**“How might everyday experiences shape biodiversity
understanding? A perspective to spark new research”**

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1. Abstract

In this perspective article we start from the theories of constructivism and conceptual change within the field of education to develop and present hypotheses about how understandings of biodiversity and diversity more generally are formed. We argue that extrinsic and circumstantial elements from everyday experiences are relevant in shaping understandings of biodiversity.

We discuss how children's games and food-related experiences may influence how children form conceptions of biodiversity. We focus on 'misconceptions,' areas where conceptions differ from established ideas in ecology. These include: underestimating the importance of diversity for "complementarity" and over-simplifications of how nature works. Firstly, we examine a type of children's game that often concerns biodiversity and consists of a puzzle where the forming of categories is encouraged. Secondly, we discuss people's relation to nature through food in their diets.

We believe that targeted intervention is needed to move towards an inclusive and multi-faceted representation of biodiversity, one that emphasises fundamental properties that make a whole and interacting parts. We argue that experiences of games and food can be pivotal in developing a deeper understanding of these fundamental properties of biodiversity. These would be important experiences to consider when attempting transformative change of relationships between people and nature.

Keywords: diversity, biodiversity attitudes, food experiences, children's games, environmental education

2. Introduction

We start from an understanding of biodiversity developed in the environmental sciences and adopted in national and international environmental policy. The UN Convention on Biological Diversity defines biodiversity as the variety and number of living organisms in the world or in a particular habitat, including humans (Convention on Biological Diversity, 2010; Magurran, 2004). We acknowledge that this definition only represents one of multiple perspectives on biodiversity (and therefore is limited in scope), likely biased by our upbringing as WEIRD (western, educated, industrialized, rich and democratic) authors (Heinrich, 2010). Biodiversity plays an important role in ecosystem functioning and adaptation to change (Cardinale et al., 2012; Duffy, 2009). Tackling the global biodiversity decline often requires the involvement of people in decision making that are not biodiversity scientists (Johnson et al., 2017, Michel & Backhaus 2019). The notions people have about biodiversity have been shown to affect their support of biodiversity management measures (Buijs, Fischer, Rink, & Young, 2008, Hooykaas et al., 2020). It is relevant to ask how the concept of biodiversity develops in lay people, a study that would be within the scope of environmental education (Kassas, 2002). Here we formulate the question as follows: how do every day experiences shape people's notions of biodiversity?

Throughout this paper we refer to “diversity” when we talk about a group of different elements that are not biological and to biodiversity when the group contains biological elements (usually organisms). Humans can perceive biodiversity using all their sensory organs, through aspects such as diversity of colours, shapes, sounds, and tastes. For early humans, experiencing biodiversity meant understanding, for example, which species they could eat and which were poisonous, or which could be used as medicine, a valuable asset for survival

(Oksanen & Pietarinen, 2004). There is practical value in being able to derive information about biodiversity from everyday life experiences. In his works on ethnobiology, Berlin (1992) tells of the large and specific knowledge contained in traditional, non-literate societies of many parts of the world, on plant and animal classifications. Many of these systems of classification are comparable to or better in depth and accuracy than scientific taxonomy (Atran et al., 2002).

While some children grow up immersed in knowledge about plant and animal species, many learn about biodiversity from secondary sources, which could also lead to misconceptions. Since biodiversity is a term that was coined in the scientific realm, for the purpose of this perspective, we speak of “misconceptions” in cases of beliefs, views and opinions that are inconsistent with the science-based worldview underlying most national and international environmental policy documents. For us--authors with an academic background--background--narratives, stories and other lay people’s accounts of biodiversity have an educational value to convey the scientific concept of biodiversity, as long as they are consistent with it. We do, however, acknowledge that in other contexts (e.g., religious rituals) different notions of biodiversity are very important and equally valid (and often the different notions are connected, see e.g. Frascaroli et al. 2014).

