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RESEARCH ARTICLE

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How do young identify plants? Using the drawing method to explore early ethnobotanical knowledge in Madagascar

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Abstract

1. In small-scale societies, people learn to identify plant species during childhood. Plant recognition is an important baseline knowledge, immediately useful to avoid intoxication risk due to wrong identification. Plant recognition is the basis of other ethnobotanical knowledge essential for safeguarding biocultural diversity. However, despite many studies on folk classification, we still have a narrow understanding of the criteria locally used for species identification; the gap being even larger regarding children's plant identification criteria.
2. Here, we study the criteria used by Betsileo children and adolescents to identify wild edible plant (WEP) species using a child-adapted method including drawings and follow-up interviews. We worked with 80 teenagers (from 12 to 17 years old; 51 girls, and 29 boys).
3. Our results suggest that teenagers use a large spectrum of visual criteria to identify plants and that these criteria match with botanical and ecological knowledge documented in the literature and herbarium vouchers. We found that 35% of the identification criteria used were non-morphological (e.g. phenology, biotic interactions), suggesting deep ecological knowledge.
4. On average, teenagers use more than nine distinct criteria per plant, which allows them to identify most plant species with a very high level of precision. The precision level of plant representation increases with age for boys, but remains constant for girls, suggesting different dynamics in plant identification knowledge acquisition.
5. We also found that boys and girls use different identification criteria: girls focus on morphological criteria while boys also incorporate ecological criteria, such as landscape features and biotic interactions, in their spectrum of identification keys.
6. Our results highlight the complexity of teenagers' plant knowledge and the importance of the ecological context and gender in plant identification's knowledge acquisition.

7. This knowledge acquired very early in childhood, constitutes the foundation of future interactions with nature and should be at the heart of environmental humanities studies and knowledge co-production projects to tackle socio-ecological concerns. Hence, we urge further research to explore innovative methods that complement traditional ethnoecological tools and capture complex sensory aspects of folk children's taxonomy to better understand human-plant interactions and knowledge.

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KEYWORDS

Betsileo, children knowledge, cognitive anthropology, plant identification

1 | INTRODUCTION

In 1960, A. H. Smith was amazed in Ryùkyù Islands by Kabira children's ability to identify plants using a diversity of details: '*Even a child can often identify the species of a tree from a small fragment of wood, and, what is more, the sex of that tree, [...] and this, by observing the appearance of the wood and bark, the odor, the hardness, and other characters of the same kind*' (p. 150).

The abilities to identify and name useful plants are probably among the first skills and knowledge learned in childhood in small-scale societies (Porcher et al., 2022; Reyes-García et al., 2007), with cross-cultural studies showing that individuals in forager societies also learn any other complex subsistence skills during childhood (Lew-Levy et al., 2017). Identifying plant species—and other elements of nature—seems to be an essential prerequisite for the acquisition of more complex knowledge and skills that an individual will accumulate over the life course, for which it is not surprising that plant knowledge acquisition starts during early childhood and is well mastered by young adults (Gallois et al., 2017; Quinlan et al., 2016; Schniter et al., 2021). For example, plant identification is vital to distinguish between poisonous and edible plants and thus to avoid the risk of poisoning (Cuadra et al., 2012). Importantly, beyond being a basic skill to interact with the environment (de Garine & Hugh-Jones, 1996), learning to decode the natural environment by identifying and differentiating species is also a way of making sense and ordering the living world, and therefore of situating oneself into it (Ingold, 2004). Plant identification is therefore a fundamental aspect of cultural learning from which other bio-cultural interactions will flow, nurtured by cultural settings such as ontologies and or 'mode of existence' (Descola, 2021; Latour, 2012).

Despite the potential importance of plant identification for livelihood activities and culture, researchers have hardly explored which criteria children use to identify plants, and even less in small-scale societies. Recent work addresses how children in Switzerland identify plants and animals (Jaun-Holderegger et al., 2021). They showed the importance of sensorial and emotional aspects in children's recognition of plants. However, such an approach is still rare as most of the studies have approached botanical knowledge through cognitive lens, as for instance through a growing interest in folk classification in the 1970s (Conklin, 1980). More recent work has emphasized the measurement of plant, fungi or animal identification skills (Quinlan et al., 2016; van den Boog et al., 2017), and recent studies on linguistic ethnobiology reveal that the nomenclature locally used to name plant species often encodes information on taxa morphology, ecology, uses and phenology, among others, thus giving an indication of some identification criteria used locally (Hidayati et al., 2022). However, the local plant lexicon might only offer a partial view of the details used by local people for the precise identification of a taxon and only a few studies have studied on the local criteria used for plant species identification (e.g. Atran, 1999; Berlin, 2014; Jernigan, 2006; Zent, 1999). The few studies on folk classification of small-scale societies have focused on criteria used to define broad biological categories (i.e. kingdom, family, genus), not addressing species identification criteria. Moreover, information about children's folk taxonomies is absent or anecdotal in such works (e.g. Lancy, 1996; Morris, 2010; Smith, 1960; Tian & Leÿs, 2021).

Local criteria used in plant identification might be complex and rely on many different knowledge dimensions (Jaun-Holderegger et al., 2021), and might even show variation among individuals according to their age or gender (Jernigan, 2006, 2008; Shepard Jr, 2004). For example, Schniter et al. (2021) shown that Choyeros people (Mexico) acquire sets of plant knowledge specific to their age and gender with different degrees and rates of acquisition. Similar findings were observed with the Betsileo people (Madagascar), whose knowledge varies according to gender and age, displaying children's and women's specific plant knowledge (Porcher et al., 2022). The role of gender in the differentiation of local ecological knowledge is particularly important during adolescence, as this period corresponds to the progressive incorporation of normative rules of the society and gendered division in daily activities (Fehr et al., 2008).

