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Reply to editor comments on the revised manuscript “Engaging children in geosciences through storytelling and creative dance” by Ana Matias, A. Rita Carrasco, Ana A. Ramos, Rita Borges

"Editor comments" and authors' reply.

"1. Please revisit the quality of your figures, and ensure that they are in high resolution with well-focussed text that is easy to read."

Reply: We revisited all figures and we believe they are now suitable for publication. High resolution files (jpeg or tiff) are ready, if requested.

"2. Please re-word Section 5, as you have not 'qualitatively evaluated' the activity, and indeed you have pointed out that the lack of such an evaluation is a shortcoming of this work. This is still a valuable piece of research, and is an excellent example of a pilot programme that will lead to further work and subsequent evaluation, but at the moment it would be stretching the point to say that such an evaluation has been conducted."

Reply: We have made changes to section 5 in order to make sure it is not explicit or implicit that we have conducted an appropriate quantitative or qualitative evaluation.

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, gaming, 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 and 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

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36 effectiveness of such communication to the general public, with scientists often seen as being
37 trapped in the ivory tower (e.g. Baron, 2010) and commonly using scientific jargon hard to
38 understand by the common citizen. There are a vast range of approaches to engaging public
39 audiences with scientific concepts (Bultitude, 2011); Mesure (2007) identified over 1500 active
40 initiatives within the UK alone. There are three main forms of media used in science
41 communication to the public: traditional journalism; live or face-to-face events, and online
42 interactions. According to Bultitude (2011), live events have the advantages of being more
43 personal, scientists are able to better control the content, engenders two-way communication,
44 and can involve partnering with other external organizations with complementary expertise. The
45 disadvantages are limited audience reach, resource intensive, leading to low sustainability of
46 activities, and can be criticised for only attracting audiences with a pre-existing interest.
47 According to Kim (2012), effective communication of science lies in the processes of public
48 engagement with a problem or an issue relative to science; the processes of engagement
49 develops from the acts of exposing and focusing attention to the act of cognizing. Science
50 journalism and classroom instruction seem to hold strongly to the traditional learning-theory
51 paradigm that mere exposure to scientific knowledge would lead to scientific literacy and public
52 understanding (Kim, 2012). In this work, engagement will not be used in the same sense as
53 Public Engagement with Science, which has a specific meaning that refers to activities, events,
54 or interactions characterized by mutual learning among people of varied backgrounds, scientific
55 expertise, and life experiences who articulate and discuss their perspectives, ideas, knowledge,
56 and values in response to scientific questions or science-related controversies (McCallie et al.,
57 2009). Here, in terms of informal science education, engagement is a loosely defined term
58 referring to behaviours that demonstrate interest in, or interaction with science-related activity
59 or experience.

60 Recent work indicates that storytelling and narrative can help communicate science to non-
61 experts, within the wider context of “framing” as an important feature of public outreach
62 (Martinez-Conde and Macknik, 2017). Furthermore, strategies fusing arts and science (e.g.
63 using games, poetry, music, painting, sketching) are becoming a favoured medium for
64 conveying science to the public (e.g., Cachapuz (2014), Von Roten and Moeschler (2007),
65 Gabrys and Yusoff (2012)). Collaborative projects between artists and Science, Technology,
66 Engineering, and Mathematics (STEM) fields are not new, with renewed interest over the last
67 decades (Heras and Tàbara, 2014), hence Science, Technology, Engineering, Arts and
68 Mathematics - STEAM is increasingly replacing the traditional STEM designation. A maturing
69 body of work indicates that the arts can deeply engage people by focusing on the affective
70 domain of learning (i.e., engagement, attitude, or emotion) rather than on the cognitive domain
71 (i.e., understanding, comprehension, or application), which is often emphasized in science
72 education (Friedman, 2013). Therefore, science communication through art brings science to the