According to constructivist theories in education, misconceptions can emerge from everyday experiences and also from inaccurate, incomplete or incorrect teaching (Coley & Tanner, 2012). Such misconceptions can, for example, be based on the idea that correlation implies causation or the misunderstanding that humans evolved from monkeys. A common misconception regarding biodiversity is, for example, to think that people and other species should not or cannot coexist in urban spaces; that each needs their separated space to thrive. This misconception is particularly held by people that live in urban spaces and have only

87 learned about conservation projects as being valid and useful in pristine areas, such as national
88 parks (Soanes et al., 2019). In education, misconceptions can be regarded as a normal part of
89 the learning process; but they need to be identified and addressed in order to lead a learner
90 through a conceptual change process towards a more accurate understanding (Moore et al.,
91 1990).

92 Environmental cognition is concerned with the way we learn about the environment,
93 including how small children understand the environment that surrounds them (Palmer et al.,
94 1996). Numerous misconceptions in children about different aspects of biology have been
95 identified but little attention has been given in particular to the concept of biodiversity (Coley
96 & Tanner, 2012). Identifying misconceptions, their origin and their associations early is
97 important to develop a more accurate and effective curriculum that gives the correct tools to
98 people involved in education. In the absence of a conceptual change, some misconceptions
99 may result in detrimental decisions. For example, misconceptions regarding how the immune
100 system works are one of the cited causes for parents to not vaccinate their children against
101 some diseases, increasing their own vulnerability and that of their community (McKee and
102 Bohannon, 2016). We suggest that there is scope and need for research into whether
103 misconceptions regarding biodiversity and its functional significance exist, how they are
104 created, and how they may be appropriately addressed. More specifically, we develop and
105 describe (but do not test here) the hypothesis that many experiences of daily life activities
106 regarding a) children's games and b) food cooking and eating may be relevant to how people
107 form notions around the concept of biodiversity.

108 The general aim of this article is to propose a perspective on how biodiversity
109 understanding could be shaped by informal experience, to raise awareness of the current lack
110 of research in this realm, and to present hypotheses that could promote dialogue and spark

further research. We use two examples to illustrate our perspective: 1) children's games with representations of organisms and 2) contents of people's diets. In both examples, experiences can help or hinder people's understanding of how biodiversity matters for the maintenance of a healthy environment and can help people to reconnect with the biodiversity that is near them. All of our hypotheses are largely untested, and we do not here present tests of them. Furthermore, it is beyond the scope of the paper to refer to the generality of particular misconceptions across all social and cultural contexts. We hope to spark a debate and further research in this direction.

2.1. How do people learn new concepts?

We explored the application of a constructivist approach in education (Piaget, 1953; Vosniadou, 2007; Vygotsky, 1978) to how the personal understanding of biodiversity is formed. In this learning theory, new knowledge builds upon prior knowledge and is constructed through experiences and discoveries, according to a learner's developmental stage (Piaget, 1953). Culture and language play an important role in how this process occurs and its outcome, through limiting the type of experiences that the learners are exposed to and through the impressions that the tutors imprint on the learning process (e.g., values, beliefs) (Vygotsky, 1978). A large body of research by cognitive psychologists and developmental researchers demonstrates that children develop many concepts from their experience of nature (Busch et al., 2018; Waxman & Medin, 2007).

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134 ----- Beginning of Box 1

135 **Box 1: What is *biodiversity*?**

136 The definition of biodiversity as the “diversity of living forms” encompasses, perhaps
137 inadvertently, the definition of what diversity in general is. We define the concept of
138 biodiversity for the present perspective in the following way (Figure 1):

- 139 • Understanding biodiversity implies understanding the unique aspects of interacting
140 elements, as much as the aspects shared with other elements (their degree of
141 similarity),
- 142 • The concept of biodiversity is tightly linked with the concept of inclusion since we
143 can only define a group of elements as diverse, when they are all part of that group.

144 The degree of similarity between elements of a group depends on the type and number of
145 dimensions in which we choose to describe it. Hence, characterizations of biodiversity will
146 always show a reduced picture of the true diversity in the group. Which dimensions we choose
147 should be done by agreement between all interested parties in describing this biodiversity, with
148 a purposeful aim of doing so and the knowledge that it does not depict the entirety of
149 biodiversity. The number and type of dimensions, the size of the group of inclusion, as well as
150 the position of the elements is for most systems in the world arguable, subjective and can
151 change over time.