As ethnobotanical knowledge is the result of human-plant interactions mediated by human senses, it is not surprising that sensory aspects are used for species identification (Shepard Jr, 2004). Understanding such identification criteria could contribute to developing more holistic and transdisciplinary approaches to document local plant identification criteria and to explore potential variation in the criteria used according to age, gender and cultural setting. In addition, these approaches might also allow recognizing complementary between knowledge systems, by addressing divergence and overlaps between local and scientific plant identification criteria (Roue & Nakashima, 2018; Tengö et al., 2014).

Studying the criteria used by children to identify plant species entails a double challenge, which might explain why the topic has not been addressed before, beside the work of Jaun-Holderegger et al. (2021) in Switzerland. The first challenge is to capture the system used for plant identification from an emic point of view. Embracing the diversity and the complexity of 'knowledge' calls up different knowledge dimensions, cognitions and sensory aspects in a holistic approach. The second challenge is to capture the complexity of the knowledge held by children, an effort that deserves to use adapted tools. In the last decade, several works have developed and used a methodological tool that combines drawings and interviews to document children's ethnoecological knowledge (Carrière & Gastineau, 2010), a combination that allows recording specific information that the child may not always be able to express verbally (Carrière et al., 2017; Dounias & Aumeeruddy-Thomas, 2017). Indeed, this tool has proven particularly efficient in catching emic perspectives providing a concrete focal point for discussion with children (Mitchell, 2006; Soukup, 2014). Results from this work have brought new insights into the emergent field of children's anthropology particularly regarding children's perception of natural landscapes and environmental changes (Alerby, 2000; Chabanet et al., 2018; Fache, Piovano, et al., 2022; Fache, Sabinot, et al., 2022; Pellier et al., 2014), although the tool has not yet been used to explore specific knowledge realms such as plant identification and folk taxonomy.

The goal of this work was to understand how Betsileo adolescents identify and distinguish WEP species, focusing on visual aspects through the use of drawing interviews. We organize our work around four research questions: (1) What criteria do Betsileo adolescents use to identify WEP? (2) How precise are adolescents while representing plants? (3) Do the criteria used and the precision vary according to adolescents' gender and age? And (4) do adolescent identification criteria share similarity with science?

2 | MATERIALS AND METHODS

2.1 | Study site

Fieldwork was conducted from February to April 2022, in the Namoly valley, district of Haute-Matsiatra, southeast central highland of Madagascar. The valley is composed of more than 20 small hamlets spread all along the north limit of the Andringitra National Park. The area is a complex mosaic of ecological habitats, from more anthropogenic vegetation (i.e. paddy rice, crop, pastures, villages) to less disturbed ones (i.e. inselberg, cloud forest, moist altitude forest) where a diversity of rare endemic and introduced species grow. While relying on a mix-economy, Betsileo people are mainly agro-pastoralists. Rice cultivation, mostly in flooded rice terraces, numerous crop fields and home gardens, zebu grazing and logging activities rhythm the daily life of the Betsileo and shape the landscape, offering a great diversity of WEP colonizing the different habitats of the valley. Adults and children collect, prepare, and consume WEP as snacks, side dishes, or staple food, for which WEP constitute a non-negligible part of the diet throughout the year.

2.2 | Ethics

Before starting data collection, we obtained the agreement from the relevant administrative-territorial organizations (Fokontany chefs) and obtained oral free prior and informed consent (FPIC) from each participant. As we worked with adolescents, we asked for both their own FPIC and their parents' FPIC, always reiterating adolescents' right to withdraw from the study at any time. This research was approved by the ethics committee of the Autonomous University of Barcelona (CEEAH 4902). It was carried out following the ethical charter of Ethical Research Involving Children (Graham et al., 2013) and the ethical code of the International Society of Ethnobiology (ISE).

2.3 | Data collection

We worked with 85 adolescents (between 12 and 17 years old) including 55 girls and 30 boys. Our sample constitutes almost the full population of adolescents of this age class for the study site (only five adolescents in the valley were not part of the sample). We purposely selected children over the age of eight to ensure that interviewees were able to represent items with fine details while using drawing interviews, in line with the work of Carrière et al. (2017). Adolescents in our sampling come from 17 different hamlets spread over the whole valley. However, for practical reasons and to have access to tables and chairs, all the interviews took place in the same room (different from school, to avoid interviewees associating the drawing activities with evaluation).

To document the criteria used by teenagers to identify WEP species and the precision in the use of such criteria, we used a transdisciplinary approach and adapted the drawing interview method developed by Carrière et al. (2017). This method, using drawing as support for interviews, is adapted for work with children as it allows young interviewees to express complex and detailed knowledge that they are not always able to verbalize with standard methods such as semi-structured interviews (Carrière et al., 2017). In addition, it reduces the times of interviews which allows children to feel more comfortable and less tired during the activities (see also Fache, Piovano, et al. (2022) and Fache, Sabinot, et al. (2022) for more methodological and epistemological considerations of this method).

