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1 **TEACHERS' PERSPECTIVES AND PRACTICES ON BIODIVERSITY WEB PORTALS**
2 **AS AN OPPORTUNITY TO RECONNECT EDUCATION WITH NATURE**

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11

12 **Summary**

13 Biodiversity loss is a complex issue, and a risk that education cannot overlook. Teachers
14 play a crucial role in how biodiversity, and in particular local biodiversity, is understood.
15 To provide insight on how to improve communication on the subject, we investigate
16 teachers' perspectives and social representations about biodiversity, their fluency on the
17 internet, familiarity with biodiversity web portals, and perceived technology pedagogical
18 usefulness. A sample of 243 K-12' school-teachers of multiple scientific domains, from
19 eight Azorean Islands answered an online survey, including three free-word association
20 tests using inductive terms such as 'internet', 'biodiversity' and 'familiar biodiversity
21 portals'. Overall, they failed to incorporate the multidimensionality of the biodiversity
22 concept (including natural science teachers), or show technological fluency, and tended
23 not to use biodiversity web portals as tools to engage students in teaching activities. Our
24 results indicate that teachers' perspectives about biodiversity need to be broadened and
25 improved, and that it is worth exploring whether ICT represents a window of opportunity
26 to do so. As an example, biodiversity web portals, widely recognized as trustworthy
27 information repositories, may be used to engage teachers in this endeavour.

28

29 *Keywords:* nature experience, place-based education, digital education, biodiversity
30 education, Azores, ICT, social representations, free-word association

31 INTRODUCTION

32 The loss of biodiversity, at all levels, including species extinctions and functional and
33 phylogenetic diversity erosion, can lead to a breakdown of ecosystems (IPBES 2019,
34 Rockström et al. 2009). The characteristics of this risk, including its high probability of
35 occurrence and potential damage, are well-known (Liu et al. 2015), but barely recognized
36 by the general public, possibly due to its complexity, ambiguity, and insidious nature
37 (Renn 2008).

38 Thus, effective communication of biodiversity loss to society is not as efficient in
39 comparison to other environmental problems such as climate change (Arroz et al. 2016).
40 Evidence of communication failure includes the poor progress on the 20 'Aichi Targets'
41 of the Strategic Plan on Biodiversity 2011–2020 of the Convention on Biological Diversity
42 (Díaz et al. 2019) and the need for the global coalition for biodiversity launched by the
43 European Commission in March 2020.

44 The lack of audibility regarding biodiversity loss has not been accompanied by research
45 on the reasons underling people's detachment from this issue or on understanding their
46 perspectives on biodiversity (but see Fischer & Young 2007; Dikmenli 2010), yet
47 individuals can use biodiversity with different scientific, political, and symbolic meanings,
48 depending on the context and timing; both knowledge and value associated with
49 biodiversity vary. Investigating people's perspectives on biodiversity, including their
50 arguments in order to be able to counter them, would thus allow expanding knowledge
51 and raising biodiversity awareness.

52 Education is key because it constitutes a beneficial instrument for conceptual change,
53 ensuring the development of skills and the confidence to protect biodiversity (Edison
54 2017). However, this effectiveness requires teachers' perspectives to be aligned with the
55 curricula and with national and international goals for biodiversity and nature
56 conservation. Although there is little research about teachers' perspectives on
57 biodiversity, teachers are aware of its inherent complexity and express concern about
58 biodiversity loss (Gayford 2000). Despite that, given time constraints of covering the entire
59 curriculum, teachers fail to seize opportunities to explore essential links on biodiversity,
60 which would enable students to relate knowledge and understanding with behaviours and
61 attitudes (Gayford 2000).

62 The disconnection between people and nature is considered one of four major challenges
63 in biodiversity education (Navarro-Perez & Tidball 2012), however, it is not limited to
64 school settings: due to its unpredictable consequences, this 'extinction of experience'
65 (Miller 2005, Gaston & Soga 2020), is an actual challenge for society.

66 The growing importance of technology has certainly contributed to withdrawal from nature
67 (Hasebrink 2009, Brennen & Kreiss 2016), and led to a concept of 'technological nature',
68 comprising the technologies that, in various ways mediate, augment, or simulate the
69 natural world (Kahn et al. 2009). However, the relationship between this technological
70 nature and 'real nature' is complex: the former can simultaneously displace and remove
71 space from the relationship with real nature (e.g. Pergams & Zaradic 2006), or constitute
72 an awareness tool for nature conservation and biodiversity loss (e.g. Selby & Kagawa
73 2018).