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74 public in ways that are engaging, instructive, artistic and, always, content-driven (Schwartz,
75 2014). Examples of “Science and Art” projects include theatre as a way of communicating
76 coastal risk (Brown et al., 2017), hip-hop dance as a way of learning ecology (Wigfall, 2015), or
77 art installations inspired in neuroscience laboratories (Lopes, 2015). Varelas et al. (2010)
78 observed that while participating in a play representing STEM concepts, students engaged in
79 understanding science from multiple perspectives. Embodied exercises situate abstract concepts
80 in a concrete context, thus relating intangible ideas with corporeal information, and so rich
81 multimodal distributed neural representations are forged (Hayes and Kraemer, 2017). Chang
82 (2015) compiled an environmental science artwork database that consisted of 252 artworks, but
83 only 4% included artistic mediums like poetry, dance and performances; the majority was from
84 the visual arts domain. Good examples of STEM education through creative dance can be found
85 in Landalf (1997) approaching earth sciences and in Abbott (2013) approaching mathematics.
86 Creative dance is thus one mode for learning that involves using the body and the senses to
87 gather information, communicate, and demonstrate conceptual understanding (Cone and Cone,
88 2012).

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

97 Coastal and marine geology have traditionally been disseminated in science outreach activities
98 in the form of formal one-way presentations or, at best, field trips or lab experiences. The
99 success of outreach actions and education programs requires knowing and understanding
100 different audiences and strategizing how to reach them. So, efforts are kept now in the
101 improvement of marine science literacy with accurate and appealing techniques that strengthen
102 the learner’s emotional connection to the ocean. The Intergovernmental Oceanographic
103 Commission (IOC) of UNESCO stands that only through Ocean Literacy it will be possible to
104 create an educated society capable of making informed decisions and caring for the preservation
105 of Ocean’s health (Santoro et al., 2017). In this context, effective geoscience communication
106 activities addressing Principle 2 of Ocean literacy defined by the IOC: “The ocean and life in
107 the ocean shape the features of the Earth” are in great need and aligned with UNESCO
108 Sustainable Development Goal (SDG) 14: “Conserve and sustainably use the oceans, seas and
109 marine resources for sustainable development”, are in great need.

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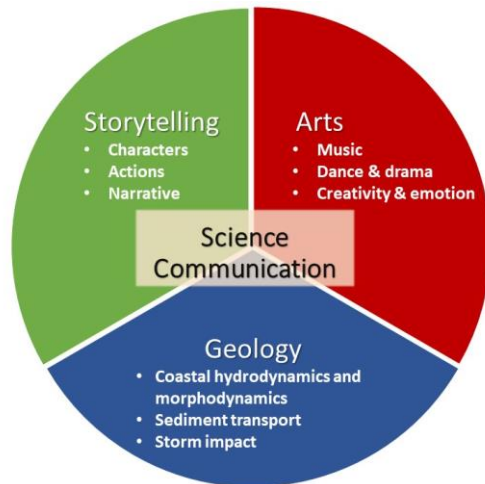
113 Aligned with SDG 14 and IOC Principle 2 of Ocean literacy, the objective of this work was to
114 develop an alternative and innovative activity to engage children in geosciences, by combining
115 scientific concepts transmission with creative dance. Moreover, this work intended to provide
116 additional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

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

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

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

139

140 **2.1. Scientific contents**

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

148 The activity was composed by a series of six exercises (Figure 2) that were preceded by a
 149 simplified but accurate scientific explanation, adapted to the average expected pedagogical
 150 level, starting with an introduction, followed by basic geoscience concepts explanation, and
 151 enforcing the message with a resume at the end. The key geosciences concepts were wave, wave
 152 size, breaking waves, sand grain, sediment transport, beach dynamics, and seasonality. Waves
 153 form when the water surface is disturbed, for example, by wind, earthquakes or planetary
 154 gravitational forces. During such disturbances energy and momentum are transferred to the
 155 water mass and transmitted in the direction of the impelling force (e.g., Carter, 1988). At the
 156 shoreline, part of the incoming wave energy is reflected and is propagated back to the open sea,
 157 very much the way light bounces off a mirror; most of the incoming wave energy, however, is
 158 transformed to generate nearshore currents and sediment transport, and is ultimately the driving
 159 force behind morphological change at the coast (e.g., Masselink and Hughes, 2003). The portion
 160 of the coast most familiar to most people is the beach. The beach includes the adjacent seabed