This method follows a two-phase protocol. During the first phase, we asked the 85 participants to make a drawing following this instruction: 'Draw me the wild edible plants you know with all the details that allow you to recognize the plant and differentiate it from another'. We did not give a time limitation and the first phase lasted between 1 h and a half and 2 h. In the second phase, we interviewed the adolescents about their drawings. Specifically, we asked them to explain the details in their drawing (e.g. shape, colour choices). We also collected information about the plant species' local name, morphology, phenology and ecology, as well as the name of other species drawn in association with the WEP (including plant, animal and fungi), and the anthropic and landscape features drawn, if any. Interviews lasted about 15 min per drawing and were conducted away from other children by a mixed research team consisting of S.C.R, a Malagasy woman who speaks Betsileo and V.P., a French man to limit the effects of gender and ethnicity. All the interviews were conducted in the Betsileo language, thanks to S.C.R. A first inspection of the drawings suggested that some participants copied from their neighbours during the session. We removed these drawings from the analysis, for which our final sample is 80 drawings.

2.4 | Data analysis

To meet our research objectives, we analysed the adolescents' drawings in three stages (Figure 1) and tested the effect of gender and age (our third objective) throughout the different stages of the analysis. First, to have a general overview of the WEP known by Betsileo adolescents, we counted the number of WEP species represented in each drawing, the total diversity of species drawn by all the participants, and whether the average number of species varied according to adolescent's sex (Figure 1 stage 1). While counting the number of species of wild edible plants, we considered the emic point of view, keeping in our analysis certain species that could have been domesticated outside Madagascar but considered wild locally because they are not cultivated and grow spontaneously (see Table S1).

We then used information collected from the drawings and during interviews to assess the identification criteria used (Figure 1, stage 2). Overall, we identified 16 different identification criteria that we distributed across four categories, this included nine morphological, two phenological, four ecological and one anthropic identification criteria (see Table 1; Appendix S1). We grouped under morphological criteria those that follow standard botanical identification keys (Schatz & Wilmé, 2001) (i.e. life forms, plant architecture, phyllotaxy, fertile position, leaves morphology, root system, flower and fruit morphology), also adding plant architecture, that is, the rhythmicity, dynamics and position of ramification (Barthélémy & Caraglio, 2007), because the architectural models of most plants were frequently represented. As some plant species have specific organs, we also added a criterion called 'Extra accurate details' (EAD) where we included any specific detail drawn (e.g. tendrils, stipules, spines and other specific plant structures not included in the previous variables). To better catch the complexity and the variability in the plant representation, we coded every plant following the 16 criteria according to the precision (level of details and complexity) of their representation (Figure 1, stage 3). For example, criteria such as phyllotaxy were coded as simple absence/presence (0–1), while criteria such as flower morphology were coded according to the precision of their representation with a score (0–3) from the most simple 1 to the most precise 3, and were the absence of the criteria on the plant is coded 0 (Table 1, for details about the coding system see, Appendix S1). We used this coding system to calculate the precision score of each plant drawn as the sum of the score of each criterion used to represent it.

We considered whether the adolescent used each of the 16 criteria in the drawing by coding the corresponding variable as presence/absence. Then, we calculated the frequency with which an identification criterion was used by an adolescent and the average number of criteria used to identify a WEP, taking into consideration all the plants represented in a drawing. We compared the average number of criteria used by girls and boys using the Welch two-sample *t*-test and tested the relation between the number of criteria and the age with linear regression.

To establish profiles of adolescents according to the criteria used in their drawings, we performed a principal component analysis (PCA using the r package *factoextra*) on a matrix describing the 80 drawings from the 16 criteria transformed in the presence/absence

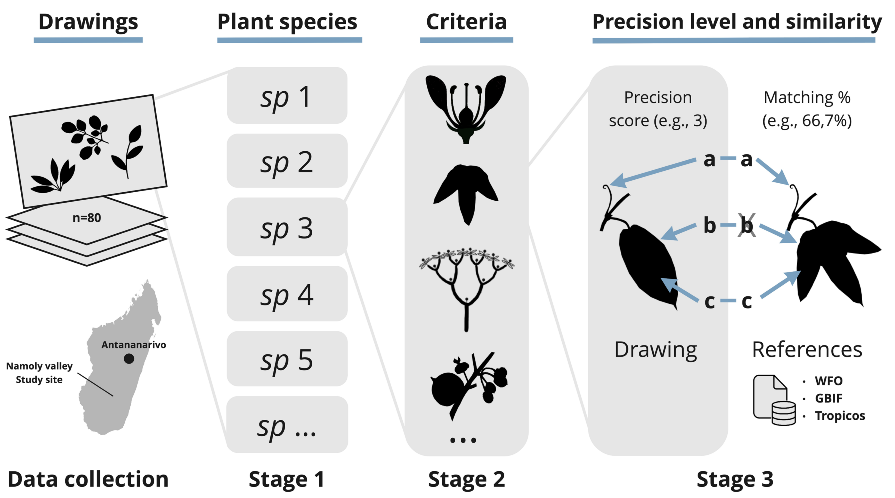

FIGURE 1 Graphical abstract of the methodological approach; from data collection to analysis.

TABLE 1 Criteria used to analyse adolescents's WEP identification.

Categories	Code_ID	Variable description	Code
WEP	nbspW	Number of WEP species: count of the WEP species drawn	/
Morphology	life	Life forms: type, e.g. vine, tree, herbaceous	(0-1)
	archi	Plant architecture: rhythmicity, dynamics and position of ramification	(0-1)
	phylo	Phyllotaxy: arrangement of leaves on the axis	(0-1)
	ferPo	Fertile position: position of the flowers and fruits on the plant	(0-1)
	Leav	Leaves morphology	(0-3)
	root	Root system: type	(0-2)
	flo	Flower morphology	(0-3)
	fru	Fruit morphology	(0-4)
	EAD	Extra accurate details: e.g. tendril, stipule, hairs, buds	(0-1)
Phenology	pheF	Reproductive phenology	(0-1)
	pheL	Vegetative phenology: e.g. leaves, new shoot, sprout	(0-1)
Ecology	Land	Landscape items: e.g. forest, road, field	(0-1)
	Soil	Soil: colour, texture	(0-2)
	fauna	Fauna interactions, number of animal species	(0-max)
	flora	Flora interactions, number of non-edible plant species	(0-max)
Anthropic	use	Uses: human interaction with WEP, e.g. gathering. consumption	(0-1)

variable. Using our PCA, we calculated the contribution of each variable to the distribution of drawings in two main factorial planes (Dim 2,1 and Dim 2,3). Finally, to discriminate against adolescent's profiles according to their gender, we added the gender of the individuals as explanatory variable and calculated the confidence interval (ellipse) of 95% around barycenters of each gender group (girls and boys) in both factorial planes.