152

Figure 1. Graphical representation of the concept of diversity. The distance between unique elements within a group of inclusion is defined by the degree of similarity along several dimensions, arbitrarily used to characterize them.

----- End of Box 1

A graphical representation of the conceptual model used throughout this perspective about the formation of different personal understandings of knowledge is presented in Figure 2. In this model, knowledge is constructed actively by the learner putting together available pieces of information that are filtered through “invisible membranes” (e.g. cultural biases, social norms) that shape that construction (Roopnarine and Johnson 2015). During the exploration phase, the learner forges a naïve understanding of a topic (Pope and Hilbert 1983, Vosniadou 2007). If contested, further education and experience allow the learner to correct possible misconceptions that may have developed during the exploration phase (this process is known as conceptual change, i.e. note the position of the dark blue tiles – Fig. 2) and to go

deeper into a topic, towards an expert understanding (i.e. adding more pieces of knowledge in the correct position to develop a bigger picture of a topic).

Figure 2. A conceptual model of construction of the personal understanding of biodiversity. The learners get their first notions on a topic (e.g., biodiversity) through exploration of nature and everyday life, shaped by internal and external factors, such as culture. This naïve understanding is later contested and expanded through experience and formal education.

In accordance with this model, there is the possibility that multiple conceptions of biodiversity coexist in society, which we represent by acknowledging both the scientific and social/traditional knowledge conceptions (Figure 3). In Figure 3, the purple circle includes concepts of biodiversity derived by the scientific method. Purple dots within that circle represent personal understandings of biodiversity. The brown circle denotes social constructs

of diversity, which refers to elements in general. The red dots therein represent personal understandings of diversity. The pink circle represents social constructs of biodiversity, which refers to organisms. The understandings of some individuals may have more influence than others; these differences are indicated by circles of different sizes.

Understandings outside the purple circle are misconceptions, at least relative to understandings derived by scientific methods. Such misconceptions may be derived from social explorations. As mentioned earlier, we do not consider social concepts of biodiversity wrong or right on their own; we only consider them to be misunderstandings/misconceptions when they are at odds with a generally accepted conception/understanding in science.

Figure 3. A conceptual model of relations between the scientific construct of biodiversity and the social constructs of diversity and biodiversity. The figure shows how, potentially, the social construct of biodiversity is formed in the intersection of the construct of diversity and the scientific concept of biodiversity.

3. Experiencing biodiversity through puzzles

Games and puzzles are one of the first ways in which many children are introduced to concepts in life (Brown & Freeman, 2001). Through playing and exploring, children instinctively build naïve understandings, based on experience, even without input from formal education. Games, puzzles, books and other media are informal sources of information that encourage interpretations about the biological world, consistent with the beliefs of the mainstream culture (Geerdts et al., 2016). Some of these early formed conceptions stick despite formal education and are highly resistant to change (Duit & Treagust, 2003). For example, misunderstandings about natural selection, caused by over-simplification and interpretation of evolution as organisms' "anthropomorphic will to adapt" are widespread in initial education and hard to overcome even after lengthy higher education activities (Emmons et al., 2018; Geerdts et al., 2016).

Children's picture books have been found to influence how children understand the world around them, particularly regarding animals and plants (Ganea et al., 2011; Kelemen et al., 2014). However, less research has been done on the impact of children's games and puzzles on this understanding. Naïve understandings and conceptual changes (Duit & Treagust, 2003) in sciences have been explored thoroughly for concepts in mathematics, physics, and general biology (e.g. the concept of evolution — but not yet for biodiversity) (Thompson, 2006). We wonder whether such early experiences might have large and long-lasting effects on children's understandings of biodiversity and its effects on the functioning of ecosystems and the natural world at large (Bermudez and Lindemann-Matthies, 2018).

One puzzle often played by children is known as "Which one does not belong?" It encourages sorting of objects based on differences among them (Figure 4). This puzzle is

usually played in its most basic form by young children in kindergarten, often under 6 years old, in relation to mathematics. It is possible that children play the game alone or guided by adult tutors (parents or teachers). The puzzle is common at least in European and North and Latin-American countries, where the authors of this perspective come from, as exemplified by websites such as WODB.ca. Naturally, there are many other puzzles played by children, which would also warrant investigation, but we use this puzzle to illustrate our point and call for further research on this and other games. Furthermore, the diverse situations in which they can be played may influence the conceptions created and influenced by the puzzles.