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161 below shallow marine waters, generally called the nearshore environment until the highest high
162 tide line. The beach is composed of nearly anything that can be transported by waves (e.g.,
163 Davis, 1996), predominantly sand but also gravel, mineral as well as organic, that come from
164 river discharge, cliff erosion, glacier melting, organic shells production, volcanic activity, and
165 ocean continental shelf, amongst others (e.g., Anthony, 2014). The exchange of beach sediment
166 between submerged and sub-aerial portions of the beach is accomplished by onshore-offshore
167 transport, mainly by waves, but aided sometimes by wind (e.g., Carter, 1988). Beach
168 morphology thus responds to changing wave conditions, and has a cyclic behaviour. In many
169 occasions, the cycles are seasonal; wave conditions during winter storms shift sand offshore,
170 whilst calm conditions during the summer induce landward migration of sediments back to
171 upper parts of the beach (e.g., Komar, 1976).
172 Important associations from this activity are the connection between atmosphere, ocean and the
173 coast, and the insight between casual observations that the students make, i.e., their empirical
174 knowledge of the coast, for example, breaking waves, beach width, sand grains, and the science
175 behind it.
176 The scientific content was divided into three major coastal hydrodynamic and morphodynamics
177 situations: wave generation and propagation, sediment transport and storm/fair-weather
178 conditions. Wind blowing on ocean surface and wave generation were explained not only to
179 elucidate how waves are generated but also to demonstrate the connection between separate
180 environments (atmosphere and the oceans). Wave propagation was used to illustrate energy
181 transference across the ocean surface, opposite to mass transference and to make the transition
182 from the ocean to the coastal environment, until waves break at the shore (Figure 3). The
183 generation of onshore currents under the presence of waves from the submerged to the sub-
184 aerial part of the beach was then introduced. Sediment transport by onshore currents was
185 explained as a straightforward effect, in the presence of grains in the bottom (lower block-
186 diagram and pink arrow on Figure 4). Here sediment variability, including shape, size and
187 composition, were introduced in relation to possible sources, such as volcanic rocks or coral
188 reefs.
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	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	

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

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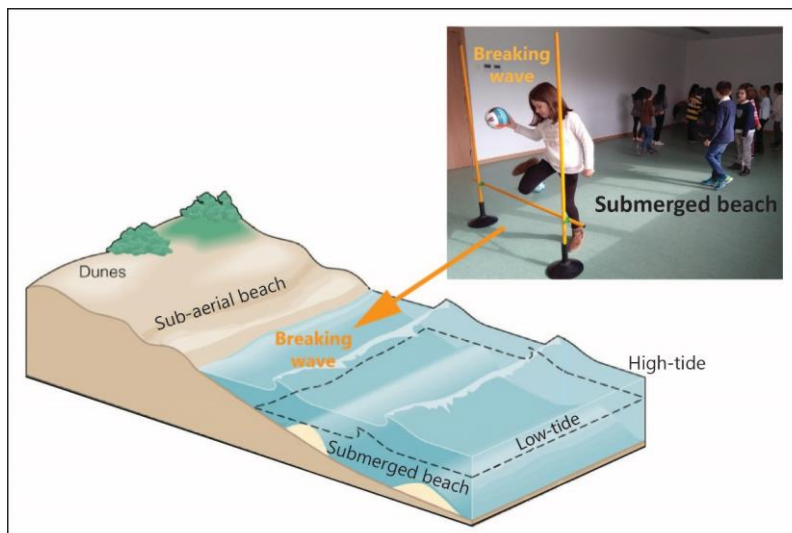


Figure 3

- 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”).