74 Thus, a new realm has emerged, between teaching young people and creating new
75 pedagogical opportunities that take advantage of digital information and interactive
76 communication technologies (ICT) (Navarro-Perez & Tidball 2012), since these are
77 particularly popular amongst the new generations (Kouper 2010). There has been an
78 increase in biodiversity education methods like experiential learning (Fattorini et al. 2017),
79 inquiry-based learning or place-based learning (Barnes et al. 2019), and digital
80 technologies connecting students to living environments (Yli-Panula et al. 2018). When
81 adjusted to teachers' and students' interests, ICT can enhance learning techniques
82 allowing effective and efficient communication skills, knowledge, and attitudes in support
83 of biodiversity conservation goals (Jacobson et al. 2006, Ferreira et al. 2015).

84 Little is known about the experiences of teachers as internet users and what they think
85 about it (but see Lagarto & Lopes 2018). For instance, there are several digital teaching
86 platforms for biodiversity (e.g. biodiversity4all [Inaturalist], Naturdata, Biodiversity
87 Learning Platform), but studies on their impacts on teaching and learning are scarce;
88 besides, the information sources provided by these platforms are not always validated
89 and updated. On the other hand, several biodiversity web portals play a central role in the
90 exchange of accurate information, mainly for cooperation and exchanging knowledge
91 among researchers (Borges et al. 2010). For instance, an Academic Google search on
92 'GBIF' returned 25 300 results, and on 'Atlas of Living Australia' 2 800, while the more
93 generic concept 'Biodiversity Portal' returned 690 results. When adding the term
94 'teaching' to each search, the number of citations fell to less than 10% of their original
95 values, the fall suggesting that portals represent a resource much-underused by the
96 educational community. We did not find any studies addressing biodiversity teaching

97 using web portals. The educational potential of web portals becomes even more evident
98 when local communities benefit from the existence of portals specialized in local
99 biodiversity, which can be mobilized for place-based learning and allow an efficient
100 dialogue between the digital and real 'versions' of biodiversity.

101 It is therefore relevant to understand how teachers in a region like the Azores value ICT
102 as a communication strategy, how comfortable they feel with digital tools, and how and if
103 they mobilize them in teaching biodiversity. We formulated the following research
104 questions: (1) How do teachers incorporate the ICT in their work? What are their thoughts
105 about the internet? And how do they use it? (2) How do teachers perceive biodiversity?
106 What aspects do they emphasize? What are their conceptual gaps? What helps explain
107 their representations? (3) To what extent are biodiversity portals a relevant tool for the
108 teaching-learning process? How do teachers envisage their usefulness and
109 contributions?

110

111 **METHODOLOGY**

112 *Study area and participants*

113 The Azores is a Portuguese archipelago located in the North Atlantic between 37°–40°N
114 and 25°–31°W. It consists of nine volcanic islands with 242,723 inhabitants, 122,300 of
115 whom are professionally active, 40% of them with a secondary or higher education degree
116 (SREA 2019). This region is known for its high biodiversity importance in the context of
117 the Macaronesia hotspot (Myers 2000; Borges *et al.* 2010).

118 From August to October 2019, 243 public school teachers (197 female; 43 male; 3
119 unknown gender), between the ages of 29 and 67 years (mean 46.2 SD ± 6.8 years), with

120 an average work experience of 22 years (SD \pm 7 years), working on eight Azorean islands,
121 completed an online survey (Table S1). About half of the participants (53%) were native
122 to the Azores (Table S1). This sample represents 6% of the total 4 635 Azorean teachers,
123 with significant differences of gender (3194 female; 1044 male; Chi^2 (1df) = 5.58; p
124 <0.002), age (49 ± 7.5 years; Chi^2 (3df) = 30.49; $p <1.09 \text{ E-}06$) and teaching experience
125 (18 ± 8 years; Chi^2 (5df) = 91.55; $p <3.18 \text{ E-}18$).

126 *Instrument and procedure*

127 The online survey by questionnaire (Appendix S0) comprised: (i) three free word
128 association tests regarding the inductive terms 'internet', 'biodiversity', and 'a familiar web
129 portal related to biodiversity and/or nature conservation' to reveal the cognitive structures
130 of the collective representations (Moscovici 1991, Abric 2003); (ii) 20 questions about the
131 use of ICT/internet and web portals as educational resources; (iii) the Nature Exposure
132 Scale (NES), a 5-point Likert-type instrument, from 1 (minimum) to 5 (maximum),
133 measuring the representations of 'direct physical and or sensory contact with the natural
134 environment' (Kamitsis & Francis 2013, p.137). The scale has four items: two assessing
135 exposure to nature in everyday life, and two in rich environments. The scale shows
136 acceptable psychometric qualities; Appendix S4); and (iv) nine socio-demographic
137 questions about age, gender, place of birth, residence, educational background, years of
138 teaching experience, teaching subject, teaching educational level, teaching school.

139 Upon approval of the study by the Azores University Ethics Committee, all teachers
140 working in Azorean public schools received a link to an anonymous Google Forms
141 questionnaire through an official e-mail by the Education Services.

