests.

The authors declare that they have no conflict of interest.

Acknowledgements

This study was supported by EVREST project, PTDC/MAR-EST/1031/2014, A. Matias was supported by Investigator Programme, IF/00354/2012, and A.R. Carrasco and A.A. Ramos were supported by a contract under the D.L. n.º 57/2016 changed by Law n.º 57/2017 all financed by FCT, PortugalFCT under the contracts DL 57/2016/CP1361/CT0002 and DL 57/2016/CP1432/CT0001, respectively. The authors are thankful for the two reviewers' comments and contributions, in particular to Reviewer 2 that proposed a future evaluation plan for the activity.

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