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Wave height variations throughout the year were explained by introducing the concept of storm waves and induced sediment transport patterns (upper block-diagram and pink arrow on Figure 4). Because onshore currents generated by fair-weather were explained, offshore currents 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.

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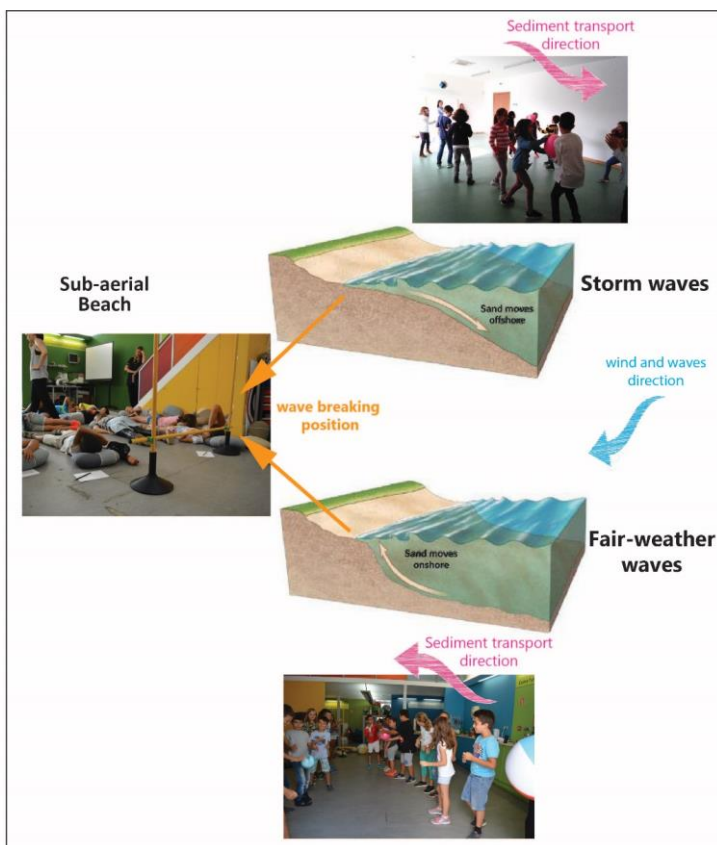
2.2. Storytelling and metaphors

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. 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

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221 between the psyche (mental processes) and motoric (physical activities). Typical psychomotor
 222 equipment (cf., European Forum of Psychomotricity, 2016) for children includes colourful
 223 hoops, balls, cones, mats, bags, blocks, and poles, that can be used isolated or as frames,
 224 tunnels, tracks, climbing sets or balancing courses.
 225 There were three main settings: the deep ocean, the beach under water and the sub-aerial beach
 226 (Figure 3). The limit of the sub-aerial and submerged beach, i.e., the wave breaking position
 227 was marked with two poles and a horizontal bar, while sediment balls of different sizes, colours,
 228 shapes and textures represented sediments (Figure 3). The settings/scenario of the action
 229 (marine and coastal environments) were also suggested by specific actions such as diving into
 230 the ocean (jump over the horizontal bar), imaginary application of sunscreen, and sunbathing
 231 (relaxation, Figure 4). Characters performed by students were beach users (scenes 1, 2 and 6,
 232 Figure 2) and water particles (scenes 3 to 5, Figure 2).
 233



234
 235 **Figure 4 - Coastal environments, coastal processes and metaphors. The image illustrates waves approaching**
 236 **the coast, coming from the right side (blue arrow). The direction of sediment transport (pink arrows on top of**