142 *Data analysis*

143 Data were downloaded from Google Forms into an Excel file, and the resulting database
144 was exported to different software according to the data properties and the research
145 questions. All evocations were translated from Portuguese to English.

146 Descriptive statistical analysis was conducted for all nominal and ordinal variables; the
147 total sum of values was also calculated for NES scale.

148 The study used a multimethod approach to explore the free word association results in
149 order to identify the structure of social representations (SRs), deepen their understanding
150 and strengthen their validity (Abric 2003). The tests started with the analysis of the
151 'semantic field', calculating the indexes of Fluidity (total number of evocations; n_F),
152 Amplitude (number of different evocations; n_A) and Richness (ratio between them)
153 (Poelsch & Ribeiro 2010).

154 Data were also subject to a prototypical analysis (e. g. Vale & Maciel 2019) to reveal a
155 hypothetical organization of SR contents resulting in the division of evoked terms into four
156 quadrants, according to the crossover of frequency and order of evocation (Abric 2003):
157 the first quadrant, upper left, has words with high frequency and low evocation order, and
158 aggregates the central core of the SR; the second quadrant, upper right, has words with
159 high frequency and high evocation order, and completes and protects the SR core; the
160 third quadrant, lower left, has words with low frequency and evocation order, showing
161 possible alternatives to the core SR or complementing it; and the fourth quadrant, lower
162 right, has words with low frequency and high evocation order, exhibiting more transitional
163 elements. We calculated threshold values according to the recommendations of
164 Wachelke & Wolter (2011). The Ellegard's R_n index compares the resemblance between

165 the lexicons of two semantic fields organized by predictive variables (e.g. older vs
166 younger); it considers the number of words common to the two semantic fields, divided
167 by the square root of the product of the amplitude of the two fields, and varies from 0 to
168 1 (Di Giacomo 1986).

169 The same data were then subjected to a similarity analysis to test and consolidate the
170 SR. This analysis is based on graph theory and identifies the organization of the various
171 elements of the representation through the degree of connectivity between the evoked
172 terms, resulting in a maximum tree, which indicates the visual distribution of the different
173 sized categories and micro-categories, and their relationship with the core representation
174 (Alves-Mazzoti 2007).

175 Data of the free word association tests were processed using the freeware program
176 IRAMUTEQ (Ratinaud 2009, Camargo & Justo 2013).

177

178 **RESULTS**

179 ***How do teachers incorporate the ICT in their work? What are their thoughts about***
180 ***the internet? And how do they use it?***

181 Using 'internet' as an inductive term, the 243 teachers produced 1064 evocations, 239 of
182 which were different words, 213 repeated words; 123 words were mentioned only once
183 and thus disregarded from the analysis (Appendix S1).

184 The central core of the prototypical analysis of 'internet', corresponding to 51% of the total
185 evocations (Fig. 1a), revealed a kind of 'global information database', that people access

186 to search, communicate, and work with, individually or collaboratively, through Google,
187 social networks or e-mail. The contrast zone shows the risks associated with web surfing.
188 Most terms used by teachers tended to describe the 'what' and 'how' of the internet, while
189 their qualifying properties, such as 'fast', 'ease', 'fun' were distributed across the various
190 quadrants (Fig. 1a).

191 Fig. 1

192 Bearing in mind that the content of the central core of the prototypical analysis constitutes
193 only a hypothesis of the centrality of SR (Abric 2003), the subsequent similarity analysis
194 allowed us to understand the groupings and the organization of the various elements
195 identified, and thus to capture the meaning of the representation (Fig. 1b).

196 The word 'internet' elicited three groups or stars, centralized around the terms
197 'information', 'search' and 'knowledge' (Fig. 1b). 'Information' took the lead both in terms
198 of frequency and number of points of co-occurrence (*fc*, frequency of co-occurrence). A
199 series of terms revolved around 'information', even though its meaning is in close
200 relationship with 'communication'. The internet's global character, contents, means, and
201 risks associated with this repository and its sharing were emphasized. Furthermore, the
202 quality of the surfing experience was highlighted in an autonomous branch, congregating,
203 'speed', 'ease' and 'convenience'. Enjoying a strong co-occurrence with 'information'
204 (*fc*=39), the term 'search' was connected with different devices, including search engines,
205 social networks, and various applications. It related to the third star, 'knowledge' (*fc*=27),
206 that associated different ways to understand and experience the world: scientific, ludic
207 and virtual.

208 Our analysis shows a collective and homogeneous representation of the 'internet', since
209 we did not find significant differences with most tested predictors (Appendix S1).
210 However, natural science teachers and male teachers, in particular, produced higher
211 average numbers of words (Appendix S1).

212 The surveyed Azorean teachers were commonly using the internet: 216 (90%) more than
213 once a day and with multiple hardware ICT tools to access it (Fig. S1a), reflecting a routine
214 use of internet, which has most likely increased due to mandatory confinement and
215 telework after the pandemic of COVID-19.

