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### Teachers' perspectives and practices on biodiversity web portals as an opportunity to reconnect education with nature

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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;  $\text{Chi}^2$  (1df) = 5.58;  $p$   
124  $<0.002$ ), age ( $49 \pm 7.5$  years;  $\text{Chi}^2$  (3df) = 30.49;  $p <1.09 \text{ E-}06$ ) and teaching experience  
125 ( $18 \pm 8$  years;  $\text{Chi}^2$  (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 ( $\text{Chi}^2$  (1df) 17.65;  
231  $p < 0.000$ ) and scientific teaching area ( $\text{Chi}^2$  (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 ( $\text{Chi}^2$  (1df)  
234 5.82;  $p < 0.05$ ) and teachers of other scientific areas ( $\text{Chi}^2$  (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 ( $\chi^2$  (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

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546 Word count: 5530.

547

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.