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237 photographs) was embodied by the direction of the hand-to-hand balls (representing sediment grains) passage
238 during storms (top right) and fair-weather (bottom right). The wave breaking position is represented in the
239 room by two yellow vertical poles + horizontal bar, with the sub-aerial beach towards the left hand-side (where
240 children are resting on the middle photograph).
241

242 The narrative consisted of a set of six practical actions (exercises) that were plotted in a
243 predefined sequence of increasing complexity and excitement (at the beginning of the activity),
244 with a sharp decline to relaxation (at the end of the activity), following the narrative arc (Figure
245 2). During scenes 1 and 2, an exposition to the theme and settings was conducted, obtained by
246 the verbal explanation of the beach topic and by suggesting a sequence of actions that mimic a
247 trip to the beach, finishing with the dive into the ocean; students (actors) embodied beach users.
248 From scenes 3 to 4 settings were kept, but characters were changed, and actors embodied water
249 particles, instead of beach users. The actions involved exercises of increasing complexity,
250 reflecting a rise in action, as they impersonated water particles of the sea surface and then water
251 particles as a current that transported grains to the shore. In scene 5, the climax was attained
252 when storm waves reached the coast in several moments, and sediments could move in opposite
253 directions. During scene 6, characters returned to beach users again; actors came out of the
254 ocean and sunbathed, in a falling action (Figure 2 and 4).
255

256 2.3 Creative dance structure

257 According to Gilbert (2015), creative dance is a dance form that combines the mastery of
258 movement with the artistry of expression. In creative dance, children generate, vary, and
259 manipulate movement by using the elements of dance through the process of improvisation
260 (Cone and Cone, 2012). The basic movement concepts used here derive from Laban Movement
261 Analysis. Rudolf Laban's (1897-1958) philosophy was based on the belief that the human body
262 and mind are one and inseparably fused (e.g., Newlove and Dalby, 2004). It was Laban's firm
263 belief that it is the birth right of every man to dance – not just trained dancers or folk dancers
264 and the like, but all human beings (Newlove and Dalby, 2004). Laban Movement Analysis is a
265 method to describe and analyse human movement and to establish a notation system with
266 precision and clarity (cf., Laban, 1963). Laban's ideas have been picked up, reinterpreted,
267 evolved and ramified, for example, to Dance Movement Psychotherapy (e.g., Best, 2008),
268 programmes for individuals affected by complex needs (e.g., Price, 2008) and creative dance
269 (e.g., Gilbert (2015). Structure and elements used here were also based on techniques described
270 by several dance educators (Landalf, 1997; Carline, 2011; Cone and Cone, 2012; Abbott, 2013;
271 Gilbert, 2015). The creative dance unit focused on the effort concepts of time (fast/slow), space
272 (direction), and flow (bond/free). A typical session of creative dance is composed of: 1)

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274 warming up; 2) Exploring the concept; 3) Developing skills; 4) Creating; and 5) Cooling down
275 (Gilbert, 2015).

276 During the first exercise (scene 1), applying sunscreen, there was a warm up of muscles and
277 mobilization of articulations through light aerobic movements, such as bending, twisting and
278 curling (see dance/movement on Figure 2). During the second exercise (scene 2), students
279 jumped over the obstacle (diving into the sea, Figure 3), in turns, and made swimming free
280 movements across the space. In the third exercise (scene 3), students stand in two lines facing
281 each-other, reproducing several waves with the body curling up, with arms up, in a cadence.

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282 The movement was repeated in a cadence of dance improvisation. During the fourth
283 exercise/scene, the two rows of students performed dance improvisation while passing different
284 balls (representing sediment transport) in the direction of the obstacle (the sub-aerial beach,
285 Figure 4), jumping to mimic breaking waves. In the fifth exercise/scene, students applied the
286 same type of movements than in the fourth exercise/scene, but listening a different soundtrack;
287 music changed in intensity and the balls moved to the obstacle when the music's intensity was
288 lighter and move in the opposite direction when the music was louder and more intense to
289 represent fair-weather waves and storm waves, respectively. During the sixth exercise/scene,
290 students spread through the available space and rested on the floor, while relaxing, and sensory
291 stimulation was induced by speech, appealing to sensations felt while sunbathing (sea smell,
292 warm on the skin, wind sensation, sand grains below the body).