216 Among teachers' activities performed online, there were two non-mutually exclusive
217 cores: one revealed a personal pattern of internet use, grouped around 'getting
218 information' (n=165), also comprising 'keep updated on the news' and 'keep in contact
219 with friends'; the other, revealed a professional pattern, aggregated around 'class
220 preparation' (n=168), and including 'social networking', 'file-sharing' or 'researching in
221 books and science texts'. The use of e-mail was common among almost all teachers
222 (96%) (Fig. S1b, 1c).

223 ***How do teachers perceive biodiversity? What aspects do they emphasize? What***
224 ***are their conceptual gaps? What helps explain representations?***

225 In a free-word association on the concept of 'biodiversity', 240 teachers mentioned 857
226 words, 90 of which were different. The evocation frequencies varied between one (35
227 single words) and 86.

228 The number of teachers' evocations concerning 'biodiversity' was much lower than that
229 relating to 'internet', although it remained quite homogeneous and weak (Table 1). The

230 amplitude of the semantic fields differed only according to gender (Chi^2 (1df) 17.65;
231 $p < 0.000$) and scientific teaching area (Chi^2 (1df) 18.41; $p < 0.000$), where male teachers
232 and teachers of exact and natural sciences showed greater erudition. The same groups
233 also showed significant differences in terms of fluidity, with female teachers (Chi^2 (1df)
234 5.82; $p < 0.05$) and teachers of other scientific areas (Chi^2 (1df) 5.06; $p < 0.05$) presenting
235 less extensive lexicons. Thus, the less rich – or more stereotyped – semantic fields were
236 associated with the same groups of teachers.

237 Ellegard's R_n index (cf. Table 1) comparing the degree of similarity between the semantic
238 fields of the tested predictors suggests that gender ($R_n = 0.19$) and use of web portals
239 concerning biodiversity ($R_n = 0.19$) differentiated information about biodiversity more than
240 any other predictor.

241 Table 1

242 The prototypical analysis revealed the content of the SR of biodiversity for the 234
243 Azorean teachers, presenting a descriptive central core mentioning 'diversity', 'life' and
244 'nature'. Among the three levels of the concept recognized by the Convention on
245 Biological Diversity (CBD), the focus was on the specific level (e.g. fauna, flora, species),
246 while the genetic and ecosystem levels were practically absent (Fig. 2a; Appendix S2).
247 Complementing the central core there was also the recognition of the need of
248 environmental conservation, underlined by terms such as 'risk', 'planet', 'preservation'
249 and 'sustainability'.

250 Fig. 2

251 The first periphery quadrant shows the terms 'ecosystems' and 'equilibrium',
252 supplementing the specific level with the relationships among living beings (Fig. 2a). The
253 contrast zone focused on the geographical context – the Azores, a biodiversity hotspot,
254 and its 'endemic species'. Furthermore, it contained evocations about the scientific
255 background of biodiversity ('sciences', 'biology'). It is noticeable that 'birds' are the only
256 taxonomic class mentioned (Fig. 2a). The recognition that biodiversity is crucial for the
257 'survival' and the 'future' of 'humankind' emerged only in the second periphery that
258 aggregates the terms evoked fewer times and with lower evocation orders (Fig. 2a).

259 The similarity analysis of the same lexicon revealed three clusters, represented by nature
260 preservation, ecosystem diversity, and fauna and flora, all bearing strong co-occurrence
261 links ($fc=24$ and $fc=28$, respectively) (Fig. 2b). The 'diversity' cluster had the highest
262 number of co-occurrence' links. The metaphor that emerged from the semantic
263 relationship between the terms that composed it leads us to a global ecosystem, Gaia,
264 which encompasses not only the species and their habitats but also the knowledge
265 produced about them and the need to ensure life sustainability (Fig. 2b). In the second
266 cluster, the main idea was the preservation of nature and the environment, given human
267 responsibility to ensure the necessary balance for species and planetary survival (Fig.
268 2b). The third cluster was more focused on elements such as living beings, their habitats
269 and resources needed. However, there were no evident relationships among them, hence
270 the link between these elements and the second cluster, since it connected with 'nature'
271 and not with ecosystems' relationships (Fig. 2b).

272 For the first cluster, biodiversity was 'Gaia'. For the second cluster, biodiversity was a
273 natural heritage to be preserved, while in the third cluster, biodiversity was the set of living
274 beings and their habits (Fig. 2b).

275 ***To what extent are biodiversity portals relevant tools for the teaching-learning***
276 ***process? How do teachers envisage their usefulness and contributions?***

277 About two thirds of the teachers (67%) were using different portals to prepare classes,
278 and more than three quarters (79%) were doing so during classes. Although only six of
279 the 82 spontaneously mentioned portals were related to biodiversity and/or nature
280 conservation, when asked to select portals they knew from a list including ten portals
281 concerning Azorean biodiversity, about half of the teachers (n=125) selected at least one,
282 although more than half selected only one or two portals (2.7 portals in average). The
283 teachers that use biodiversity portals are a small subset of the ones that have heard about
284 them.