Figure 4. A typical preschool sorting puzzle, with the title “Watch out! Which one does not belong” representing common descriptions of what such puzzles exclude (“Correct answer”). This image has been based particularly on a game from the brand Bandolino (Germany), which is similar to many others found online in educational websites.

We examined this type of game in particular because the concept of (bio)diversity is clear (there is a group of objects that display some pattern of variation/difference in their

properties) and because the player is required to identify a particular element of that diversity and do something with that pattern of variation. We looked into three aspects of this puzzle and provide possible solutions that can lead to conceptual change: 1) language used, 2) grouping of elements as “correct”, 3) tendency to homogenize (differences between individuals categorized with the same name).

3.1. Language used

These puzzles commonly use language that implies difference as an undesirable property of an object, such as “Watch out! Which one does not belong”, “Cross out the picture that does not go with the rest”, “Select the one that does not fit”. We hypothesise that this use of language could lead to a conceptual understanding that difference of one object from others is a negative attribute, and therefore that diversity in a group of objects is undesirable. Hence, from the very earliest age, the language of these puzzles encourages an understanding that being different is a negative attribute, and that different objects when in minority should be excluded from a group. This could be a misconception in general, and certainly is so relative to understandings of the functional importance of biodiversity, in which biodiversity promotes ecosystem functioning and stability (Balvanera et al., 2006; Byrnes et al., 2014; Pennekamp et al., 2018). In such an ecological setting, being different can mean being complementary; things fit and work together often because they are different.

After looking up the educational concept behind “which one does not belong” in websites such as WOBD.ca, we realize that it apparently has the aim to provoke discussion of variety in students’ answers specifically related to math, most clear when using numbers and geometric shapes. In none of the examples using animals or plants there is an intention to

discuss biological concepts or an awareness on how this phrasing might be useful in math but harmful in terms of biodiversity understanding.

What changes could be made to these puzzles if they were aimed at creating an experience of differences more likely to result in a positive or neutral (or more complex) attitude towards them (e.g., which one is special/unique)? We hypothesise that simple changes in their titles and descriptions could fundamentally change player's views of diversity and biodiversity. Moreover, when the children are guided by a tutor, being aware of this misconception as a possible unintended consequence of the game could help them tailor the guidance in order to promote dialogue and clarify whether this is the impression of the student or not. Simply asking questions such as "Have you ever seen these two elements (organisms) together?", could serve as a starting conversation on when they do belong together and when or why, for practical reasons, we separate them. Alternatively, puzzles could deliberately show groups of elements and ask the child to group the elements that might interact (rather than just to group elements by similarity), thus, for example, a cow would be matched with hay rather than with a pig.

3.2. Grouping of elements as "correct"

There are several forms of this puzzle that differ in the number of answers allowed as "correct". For the ones that allow only one answer, we wonder what sort of impact it could have on the outcomes of the activity for the child, outside mathematics and hard sciences, in particular when elements used are organisms. Furthermore, the reasoning behind the categories promoted can be based on structure or appearance of the elements. Although all of these categories might be useful in different situations, the tutor could be aware of this and in accordance with the level of understanding of the children guide them towards the most comprehensive picture of

the system in consideration. Given that the use of categories to classify objects is one of the educational purposes of these puzzles, we hypothesise that using categories related to more meaningful interactions between the objects in different contexts rather than to their basic shape or colour would serve to achieve a higher understanding of the system, in particular for organisms (such as plants and animals). In contrast, when little interaction between elements is being established, and in the absence of a tutor that invites the child to rethink groups based on different classification schemes, we would risk a limited learning.

Busch et al. (2018) tested children's reasoning when classifying organisms and showed that children naturally favoured ecological reasoning, for example grouping organisms based on their ecological functions (e.g., prey/predator relations) over classification based on taxonomical groups and similarities (Busch et al., 2018). Encouraging classifications that are not based on observable ecological relations between organisms could potentially be a source of misconceptions through the educational process, such as placing all plants as land organisms, or other oversimplifications. What is needed is a change to use interactions between elements which is the fundamental aspect of complementarity, facilitation and division of labour. Multiple answers to puzzles based on different classifications, not necessarily standard across cultures, may help reduce the chances of misconceptions through this game.