To assess whether adolescents' precision in representing plants varies across gender and age, we calculated the precision level of each participant based on the average precision score of all the plants. Then, we test the relation between gender, age and the precision level by comparing them using linear regression and the Welch two-sample *t*-test to compare the average precision score between girls and boys.

To compare gender precision according to identification criteria in a given species, we calculated the girl's and boy's probabilities to represent the same plant species precisely. To do so, we focused on four species and four criteria (i.e. 'Flower morphology', 'Reproductive phenology', 'Fauna interactions' and 'Landscape items'). We chose four species represented by at least 20 girls and 20 boys to obtain a balanced sample (i.e. *Physalis peruviana*, *Vaccinium secundiflorum*, *Opuntia monacantha* and *Passiflora subpeltata*). We selected these criteria based on their variable contribution calculated by PCA, choosing the most discriminating ones. To calculate the probability species were presented with precision, we used a non-parametric Bayesian bootstrap with a Dirichlet distribution to model the randomness of a probability mass function (PMF) with the function *ethno_boot* from the R package ethnobotanyR.

In our final analysis, we assess the similarity between local and scientific knowledge in plant identification, by calculating the average percentage of matches between Betsileo's drawings and plant science for each identification criterion. We coded the information as match/mismatch for each species drawn by each participant and calculated the average percentage of matches per criterion based on all the plants drawn. We used vouchers from TAN herbarium and plant science literature as references (botanical description and ecology from World Flora Online (2023), Plant of the World Online (2023), Global Biodiversity Information Facility (2023) and Tropicos Madagascar (2023)).

3 | RESULTS

3.1 | The species drawn by adolescents

The 80 adolescents drew more than 500 items, representing a total of 58 WEP species, four non-WEP species, and 19 animal species associated with the WEP (see Table S1 for the complete list of species interacting with the WEP). WEP species drawn belong to 31 botanical families (according to APG IV classification) and include 27 introduced, 11 natives, and 20 endemic species. Most WEPs drawn are consumed for their fruit (43 sp). The WEP species drawn also include leafy vegetables which are usually boiled to be consumed (7 sp), leaves that are consumed raw (5 sp), and plants consumed for the nectar contained in the spur of flowers (3 sp). Two species are consumed both for their nectar and their tubers which are eaten raw.

On average, each adolescent drew 5.96 WEP species (SD = 2.46, range 1–18), girls drew 6.38 WEP species (SD = 2.63; range 2–18) and boys 5.22 (SD = 1.96; range 1–9). Girls drew 50 different WEP species whereas boys drew 36. Overall, 26 WEP species were shared between the subsamples of girls and boys. Twenty-four WEP species were found only on girls' drawings while ten were found only on boys' drawings. The species drawn only by girls were mostly introduced (54%), synanthropic herbaceous species growing around dwellings in the village or along roads and fields (e.g. Figure 2a). Among the species drawn only by boys, there were more endemic species (70%) coming from distinct and less anthropized areas such as forests in the surroundings (e.g. Figure 2b).

3.2 | Plant identification criteria

Fifteen out of the 16 different identification criteria considered are found in at least 25% of the drawings and eight criteria were used

FIGURE 2 (a) Drawing made by a 14-year-old girl, illustrating ten different WEP species growing near the houses. Life form, leaf shape, phyllotaxy, fruit morphology and reproductive phenology, and soil type are the main criteria appearing in the drawing. The drawing shows precisely the different morphology of leaves from one species to another but also the opposite phyllotaxy of *Psidium guajava* L., which denotes the alternate phyllotaxy of the other represented species. She also represented the different colours and textures of soil corresponding to each species. She explained during the interview that she chose the colour black for the soil of *Tsiopaka* (*Bengt-jonsellia laurentii* (Jonsel) Al-Shehbaz) to represent the plant growing in the fields after burning the plots. (b) Drawing by a 15-year-old boy illustrating three species of endemic trees growing in the forests. The drawing emphasizes the phenology of the leaves by distinguishing the young leaves (orange or bluish depending on the species) from the older ones (green) and those ready to fall (yellow or brown with a dry margin in black). He explained during the interview that the colour of the young and old leaves was different from one species to another. He also represented the biotic interactions with a nesting bird (male red fody) in *Vaccinium secundiflorum* Hook and a lemur (striped-tailed lemur) eating the fruits of *Symphonia clusioides* Baker.