285 To characterize the perspectives about biodiversity portals, these teachers provided 376
286 response terms, including 150 different words, with an average of 3.1 words per teacher
287 (Appendix S3).

288 The evocations that constituted the central core of the prototypical analysis focused on
289 generic content, evident on any biodiversity platform; the descriptive contents were
290 frequently associated with portals. The contrast zone combined both the purposes and
291 experience of portal usage. Although it is not common to include user experience in the
292 dominant depictions of biodiversity portals, usage was qualified as positive and
293 accessible. Aspects associated with the evaluation of usability, quality, and certification

294 of portals contents represented 19.7% of the evocations. References to portals as
295 repositories of resources and educational activities were less frequently expressed
296 (11.5%) (Appendix S3).

297 From the similarity analysis, four complementary clusters emerged (Fig. 3b). The term
298 'nature' led the content of the portals related to 'biodiversity', associated in turn with a
299 small cluster of content with a more regional bent (Fig. 3b). A cluster related to the
300 purpose of the portals grouped terms associated with what the portals are for and what
301 they can be used for (Fig. 3b). The cluster led by 'information' represented the type and
302 characteristics of the available contents, moving from the theme of biodiversity to more
303 functional aspects related to accessibility and other attributes of the available knowledge.
304 The fourth cluster specified the evaluation of the portals' contents as a quality resource
305 (useful, updated information, easy to access), although in low frequencies (Fig. 3b).

306 There were significant absences in the evocations regarding the instrumentality of portals
307 for teaching, which is corroborated by teachers' incipient use of the portals (Fig. 3a).

308 Fig. 3

309 When explicitly asked about the type of use teachers make of portals, it is clear that they
310 used them more as a repository of audio-visual (33.5%) and pedagogical (14.9%)
311 resources or specialized information (taxonomic [9.3%], ecological [19.1%], etc.) than as
312 a tool to engage students in teaching activities (14.9%) meant to foster scientific research
313 skills (Table S2a, Fig. S2b).

314 The biodiversity portals were not perceived as being identical nor did they enjoy the same
315 popularity among teachers. The five most referred portals were, in descending order and

316 with frequencies above 14: PARQUESAZ, SIARAM, PBA, REDA and EDUCARAZ (cf.
317 Table S2c). Considering the percentage of evocations related to each portal,
318 PARQUESAZ presented the highest instrumental value due to the available resources
319 (15%), while SIARAM and REDA were, respectively, the portals where quality and
320 usability were more often highlighted (22% each).

321 The content highlighted for SPEA and PBA portals referred to information, , and in the
322 latter its scientific origin; for SIARAM it was regional biodiversity that stood out; for REDA
323 resource diversity and accessibility were emphasized, while the terms 'conservation' and
324 'environmental protection' emerged for EDUCARAZ. The attributes assigned to the
325 PARQUESAZ portal exhibited less homogeneity (Fig. S2d).

326 Descriptive statistics show that the biodiversity portals' users among Azorean teachers
327 did not significantly differ from the teachers that did not use them (χ^2 (1df)= 0.22;
328 $p < 0.63$; Table S3).

329

330 **DISCUSSION**

331 Teachers showed greater fluidity and terminological diversity for the 'internet' ($n_F=1064$;
332 $n_A=240$) than for the 'biodiversity' ($n_F=857$; $n_A=90$) stimulus, suggesting that the latter is
333 less accessible to individual consciousness and a more peripheral phenomenon in their
334 social groups. Curiously, the same trend is seen among teachers of exact and natural
335 sciences ($n_F=217$; $n_A=96$ vs. $n_F=176$; $n_A=52$), despite their specific domain training.

336 Teachers' visions of biodiversity share some common points with the long-established
337 definition of the concept (CBD 1992), although most focus only on the species dimension.

338 An incomplete understanding of biodiversity has also been acknowledged by Dikmenli
339 (2010), when studying the conceptual framework of biodiversity on 130 biology training
340 teachers, who however exhibited a more varied and technical lexicon. The
341 multidimensionality of the biodiversity concept is more evident among the training
342 teachers, who included genetic diversity, technological terms, and major scientists, which
343 are absent in our data. Even more sophisticated views on biodiversity were found by
344 Fischer & Young (2007), focusing on notions of balance, food chains and human–nature
345 interactions, and showing desirable or ideal states of nature. This may be related to
346 different methodological devices used, such as focus group discussions and drawings.
347 The diversity of the participants may also have contributed to that conceptual richness.
348 Yet, more than in the previous studies, our results incorporate the ideas of conservation
349 and extinction risk, even if only in the contrast zone, as well as an idea of interdependence
350 between biodiversity and the future and well-being of humanity.