3.3.Reduced variation and lumping

The last aspect of the puzzles we could look at is the limited variability among objects of the same type; for which the most extreme case would be the example in Figure 4 when the same object is repeated several times with no differences between them. This is especially the case when the objects are organisms. However, this is in stark contrast to the environment around us and in particular the natural world, where variability among elements, even similar

ones, is a most general feature. There are hundreds of types of pears (*Pyrus* sp.) known around the world (Bell, 1991), while in these puzzles pears are generally represented in a single way (Figure 5).

Figure 5. Example of different pear varieties, commonly represented by a single type in children’s games.

We hypothesise that this over-simplification of organismic diversity could be partially responsible for limited appreciation of biodiversity, due to internal idealizations that homogeneity is normal and perhaps is desirable because there is one “perfect” specimen. The implications of such idealizations without proper intervention from a tutor aware of this issue could be many, from misunderstandings of the concept of biodiversity, to the loss of varieties and plants and animals, and to the belief that people differ mainly among rather than within certain groups. Interestingly, one can observe such patterns in the real-world production of food. In a nowadays revoked regulation, efforts to standardize food items for the common market of the EU have led to diverging shapes, sizes and colours of vegetables being selected against, masking the true diversity that customers could experience. For example, bananas with an “abnormal curvature” were banned from sale in the EU (European Commission, 1994). Fortunately, this regulation was revoked in 2008, leaving the decision to select to the customers. While such efforts may be well meant in terms of quality control and customer

rights, they can lead to detrimental effects. In another example of selection on visual appearance, tomatoes were bred towards an idealized optical phenotype, which has led to a loss of taste through its history of domestication (Tieman et al. 2017). We will expand on how to counter this development in the following section on the value of food diversity to form a deeper understanding of biodiversity.

In science too, underestimating variability within groups, focusing on species levels and removing “outliers”, has been the norm (Des Roches et al., 2018; Violle et al., 2012). Only recently, there is greater recognition and appreciation of the importance of differences among individuals of the same species as the basis of evolution, and that there are advantages gained by viewing diversity at finer scales (Des Roches et al., 2018; Gugerli et al., 2008; Petchey & Gaston, 2002). Thus, it has now been recognized that even at the within-individual level different packaging of chromosomes in cellular nuclei may promote diversity in gene expression within tissues and thus increase organismal functioning (Finn & Misteli 2019).

Many of these games also encourage lumping, by which we mean putting different objects into the same category. Scientists studying biodiversity tend to do a lot of lumping. However, it is becoming clearer that in many situations, lumping creates unjustified, and potentially dangerous perceptions. For example, a study of the potential effects of species extinctions on functional diversity concluded that “75% of the species could be lost before the disappearance of the first functional group” (Fonseca & Ganade, 2001). This percentage is, however, arbitrary due to the subjectivity associated with assigning species to functional groups (Petchey & Gaston, 2002).

While lumping makes the world appear simpler and apparently more understandable, it can have negative consequences such as being unwillingly subjected to biased classifications

made by others (biased to a political view, for example), slowing progress (there is an inertia to change classifications that are established in a system) or limiting our creativity (Bowker & Leigh Star, 1999). The sense of safety from reducing the complexities comes with an unrealistic view of the world (Voinov et al., 2014). We hypothesize that research into this compression of diversity into categories/groups/tribes of seemingly identical objects will reveal that it is generally unnecessary and undesirable.

4. Experiencing biodiversity through food-related activities

A common and particularly intimate experience of biodiversity comes through what we eat. Eating is an important connection with nature, from which we obtain energy and a diversity of nutrients for our existence. There are indications that children establish priorities in biodiversity conservation based on the type of biodiversity to which they are exposed (Ballouard et al., 2011). There is a rich corpus of research on the importance of dietary diversity (Kant et al., 1993; Taruvinga et al., 2013) and numerous studies that link biodiversity education and conservation to different aspects of nutrition (Chipeniuk, 1995; Crist, Mora, & Engelman, 2017; Fischer et al., 2019). Research shows that getting involved with the local plants and animals has a positive influence in children's environmental attitudes and potentially helps them become better at making decisions regarding environmental management (Brewer, 2002). Even when those responses are not beneficial *per se* towards conservation, exposure to biodiversity helped students make wiser decisions, for example, differentiating toxic and nontoxic plants (Prokop & Fančovičová, 2019).