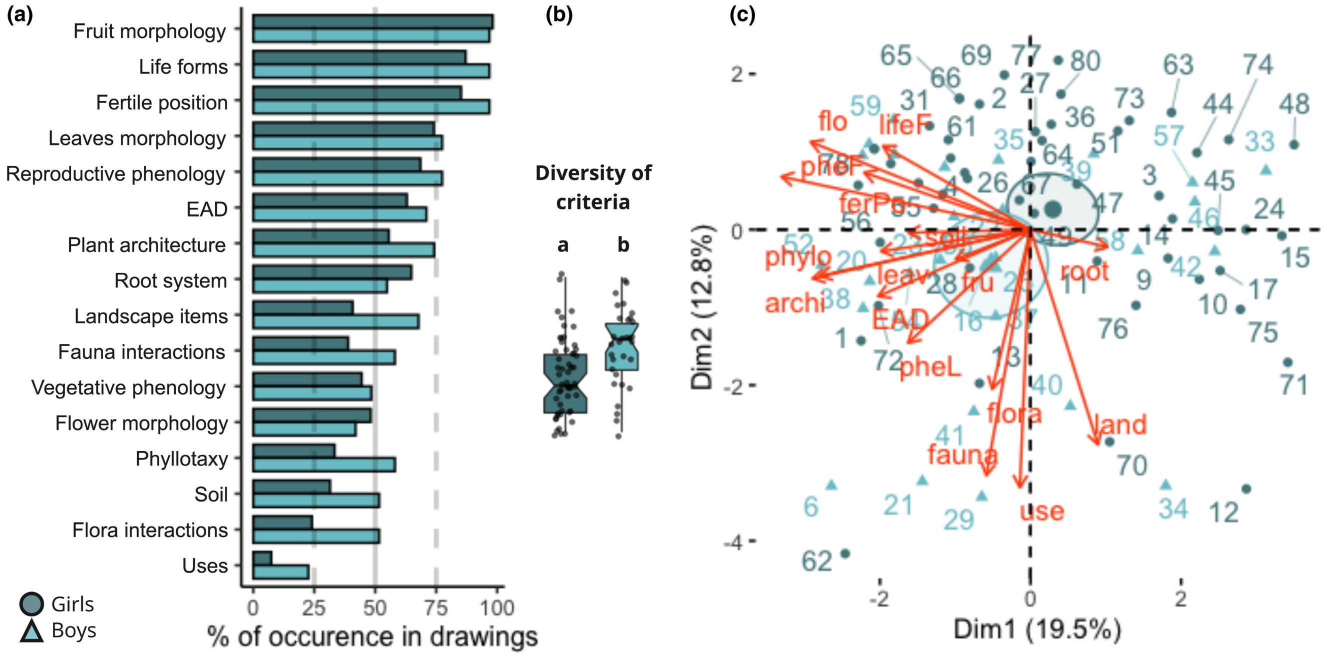

FIGURE 3 Criteria used by adolescents to identify WEP species. (A) Frequency of occurrence of the 16 criteria in the 80 drawings (individuals) split by gender and ranked from the most to the least frequent (barplot). Results from girls' drawings are indicated in blue-grey and from boys' in clear blue. (B) The average number of criteria used by girls (a) and boys (b) in a drawing is indicated by the notched boxplot. Significant differences between girls ($n = 51$) and boys ($n = 29$) are indicated by different letters (Welch two-sample t-test; p-value<0.001 for a and b). The notch displays a confidence interval based on the median, and box widths are proportional to sample size. (C) Analysis of the 80 drawings and 16 identification criteria (see Table 1) with principal component analysis (PCA). Biplot of individuals (drawings) and variables that explain the two first axes Dim 2,1 (left). Barycenters of the clouds of points of individuals of each gender are represented, with their confidence interval (ellipse).

in all drawings (Figure 3A). In the same drawing sheet, adolescents did not use the same number of criteria from one plant species to another; this induces a great variability in the level of details from one plant species to another drawn by the same individual. However, the participants used at least two criteria for each WEP drawn, with a mean number of 9.90 different criteria (SD = 1.52) by plant species drawn. On average, boys used more criteria in their drawings than girls, the difference being statistically significant in a Welch two-sample t-test (respectively avg = 10.48 with SD = −0.70; avg = 8.64 with SD = −2.97; $t = -3.2339$, df = 62.885, p-value = 0.001, Figure 3B). Overall, of the 500 plants represented, 64.4% of the identification criteria were morphological, again 35.5% non-morphological.

The PCA explains 41.1% of the variability between individual drawings on the first three factorial axes (19.5, 12.8 and 8.8%; axes 1, 2 and 3, respectively, Figure 3C; Figure S1). In the first factorial plane (Dim 2,1), the PCA grouped the variables in two main clusters: the morphological criteria (negative part of the first axis) and the non-morphological criteria (negative part of the second axis). Indeed, the first axis separates drawings using many criteria from drawings using few criteria, where all the morphological and phenological criteria (except for 'Roots') and the ecological criterion 'Soil' are linked with the negative part of the first axis. The second axis separates the drawings considering those that include ecological and anthropic criteria, found in the negative part of the axis, from the ones that do not include them (Figure 3C). The variables with a larger contribution to the first factorial plane are 'Uses', 'Fauna interaction', 'Reproductive phenology' and 'Flower morphology'. The second factorial plane (Dim 2,3) shows a similar pattern with a larger contribution of non-morphological variables, 'Uses', 'Fauna interaction' and 'Landscape items' (Figure S1).

The barycenter of the values for the variable gender (i.e. the mean point of individuals of the same gender, with 95% confidence ellipse) are separated by the axes on both factorial planes, suggesting that girls and boys do not use the same criteria to identify WEP, or use them in a divergent way in their drawings (Figure 3C).