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

299

300 3. "The Sea Rolls the Sand" activity implementation

301

302 3.1. Performing opportunities and institutional framework

303 The activity was performed six times, within national and international initiatives. During the
304 first two times, the sessions were included in the activity of the "European Researcher Night",
305 in September, 29th 2017. These sessions took place in the educational laboratory of the Tavira
306 Ciência Viva science centre, which was emptied as much as possible to create space for physical
307 activities. The other four sessions were included in a national initiative "Science and

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310 Technology Week”, on November 23th and 24th, 2017. These sessions took place at three
311 (private and public) schools, in the classrooms and in the gym.

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

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

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

328

329 3.2. Activity evaluation by participants

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

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

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

341 According to the inquiry’s responses, these children prefer to learn science through movement
342 and games, although field trips and laboratory experiments were also frequently selected
343 (20/112, Figure 5B). When questioned about how much they learned with the activity, 35%
344 answered they learned something new, and 60% answered they learned a lot, with 5% stating

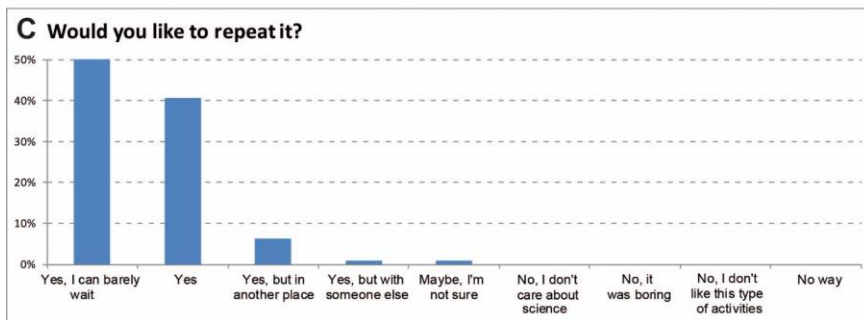
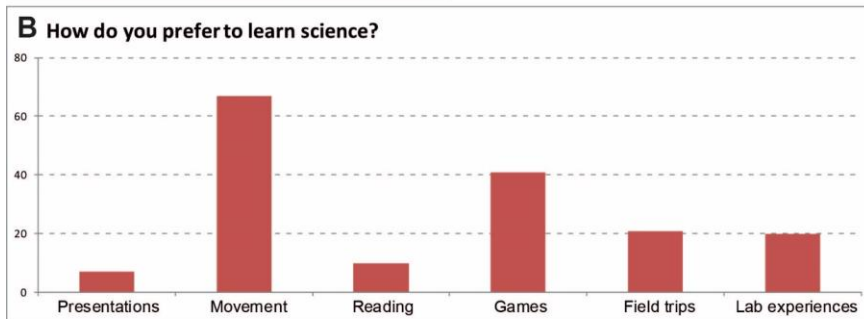
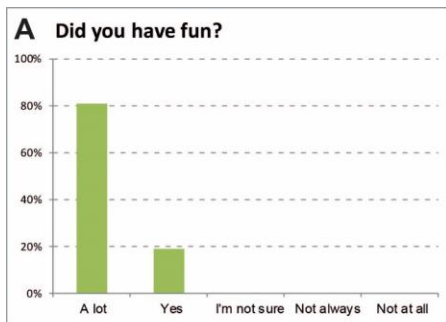
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346 they already knew everything. 99% of children want to repeat the activity, but 20% of the
 347 students from one of the schools **said**, they preferred to do it elsewhere (Figure 5C).
 348 The time constraints and the lack of personnel to assure children’s supervision did not allow a
 349 proper quantitative assessment of the schoolteacher’s opinions. Nevertheless, teachers expressed
 350 that “the activity was very nice and good for children this age”. Additionally, some teachers
 351 were concerned about some children’s inability to follow the scientific content, or not having
 352 appropriate behaviour all the time.
 353 The researcher conducting and researchers assisting the activity observed that these children,
 354 living in coastal areas, although having limited scientific background on coastal geology, have
 355 plenty of empirical experience on the coast.
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 358 **Figure 5 - Results of inquiries for some of the questions.**