We therefore suggest that analogies between cooking/eating and biodiversity theory could be used much more in education about biodiversity. Furthermore, we hypothesise that

there is considerable potential to make the biodiversity present more visible. Given the wide variety of food traditions across cultures, this approach could be at the same time useful to do research in comparing how different societies relate to the diversity in their diets, possibly having an influence in the way they understand and form attitudes towards biodiversity.

4.1. Cooking and biodiversity science analogies

Food fills the senses with a variety of colours, smells and textures; features derived from the intrinsic diversity of traits in the organisms humans consume. Recipes are combinations of parts of different organisms that interact creating new elements of different value; a concrete analogy to the importance of species composition/combinations for phenomena such as ecological coexistence and stability (de Mazancourt et al., 2013; Loreau & de Mazancourt, 2013). Because the food prepared following recipes is more than the sum of its parts, putting a value on the contributions of each individual ingredient is difficult; this is analogous to the difficulties in isolating individual species contributions to ecosystem functioning (Lawton & Brown, 1994). For many recipes, diversity is a necessary requirement, but appropriate combinations and inclusion methods are also necessary. This is echoed in many biodiversity–ecosystem functioning experiments, in which diversity and composition are simultaneously important determinants of ecosystem functioning (Spehn et al., 2005; Hector et al., 2001). Finally, more diverse ingredients do not necessarily make a better final dish, the same as more biodiversity is not, *per se*, always better for an ecosystem to function or ecosystem service to work. We hypothesise that these parallels between food/cooking and biodiversity can be employed in education about biodiversity, as they can be derived from an everyday activity, such as obtaining ingredients or even gathering wild foods or growing food

in a garden and cooking them (Poe et al. 2013). As with the example of the games, to ensure a deep and correct understanding of biodiversity using these analogies, they should be employed by a tutor, teacher or guidance of sort, guiding the students to develop the parallels themselves.

4.2. Tracking biodiversity in diet

The diversity in the food people eat could have implications beyond nutrition; it could be one of the few access points to nature they have in everyday life and therefore silently influence the way they understand biodiversity. We hypothesise that the lack of connection between the biological diversity in our diets and the natural world partially explains difficulties in understanding the concept of biodiversity. If people are not familiar with food diversity, it is possible that they will not understand how to protect its sources.

In most of the developed world, the trend is for most people to be detached from the resources they consume. For examples, one of us was not aware as a child that Sauerkraut was made from cabbage and as the teacher asked this question to the class, most of the children between 7–9 years of age did not know it either; this was 60 years ago in a small town in Switzerland (Bernhard Schmid, personal recollection). There may be few environmental sustainability considerations when people choose their diets and there is a dietary delocalization, which is proven to be both environmentally damaging and unhealthy (Rose et al., 2019; van der Horst et al., 2011). Yet, it seems that many people yearn for contact with nature (Clark et al., 2019). At the same time many species of crops, vegetables and fruits are underused in global diets, and within the ones being used the same occurs to varieties (FAO et al., 2017). While the relation between agricultural diversity and human nutrition has been somewhat explored, less importance has been given to developing concrete tools for people to track diversity in their own diets (Johns et al., 2013; Toledo & Burlingame, 2006). Providing

tools to this end would help to raise awareness on the level of diversity we foster and consume and the general sustainability of our diets.

How can students learn about biodiversity by paying attention to their experiences of diversity through food, and increase the visibility of biodiversity in their daily life? Here we developed a table with the criteria that we considered relevant, so that it could be used independently or by educators, to strengthen people's connection with the biodiversity in their diet (Figure 6). Ideally, such a table would be adapted to the local context and accompanied with a) information on how to fill in the columns, b) nutritional information for a healthy diet and c) crop, fruit and vegetable calendars with information on the availability of diverse food sources including species and varieties that could be used to reach the healthy diet.