3.3 | Precision level

When looking at the level of precision of adolescents' representation of the different WEP species, we found a variability within the same drawing. Adolescents' precision was variable among the different identification criteria used. For example, regarding morphological criteria, adolescents emphasized the fruit, flower and leaves morphology, providing a lot of details on the type, shape and colours of the organs represented by contrast with other criteria such as root systems, phyllotaxy or plant architecture. Indeed, adolescents drew and described during interviews a fruit morphology that is distinct from one species to another and often very precise and detailed such as the type of fruit or infructescence, its shape and colour. For example, the aggregated drupelets of the genus *Rubus* L., the simple or clustered drupes of the genus *Syzygium* changing from fuchsia to black as it matures (Figure 5ai), the accrescent calyx protecting the fruit of cape gooseberry (*Physalis peruviana*), or the fleshy 2-locular fruit of *Plagioscyphus stelechantus* (Radlk.) Capuron were often represented with details. Furthermore, sometimes the species was represented only by its fruit, the vegetative parts being absent and criteria like root systems were drawn with less precision, very simplified or just absent. Moreover, the precision level varies within identification criteria with the species drawn even within the same drawing (i.e. by the same individual). Big trees with small leaves were usually less accurately represented than easy to handle herbaceous plants. This is the case for example with the leaf morphology of *Passiflora* species, growing everywhere and daily consumed by children, for which tri-lobed leaves, tendrils and foliated stipule are almost systematically represented (Figure 5aii). Regarding non-morphological criteria, they were extremely precise and diverse. For example, biotic interactions included the detailed representation and explanations of the species of plants and animals interacting with the WEP, including the sex of the animals. WEP species were also contextualized in their habitat, with some drawings including details about edaphic conditions, ecology, phenological stages and humans using them (Figure 5biv).

When comparing the probability to reach the highest precision score for a selection of criteria for the four most represented plant species, we did not find a specific gender-related trend (Figure 4). In other words, for each criterion of each plant tested, the probability of high precision is highly variable showing or not gender differences without a clear repetitive gender pattern (Figure 4).

Finally, when comparing individual precision scores, we found that boys were overall more precise than girls in their drawing, as boys displayed more details ($t = -2.443$, df $= 54.14$, p-value $= 0.01$, of the Welch two sample t-test). In addition, we did not find any age effect on girls' precision scores. However, we found that boys' precision score is significantly positively related to age ($R = 0.48$, $p < 0.01$**), meaning that boys accuracy increases with age (Figure S2).

3.4 | Synergies between local and scientific knowledge

After checking each criterion used for each plant drawn (see example Figure 5a,b), we found that most of the plants represented (61.4%) matched with the botanical description or biotic interaction recorded in the literature. Overall, we found that morphological criteria matched with a lower percentage than non-morphological criteria (Figure 5c). Among the morphological criteria, the life form and the position of the fertile organs (fruit, flower) on the plants (apical, axial, cauliflory) were the criteria with the highest similarity with botanical description, respectively matching on at 81.2% and 70.74% on average. Precise details such as the spine, stipules or tendrils (EAD) matched at 69.75% on average (Figure 5a,c).

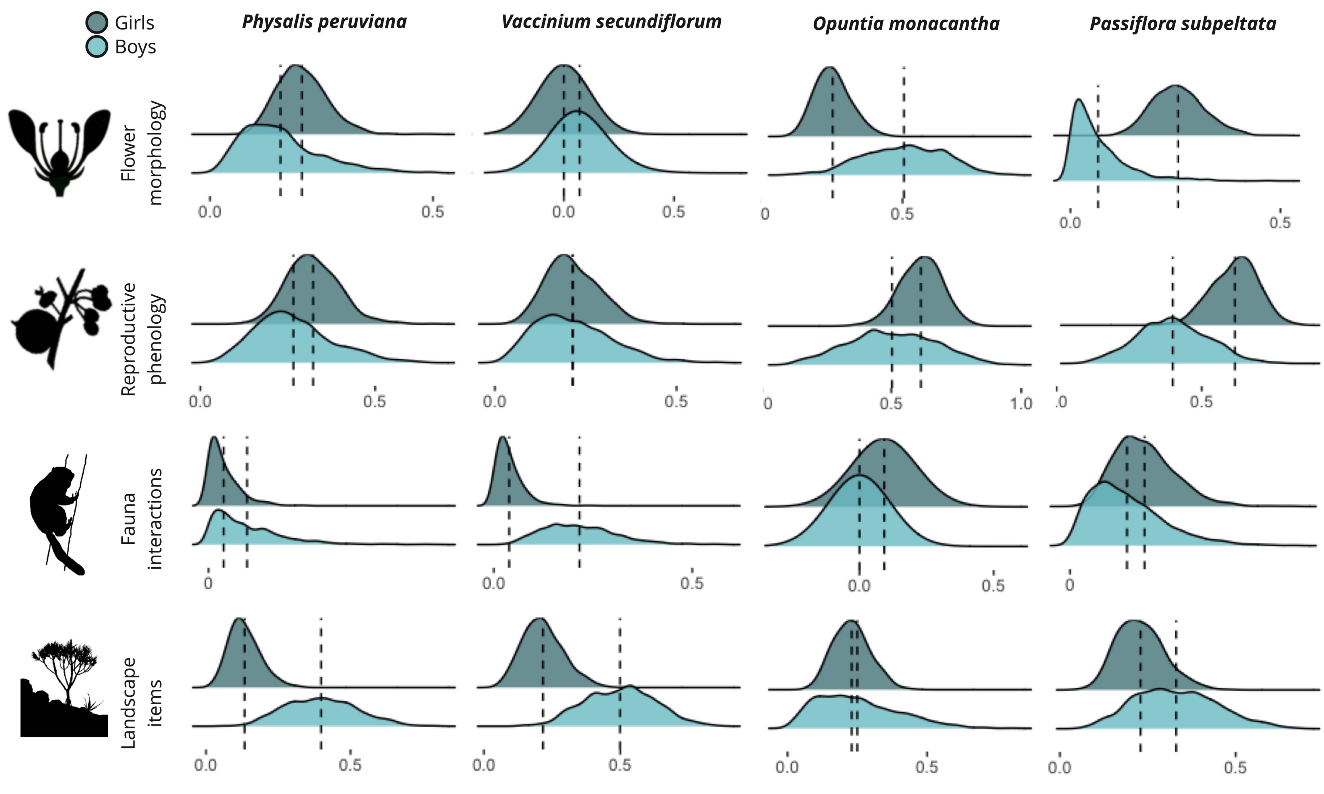

FIGURE 4 Precision level by criteria and species according to gender. 0 indicates the lowest probability to reach the highest score while 1 indicates the highest probability. Dot lines indicate the respective average probability of the group. Results from girls' drawings are displayed in blue-grey and boys' in clear blue.