351 Reviews on biodiversity teaching methods (Navarro-Perez & Tidball 2012, Yli-Panula *et*
352 *al.* 2018) do not mention strategies focusing on the digital realm; instead, the most
353 common pedagogical methods involve active participation, including experimental work
354 and experiential learning. ICT certainly poses a set of challenges concerning biodiversity
355 teaching. Biodiversity web portals, as sound scientific tools, could link research and
356 teaching, and their contents may support learning, particularly on islands. Additionally, as
357 online free tools, biodiversity web portals are resources easily accessible to both teachers
358 and students, thus serving as mediating instruments between the environment and the
359 quest for knowledge (Flavian 2019). Still, our data reveal that teachers use biodiversity
360 portals mainly to search for images and other audio-visual content. To further clarify the

361 role web portals may play towards biodiversity education in schools, and ultimately
362 towards biodiversity conservation, the relationship between technology and nature needs
363 further reflection.

364 Considering that the 'extinction of experience' with nature is fast approaching (Miller 2005,
365 Gaston & Soga 2020), we wonder: can ICTs mediate connection and reconnection with
366 the natural world? Although the positive impacts of technological nature on cognitive
367 functioning and human wellbeing are well documented (Kahn *et al.* 2009), whether
368 'technological windows' can reconnect people with nature is still under debate.

369 The dominant view is that 'technological nature' opposes and replaces experiencing 'real
370 nature' in person and *in loco* (Pergams & Zaradic 2006). However, with or without
371 technology, a departure from 'real nature' has already been witnessed. If nature and the
372 internet are useful parts of our daily lives, and if nature does not have to be close to be
373 valued (Clayton 2003), why not take advantage of ICT to promote the connection and
374 reconnection?

375 Facilitating this type of scenario involves dealing with the problems/limitations identified
376 by research on technological nature (Kahn *et al.* 2009). One of the most relevant caveats
377 regarding technological nature is the lack of differentiation between global and local
378 geographic scale, in the sense that, when experiencing nature through technological
379 windows, people become equally close (Selby & Kagawa 2018). It is therefore worthwhile
380 exploring if biodiversity portals with regional contents may address this risk. Indeed,
381 although we might observe local biodiversity through a technological window, portals may
382 promote nature relatedness via 'zoom lens' allowing a glimpse into an unknown world just
383 in our backyards (Amorim *et al.* 2016).

384 Given that ICT has the potential to reshape human existence by mediating, increasing or
385 simulating the natural world, biodiversity web portals may constitute relevant tools to raise
386 biodiversity awareness, and even to promote biophilia. However, our data showed that
387 teachers did not acknowledge much usefulness of biodiversity portals.

388 Portal managers should therefore create, enhance and promote specific pedagogical
389 resources, closely related to school curriculums, and to increase the portals'
390 instrumentality. Thus, to meet teaching and learning needs, resources should emerge
391 from multidisciplinary projects involving teachers, students, scientists and science
392 communicators (Novacek 2008). Furthermore, the development of such pedagogical
393 resources should take into account the importance of message 'crafting', according to
394 people's values and interests, to achieve effective engagement (Coffin & Elder 2005).

395 Our data show that teachers do not acknowledge many of the dimensions of the
396 biodiversity concept, it also shows that they attribute importance to conservation, and are
397 proficient internet users. Web portals may thus provide teachers with an effective link
398 between the internet and biodiversity, even more given that half of the surveyed teachers
399 are already familiar with several biodiversity portals.

400 Biodiversity communication in the learning-teaching process must adapt to societal trends
401 and emerging potentialities within ICT. Biodiversity web portals are an example of this
402 potential that has not been fully explored in education and could ultimately help halt
403 biodiversity loss.

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409

410 Author contributions

411 AP, AMA and RG led the writing of the manuscript and performed data analyses. All
412 authors contributed substantially through additions and revisions to the text and gave final
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414

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422

423 Conflict of interest

424 None.

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427 REFERENCES

428 Abric JC (2003) La recherche du noyau central et de la zone muette des représentations
429 sociales. In: *Méthodes d'étude des représentations sociales*, ed. JC Abric, pp. 59-80.
430 Toulouse, France: ERES.

431 Alves-Mazzotti A (2007) Representações da identidade docente: uma contribuição para
432 a formulação de políticas. *Ensaio: Avaliação e Políticas Públicas em Educação* 15: 579-
433 594.

434 Arroz AM, Gabriel R, Amorim IR, São Marcos R, Borges PA (2016) Bugs and society I:
435 Raising awareness about endemic biodiversity. In: *Biodiversity and Education for
436 Sustainable Development*, eds. P Castro, UM Azeiteiro, P Bacelar-Nicolau, W Leal Filho,
437 AM Azul, pp. 69-89. Switzerland: Springer International Publishing.