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362 Note: for the question about how they prefer to learn about science, multiple responses were allowed, and the
363 vertical axis is the number of responses, not a percentage.

364

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

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

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

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

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

- 388 • The interdisciplinary solution seems to be adequate as a general approach to solving
389 complex issues; the complex issue here being a generalized disconnection between
390 students and geosciences. The appeal to conceptual understanding, rather than
391 memorization in geosciences (e.g. names of minerals and rocks, types of volcanoes, and
392 their location, names of geomorphological features) aligns with the most necessary
393 improvements in curricular guidelines identified by Afonso et al. (2013) for Portuguese
394 education of sciences. The storytelling technique of content sequencing versus a plain
395 sequence of contents look as a successful technique of engagement with the activity.
- 396 • The emotional involvement in the presence of music seems to effectively encourage
397 engagement, participation and willingness to take part in different experiences. Several

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401 positive emotions and feelings were promoted during the activity, evolving from
402 anticipation, pleasure, surprise, enjoyment, to excitement, and then serenity and
403 relaxation. The assessment of emotional states was based on local observations by the
404 persons conducting and assisting/observing, both directly and by revising photos and
405 videos. Observation notes included the record of facial expressions, silence/talk/laugh,
406 and body language (heads follow/not follow the person explaining, readiness/delayed
407 movement, peek/indifference, jumping and frenzy in anticipation/apathy, inertia or
408 yawn). It seems fair to suppose that the pleasant memories of the playful visits to the
409 beach evoked during the activity (vacations, playing, and freedom) became also
410 associated with science and learning. The movement and improvisation is effective in
411 creativity stimulation, self-expression and stress release, thus being aligned with the
412 21st-century educational orientations (as demonstrated by Cone and Cone (2012)).
413 Moreover, the activity is innovative, yet not supported by screens. During the early
414 stages of the activity, shy children tended to be reluctant to participate, very self-
415 conscious and consequently their movements are small. As the activity advanced, they
416 became more open and engaged with the proposed exercises.

- 417 • The activity was able to mitigate some student's exclusion factors. Inclusion of students
418 with diverse and special needs in the classroom has been a major focus in education
419 over the past 30 years (Villanueva et al., 2012). The children's layout in space (spread
420 or in two lines facing each-other), participating in chain sequencing, allows students
421 with some degree of impairment to engage in the activity. Additionally, the organization
422 of the activity for school classes, rather than an activity for families, assures the
423 presence of children that would not participate otherwise.
- 424 • The social benefits from this type of activity can potentially include team building and
425 students learn self-discipline, gain an appreciation for other movement styles, and
426 discover the value of individual differences through creative exploration and problem
427 solving. Socially, children enjoy interacting with others through movement (Cone and
428 Cone, 2012). They laugh and talk with each other while sharing an experience that is
429 fun and rewarding. The use of free (not choreographed) movements and balls can break
430 the stereotype of "dancing is for girls" thus promoting gender equality. These are values
431 identified in creative dance (e.g., Landalf (1997), Carline (2011), Cone and Cone
432 (2012)) that can be incorporated into science communication.
- 433 • A thorough evaluation of science communication initiatives is essential to enable the
434 identification of whether long-term objectives are being met, it can help to make the
435 iteration of science communication initiatives more efficient, and can also highlight
436 areas that need further strengthening (Illingworth, 2017). There was anecdotal evidence
437 of increased familiarity and comfort with geosciences (e.g., use of scientific