Complete the table with information about the food you had in the last week

Food name (product)	<i>Beef</i>	<i>Corn</i>	<i>Cheese</i>	<i>Ginger</i>
Common name of organism	<i>Cow</i>	<i>Maize</i>	<i>Cow</i>	<i>Ginger</i>
Kingdom	<i>Animalia</i>	<i>Plantae</i>	<i>Animalia</i>	<i>Plantae</i>
Phylum /Division	<i>Chordata</i>	<i>Tracheophyta</i>	<i>Chordata</i>	<i>Tracheophyta</i>
Species (Latin name)	<i>Bos taurus</i>	<i>Zea mays</i>	<i>Bos taurus</i>	<i>Zingiber officinale</i>
Whole, part or derivated?	<i>part</i>	<i>part</i>	<i>derivate</i>	<i>part</i>
Name of part or part where it derivates from	<i>flesh</i>	<i>seed</i>	<i>milk</i>	<i>root</i>
Number of times consumed (e.g., per week)	<i>2</i>	<i>3</i>	<i>1</i>	<i>1</i>
Country where it comes from	<i>Switzerland</i>	<i>unknown</i>	<i>Switzerland</i>	<i>India</i>
Distance it travelled to your place (km)	<i>100</i>	<i>----</i>	<i>300</i>	<i>7000</i>

Figure 6. Example of a table that could help us analyse the biodiversity in our diets (Biodiversity and Global Change MOOC, University of Zurich).

With respect to the third point (availability of diverse food sources) a complementary activity to encourage is the setting of local community gardens, for exchange of information and for locally sourced food. Given that not everyone has access to land or resources to have their own garden, we think more nation-wide programmes should be fostered and encouraged. Participating in school gardens, for example, has been shown to increase understanding of biodiversity in children that were involved in gardening activities (Fischer et al., 2019; Guitart et al., 2014).

5. A call for more interdisciplinary research into how biodiversity understanding is shaped

Here we have presented our ideas and perspective on how everyday experiences and practices could inadvertently shape personal understandings of biodiversity and provided numerous hypotheses that could be tested. A general suggestion is that researchers should scrutinize representations of biodiversity and research how learners respond to these. Further, work on these representations, which are not strictly part of environmental education or ethnobotany work or about the psychology of learning, could nevertheless warrant consideration in all these areas. Also, any arising research should consider relevant work from the field of cognitive psychology (e.g. about categories and concepts) that would situate research within a larger corpus of literature (e.g., Margolis & Laurence, 2015; Murphy, 2002).

We propose that research on how people develop biodiversity understandings consider experiences outside formal science education. A concrete implementation for the games is to foster collaboration among different disciplines in game design and when possible to test the outcome of the impact that they have in understanding, e.g., through interventions, experiments or surveys. A concrete implementation for food-related activities would be to develop and

provide more resources for tracking biodiversity in our own diets. More broadly, we support policies that increase access to direct experiences of biodiversity, such as those that foster agrobiodiversity and counteract the worldwide loss of varieties via re-engagement with diverse food systems.

For example, we proposed that during the development of educational games that use organisms as elements, potentially negative consequences about the understanding of and attitudes towards biodiversity should be considered. Moreover, a game aimed to educate or practice concepts of mathematics could potentially have negative consequences in biodiversity understanding, if not carefully phrased and framed by a tutor. The reasoning behind classifying and sorting games is the development of goal-oriented behaviours (executive functions), such as working memory or mental flexibility and learning-related cognitive skills, such as math or reading (Ackerman & Friedman-Krauss, 2017). We do not question the relevance of developing these skills, but we want to raise the hypothesis that such games may have unintended and potentially undesirable effects on how children playing them understand biodiversity. It seems worth further exploring the effects that these games have on understandings of biodiversity. For example when these early learning exercises are complemented by others from environmental education settings, perhaps more positive connotations of diversity will be fostered and children might develop a conceptual change from oversimplistic representations to a more nuanced, multifaceted conception of biodiversity (e.g., Figure 7). We acknowledge that the example in figure 6 is more sophisticated and cognitively demanding than the originals in figure 4, hence suited for older children. It is difficult to avoid oversimplifications of biodiversity in pursuit of making a question/puzzle developmentally appropriate for small children. To understand the impact of games on the children that play

them, collaborations between biodiversity scientists, education experts and game designers need to be developed and strengthened.