438 Amorim IR, Arroz AM, São Marcos R, Borges PA, Gabriel R (2016) Bugs and society II:
439 testing two communication strategies for public engagement in the Azores. In: *Biodiversity
440 and Education for Sustainable Development*, eds. P Castro, UM Azeiteiro, P Bacelar-
441 Nicolau, W Leal Filho, AM Azul, pp. 125-153. Switzerland: Springer International
442 Publishing.

443 Barnes MA, Cox RD, Spott J (2019) Place-based learning with out-of-place species &
444 students: teaching international students about biological invasions. *The American
445 Biology Teacher* 81: 503-506.

446 Borges PA, Gabriel R, Arroz AM, Costa A, Cunha RT, Silva L, Cardoso P et al. (2010)
447 The Azorean Biodiversity Portal: an internet database for regional biodiversity outreach.
448 *Systematics and Biodiversity* 8: 423-434.

449 Brennen JS, Kreiss D (2016) Digitalization. In: *The International Encyclopedia of
450 Communication Theory and Philosophy*, eds. KB Jensen, EW Rothenbuhler, JD Pooley,
451 RT Craig, pp. 556-566. Chichester, UK: Wiley-Blackwell.

452 Camargo BB, Justo AM (2013) IRAMUTEQ: Um software gratuito para análise de dados
453 textuais. *Temas em Psicologia* 21: 513-518.

454 Coffin C, Elder J (2005) Building public awareness about the effects of sprawl on
455 biodiversity. In: *Nature in Fragments: The legacy of Sprawl*, eds. EA Johnson, MW
456 Klemens, pp. 335-348. Chichester, New York: Columbia University Press.

457 Clayton S (2003) Environmental identity: A conceptual and an operational definition. In:
458 *Identity and the Natural Environment*, eds. S Clayton, S Opatow, pp. 45-65. Cambridge,
459 Massachusetts: MIT Press.

460 Díaz S, Settele J, Brondízio ES, Ngo HT, Agard J, Arneth A, et al. (2019) Pervasive
461 human-driven decline of life on Earth points to the need for transformative change.
462 *Science* 366: 6471.

- 463 Dikmenli M (2010) Biology student teachers' conceptual frameworks regarding
464 biodiversity. *Education* 130: 479-489.
- 465 Di Giacomo JP (1986) Alliances et rejets intergroupes au sein d'un mouvement de
466 revendication. In: *L'étude des représentations sociales*, eds. W Doise, A Palmonari.
467 Neuchâtel: Delachaux et Niestlé.
- 468 Edison LK, Pradeep Kumar S, Pradeep NS (2017) Educating Biodiversity. In:
469 *Bioresources and Bioprocess in Biotechnology*, eds S Abdulhameed, N Pradeep, S
470 Sugathan, pp. 143-165. Singapore: Springer International Publishing.
- 471 Fattorini S, Gabriel R, Arroz AM, Amorim IR, Borges PAV, Cafaro P (2017) Children
472 preferences for less diverse green spaces do not disprove biophilia. *PNAS - Proceedings*
473 *of The National Academy of Sciences* 114: E7215.
- 474 Ferreira MJ, Moreira F, Santos-Pereira C, Durão N (2015) The role of mobile technologies
475 in the teaching/learning process improvement in Portugal. In *The 8th Annual International*
476 *Conference of Education, Research and Innovation*. Sevilha, Espanha, Pp. 4600–4610,
477 from 17th to 18th November.
- 478 Fischer A, Young JC (2007) Understanding mental constructs of biodiversity: implications
479 for biodiversity management and conservation. *Biological Conservation* 136: 271-282.
- 480 Flavian H. (2019) *Mediation and Thinking Development in Schools: Theories and*
481 *Practices for Educators*. Israel: Emerald Publishing Limited
- 482 Gaston KJ & Soga M (2020) Extinction of experience: The need to be more specific.
483 *People and Nature* 00: 1–7.
- 484 Gayford C (2000) Biodiversity education: a teacher's perspective. *Environmental*
485 *Education Research* 6: 347-361.
- 486 Gomes MAC (2012) Educação para o Desenvolvimento Sustentável no contexto da
487 década: discursos e práticas no ensino básico. Unpublished Master thesis, Lisboa:
488 Universidade de Lisboa.
- 489 Hasebrink U, Livingstone S, Haddon L, Ólafsson K (2009) Comparing children's online
490 opportunities and risks across Europe: Cross-national comparisons for EU Kids Online.
491 LSE, London: EU Kids Online. [www document] URL <http://eprints.lse.ac.uk/21656/>
- 492 IPBES–Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem
493 Services. *Summary for Policymakers of the Global Assessment Report of the*
494 *Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*.
495 IPBES Secretariat.
- 496 Jacobson SK, McDuff MD, Monroe MC (2006) *Conservation education and outreach*
497 *techniques*. New York, Oxford University Press.
- 498 Kahn Jr PH, Severson RL, Ruckert JH (2009) The human relation with nature and
499 technological nature. *Current Directions in Psychological Science* 18: 37-42.