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441 terminology by students towards the end of the activity, processes introduced by
442 researchers in the exposition scenes were translated to actions by students on the climax
443 scene), which may have been the result of the brief explanation in the beginning of the
444 section, reinforced by the physical exercises. In this study, due to the sporadic nature of
445 the event, within a major event, it would be difficult to establish a baseline of children's
446 knowledge prior to the intervention. After this session, the same students were involved
447 in a science club devoted to topics of coastal geosciences, where experiences and a field
448 trip were made.

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

472 5. Final remarks

473 A science communication activity for primary-grade children, was developed and implemented
474 through an innovative approach, by combining coastal science concepts, with storytelling, and
475 creative dance techniques. The way scientific concepts were translated into the dance class
476 structure was described thoroughly, to allow science communicators the chance to look behind-
477 the-scenes of creative dance.

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

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491 The proposed activity has the potential to promote social inclusion of children with special
492 needs and physical impairment, as students with these impairments actively participated in the
493 activity in a positive way. The theme of social inclusion in the science communication field is
494 not new; the political value of science communication was explicit in many cornerstones of the
495 history of this field (Massarani and Merzagora, 2014). Nevertheless, the exclusion from science
496 communication activities is not only a statistical fact, but also a neglected matter in
497 communication research (Dawson, 2018).

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498 Regarding the activity impacts, inquiry results showed that all children seem to enjoy,
499 themselves. Nevertheless, the improvement of geoscience literacy was not measured. Yet,
500 science communication paradigms have shifted from science literacy (the 'deficit model') to
501 "Science and Society" (e.g. Bauer (2008)). This activity is aligned with the most recent
502 paradigms, where communication is interactive and constructive, with emphasis on dialogue,
503 deliberation, participation, and empowerment (Davies and Horst, 2016). It may contribute to the

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504 students "science capital" (as defined by Archer et al. (2015)) on the following dimensions: i)
505 Science-related attitudes, values and dispositions - because science was approached in an
506 enjoyable and engaging way, with potential to have increased openness to geosciences; ii)
507 Knowing science-related jobs - because both people conducting the activity were researchers
508 and were introduced that way at the beginning, iii) Making science relevant to the everyday
509 lives of students - because geoscience study objects are part of students' lives as coastal
510 inhabitants, very familiar with barrier islands; and iv) besides the potential for increased science
511 literacy (evidenced by the use of scientific terminology towards the end of the activity).

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512 Increased science capital or science literacy by this activity are suppositions based on qualitative
513 observations and suppositions; an effort to a more evidence-based science communication
514 approach (Jensen and Gerber, 2020) and subsequent evaluation is needed and this is a
515 shortcoming of this pilot programme.

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516 The addressed geoscience topics and other adopted art forms can be combined in future
517 activities in a number of ways: for example, we can foresee as adequate, innovative and
518 engaging, volcanology and music (e.g., types of volcanoes and volcanic rocks can be
519 approached by percussion instruments and rhythms); climate change and drama (e.g., impacts of
520 heat waves can inspire a play); and oceanography and poetry (e.g., waves and currents around

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530 the world can inspire poems). An existing case of geoscience and art is the work of the artist
531 Laura Moriarty (see <http://www.lauramoriarty.com/>) who combined plate tectonics and
532 sculpture (faults and bedding planes approached and appreciated as blocks of a sculpture). This
533 almost endless number of mishmashes, on top of the aesthetical value of earth-science objects,
534 from a desert landscape, to a mineral, a geyser, satellite imagery, a canyon, a rocky shore, just to
535 name a few, is an asset worthy of further exploration in **STEAM** science communication.

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537 **Competing interests.**

538 The authors declare that they have no conflict of interest.

539

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546 for the activity.

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