Figure 7: Goal-oriented alternative puzzles with multiple answers (similar to what could be found in the field of environmental education) in which diversity is acknowledged and can be perceived as positive or neutral attributes of a system.

Furthermore, we encourage more studies on the relationship between food experiences and people's understanding of biodiversity, as we believe they have great potential to sow the seeds for dialogue (Barthel et al., 2013). Our diets are strongly connected with culture and with agricultural diversity. By highlighting the role of biodiversity in something as tangible as food, we suggest that people's general connection with nature would be enhanced and most likely also the understanding of it.

We emphasize that the concept represented in the sorting game discussed above—that structural differences make an element not "fit" to be part of a group—can be a misconception when taken in isolation, without qualification, context, or nuance, especially when referring to

497 biodiversity. We ask if such misconceptions lead to an under-appreciation of the role of
498 biodiversity by implying that parts of a groups should be the same and thus biodiversity is not
499 important. Such misconceptions could be problematic if they hinder the capacity to
500 comprehend the role of biodiversity in ecological functions. While we discuss understanding
501 the function of diversity of species and choosing a diverse diet, other areas of inquiry could
502 include cultural expressions (television, theatre), transport, and landscape or city design. These
503 issues at the same time help shape people's view of the world and are forms of expression. In
504 these areas we can explore representations of the diversity of elements, ideas and resources.
505 Highlighting the role of biodiversity in relation with these everyday topics would likely help
506 us discover what other experiences shape understanding, and when and for whom.

507 There are possible caveats and limitations to our (the authors') perspective. Primarily,
508 as mentioned above, we are naturally limited to our own experiences from our countries of
509 origin and socio-economic situations. We wish to avoid generalizing ideas or implying that
510 everyone has similar experiences with the kinds of puzzles and games describe, or access to
511 diverse diets or information on food nutrition. We are aware that many people, even in
512 developed countries, do not have access to such resources and that in many cultures these ideas
513 may not apply. It would be interesting to have an inter-cultural and inclusive discussion about
514 which other forms of biodiversity representations could be influencing the understanding of
515 biodiversity for people not contemplated in this article.

516 Secondarily, it is important to note that we do not think that all experiences of
517 biodiversity should be orchestrated to create only positive attitudes towards it. It is easy to find
518 genuine experiences of biodiversity that lead to positive attitudes (e.g., aesthetic value of
519 diverse pastures), or to negative attitudes (e.g., human wildlife conflicts for land resources)

(Schnegg & Kiaka, 2018). However, alignment of people's understandings with well-evidenced and broadly accepted scientific conclusions, e.g. that more often than not biodiversity loss has negative consequences for ecosystems, will likely require that educators attend to everyday experiences that might shape how biodiversity is understood.

Lastly, by investigating the view of biodiversity created through everyday life, it is possible that we direct the focus to local biodiversity, rather than a global or distant one. The intention would be to increase the quality of connections between people and nature by removing misconceptions. This could lead to wider support for conservation. However, a general understanding of global issues such as declines in biodiversity due to climate change or impact of global trade on the environment would still require additional efforts in education that certainly exceed what one can live through daily experiences.

6. Declaration of interests

The authors declare no competing interests in the writing of this manuscript.

7. Author's contributions and disclosure statement

M.A.P. performed the literature research, developed first draft of models, wrote first complete draft of manuscript and coordinated co-authors contributions. S.P. and M.C. participated in the development of the educational framework on personal and social understanding of biodiversity. F.A., N.B., A.D.-Z., K.H., P.N., M.M., F.P., M.J.S., M.S., B.S., V.W.M. and D.Z.-D. contributed to overall manuscript writing and provided references for specific sections and topics. I.R.G. participated in the development of the figures. O.L.P.

initiated the idea of the manuscript, wrote initial summary and first draft of key sections of the manuscript, invited co-authors and supervised the development of manuscript. None of the co-authors has any interests to declare.

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