500 Kamitsis I, Francis AJ (2013) Spirituality mediates the relationship between engagement
501 with nature and psychological wellbeing. *Journal of Environmental Psychology* 36: 136-
502 143.

503 Kouper I (2010) Science blogs and public engagement with science: Practices.
504 challenges. and opportunities. *Journal of Science Communication* 9: A02.

505 Lagarto JR, Lopes MDL (2018) Digital literacy teachers of the 2nd and 3rd cycles of Viseu
506 (Portugal) County schools. *Revista Brasileira de Educação* 23.

507 Liu J, Mooney H, Hull V, Davis SJ, Gaskell J, Hertel T *et al.* (2015) Systems integration
508 for global sustainability. *Science* 347: 1258832.

509 Miller JR (2005) Biodiversity conservation and the extinction of experience. *Trends in*
510 *Ecology & Evolution* 20: 430-434.

511 Moscovici S (1991) La nouvelle pensée magique. *Bulletin de Psychologie* 45: 301-324.

512 Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity
513 hotspots for conservation priorities. *Nature* 403: 853–858.

514 Navarro-Perez M, Tidball KG (2012) Challenges of biodiversity education. *International*
515 *Electronic Journal of Environmental Education* 2: 13-30.

516 Novacek MJ (2008) Engaging the public in biodiversity issues. *Proceedings of the*
517 *National Academy of Sciences* 105: 11571-11578.

518 Pergams OR, Zaradic PA (2006). Is love of nature in the US becoming love of electronic
519 media? 16-year downtrend in national park visits explained by watching movies, playing
520 video games, internet use, and oil prices. *Journal of Environmental Management* 80: 387-
521 393.

522 Poelsch G, Ribeiro R (2010) Ancoragens e variações nas representações sociais da corrupção.
523 *Análise Social* 196: 419-445.

524 Ratinaud P (2009). IRAMUTEQ: Interface de R pour les Analyses Multidimensionnelles
525 de Textes et de Questionnaires [Computer software]. Retrieved from
526 <http://www.iramuteq.org>

527 Renn O (2008) *Risk Governance, Coping with uncertainty in a complex world*. London:
528 Earthscan.

529 Rockström J, Steffen W, Noone K, Persson Å, Chapin III FS, Lambin E, Nykvist B *et al.*
530 (2009) Planetary boundaries: exploring the safe operating space for humanity. *Ecology*
531 *and Society* 14.

532 Selby D, Kagawa F (2018) Archipelagos of learning: Environmental education on islands.
533 *Environmental Conservation* 45: 137-146.

534 SREA—Serviço Regional de Estatística dos Açores (2019) Anuário Estatístico da Região
535 Autónoma dos Açores. Serviço Regional de Estatística dos Açores. [www document] URL
536 <https://srea.azores.gov.pt/>

537 Vale SFD, Maciel RH (2019). The structure of students' parents' social representations of
538 teachers. *Trends in Psychology* 27: 265-278.

539 Wachelke J, Wolter R (2011) Critérios de construção e relato da análise prototípica para
540 representações sociais. *Psicologia: Teoria e Pesquisa* 27: 521-526.

541 Yli-Panula E, Jeronen E, Lemmetty P, Pauna A (2018) Teaching methods in biology
542 promoting biodiversity education. *Sustainability* 10: 3812.

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546 Word count: 5530.

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548 **Fig. 1** Prototypical analysis of the inductive term 'internet': **(a)** four-box matrix. EO = evocation order; *F* =
549 frequency; **(b)** maximum tree of a similarity analysis of the most frequent evocations (N=243 teachers;
550 2019). Line thickness and numbers correspond to frequency of co-occurrence; circle size corresponds to
551 word frequency, circle colour indicates evocation order similarity clusters.

552 **Table 1** Data on the evocations for the inductive term 'biodiversity' (n=243); NES, nature exposure scale.

553 **Fig. 2.** Prototypical analysis of the inductive term 'biodiversity' categorized: **(a)** four-box matrix. EO =
554 evocation order; *F* = frequency; **(b)** maximum tree of a similarity analysis of the most frequent evocations
555 (N=234 teachers; 2019). Line thickness and numbers correspond to frequency of co-occurrence; circle size
556 corresponds to word frequency, circle colour indicates evocation order similarity clusters.

557 **Fig. 3.** Prototypical analysis of the inductive term 'web portals related to biodiversity': **(a)** four-box matrix.
558 EO = evocation order; *F* = frequency; **(b)** maximum tree of a similarity analysis of the most frequent
559 evocations (N=117 teachers; 2019). Line thickness and numbers correspond to frequency of co-
560 occurrence; circle size corresponds to word frequency, circle colour indicates evocation order similarity
561 clusters.