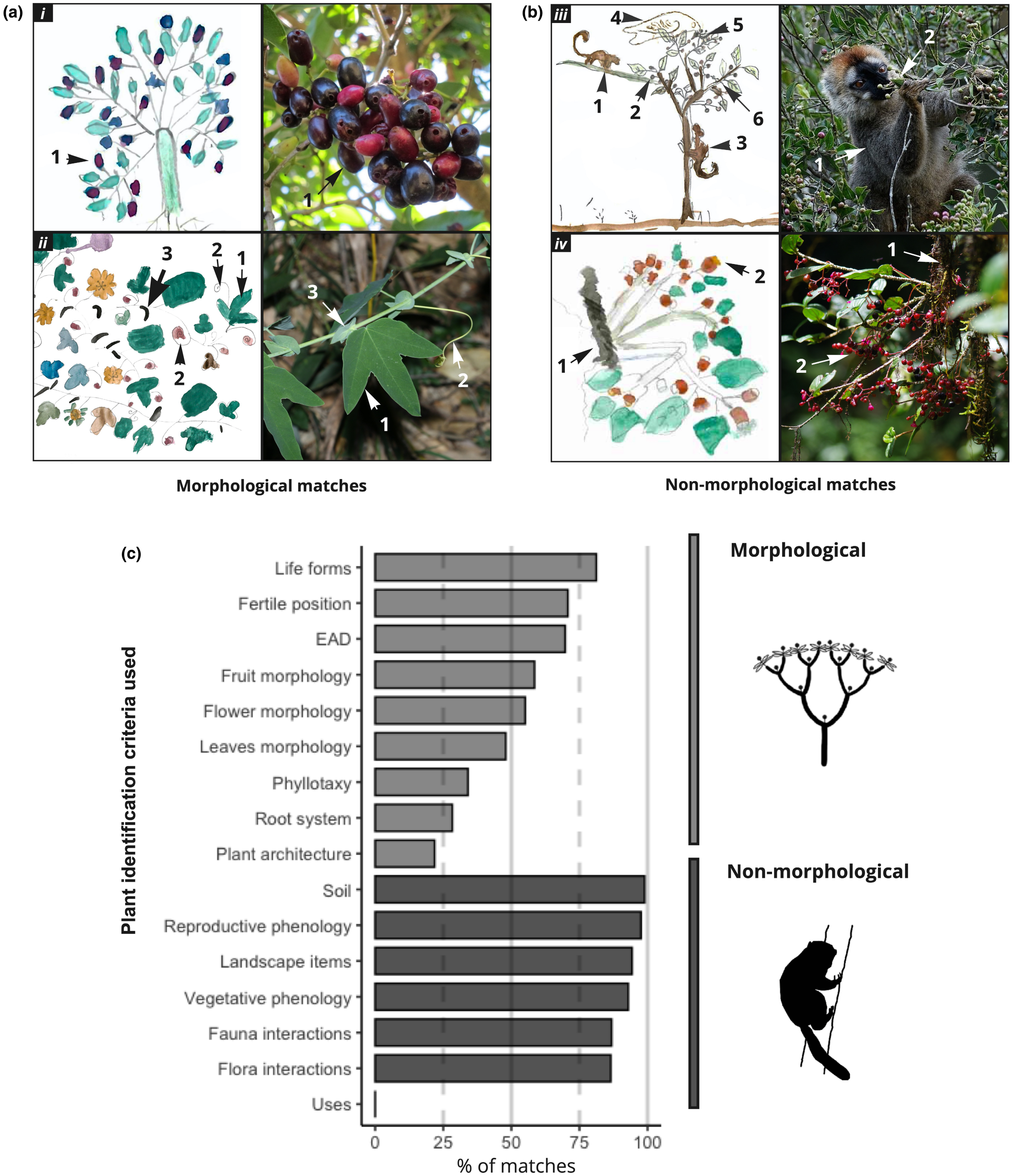

FIGURE 5 Similarity between plant identification criteria used by Betsileo adolescents and botanical identification. Selection of (a) morphological and (b) non-morphological criteria matching between adolescents' drawings (left) and naturalistic observations: pictures (right). Numbers indicate the corresponding matching point between the drawing and the pictures. (*i*) *Syzygium* clustered drupes turning dark (1). (*ii*) *Passiflora subpeltata*, tri-lobed leaves (1), tendrils (2) and foliated stipule (3). (*iii*) *Syzygium bernieri* fruit eaten by *Eulemur rufifrons* (1 & 2) and four other interactions with another lemur and three bird species (3, 4, 5 & 6). (*iv*) *Medinilla torentum* growing on rock and or epiphytic (1) with fruit and flower at the same time (2). Photo credits (*i*) Bat Vorontsova, (*ii*) Greg Tasney, (*iii*) Chien Lee, (*iv*) V.P. (c) Average percentage of matching between Betsileo's drawing and botanists per morphological and non-morphological criterion.

Fruit and flower morphology matched with botanical description at 58.5% and 55.1% while leaves morphology matched at 47.93%. Phyllotaxy, root systems and plant architecture matched botanical description by less than 40%. Non-morphological criteria, excluding 'Uses', all matched with ecological literature by over 75% on average. Information provided by adolescents through drawing and interviews about the soil, for example colour, texture and humidity, in which WEP species grow, matched 98.9% on average with literature. Reproductive and vegetative phenology as well as the landscape items describing WEP habitat matched over 90% with the literature. Information about fauna and flora interaction with WEP species were also highly matching with naturalist literature over 86% on average. In this sense, Betsileo's adolescents and scientists do focus on the same criteria to identify WEP species and their ecology.

4 | DISCUSSION

Betsileo teenagers display wide and rich ethnobotanical knowledge allowing them to accurately identify WEP species while using a large number of precise criteria involving deep knowledge about plant morphology and ecology. We found that plant identification knowledge varies with gender and age. Our results suggest that boys seem to use more criteria than girls to represent plants, and that boys' (but not girls') precision in the use of identifying criteria rises with age.

In answer to our original question: *How do children identify plants?* We discuss our results and their implications for understanding adolescent's folk taxonomy and knowledge acquisition according to three main aspects: (1) the criteria used, (2) the combination of different criteria and (3) the variability of this knowledge by gender and age. Finally, we discuss the limitations of our method and perspectives to explore further these knowledge realms.

4.1 | Plant identification criteria

Adolescents use a great diversity of criteria to identify and distinguish one plant species from another, drawing rich representations of plant species. Our results are the first ones to show the richness of such knowledge, as the few previously existing works only provide anecdotal information suggesting the existence of such knowledge, but do not fully explore it.

Like most flora and botanical determination keys developed by botanists, Betsileo adolescents use a strategy to identify plants drawing on a series of details—whose number and nature varies from one species to another (Scharf, 2009). Indeed, we found that adolescents were not only precise and used multiple criteria to identify plants but that more than half of the knowledge presented matched with botanists' representations of the same species (Figure 5c). In that sense, both knowledge systems seem to converge partially on the criteria used to identify plant species. However, we found that morphological criteria were both less precise and less similar to scientific records than non-morphological ones. This lower level of precision might be due to individual reinterpretation of identification criteria, which might have been not fully understood or remembered, inducing errors in the drawing. This interpretation will be in line with the fuzzy-trace theory of memory, which states that humans encode information into two traces: in verbatim (i.e. the exact memory of a detail or pattern) and in gist (i.e. a semantic and conceptual memory of what we perceive the pattern to be) (Barghout, 2014). Considering that drawing is a projective tool requiring recall capacity, we think that the lower precision in plant drawing might be due to information encoded as gist by teenagers. This suggests that, while learning how to identify plants, teenagers might consciously focus or not on some specific criteria and detail rather than on others. Indeed, the criteria most used by adolescents were the fruit morphology, the fertile position, and the life forms, criteria used by more than 75% of our sampling. The focus on fruit might be explained by the fact that 74% of the species drawn are consumed for their fruit, and the results could be different if the focus of the work was not on WEP. Using the part consumed or sought after as a main criterion for identifying plant species is a common strategy in small-scale societies (Jernigan, 2006; Shepard Jr, 2004). Despite low precision in specific criteria at the plant level, teenagers displayed high precision while drawing and detailing plant parts (particularly flowers, fruit and leaves), which actually resulted in the creation of a specific variable (EAD) to catch precision in these observations. Also, non-matching morphological criteria between the drawings and scientific records might be interpreted as both the results of a fuzzy representation of criteria receiving less attention by adolescents and as an unexplored divergence between knowledge systems (Aikenhead & Ogawa, 2007). The diversity of criteria used unveils the deep understanding that adolescents Betsileo have of plants by both describing fine morphological specificity and contextualizing them into a biotic and abiotic network of interactions.

4.2 | Combination of criteria

Beyond the diversity of criteria used, our results show that Betsileo adolescents frequently used these criteria simultaneously, using on average ten different criteria to describe a species. Moreover, our PCA shows that criteria were used by clusters (Figure 3C), which suggests that an individual using a criterion of a given cluster is likely to use at the same time one or several criteria of the same cluster. In other words, for Betsileo adolescents plant identification relies on a wide spectrum of details—not limited to the morphological criteria—used in combination to provide a holistic identification. Thus, rather than as a juxtaposition of observed details, the plant species drawn are a complex and coherent figuration of what the individual understood (consciously or not) about the plant and the different relations between elements of the plants and with the surrounding environment (plant organ, animals, landscape items). This holistic perception is also intrinsic to certain criteria such as phyllotaxy, the position of the fertile organs or even the architecture of the plants, which are all based on a spatial organization of the different parts of the plant. This is well illustrated by Figure 5biv, where the teenager used these three criteria together to draw a *Medinilla torentum*. In that drawing, the phyllotaxy (opposite leaves), the position of the fruits (axial on the last internodes or modules) and the architecture (model of LEEUWENBERG, Hallé & Oldeman, 1970) in the drawing not only precisely match with the photo (Figure 5biv) and the botanical description, but also reflect a deep understanding of growth habit of the plant species. It is worth noting that identifying plant species by means of holist perceptions and interpretations of interwoven cultural and biological dimensions have been foreseen and studied across different cultural groups (Dev, 2018; Greene et al., 2020; Shepard Jr, 2004). Unlike standard botanical determination keys, usually based on 'step-wise analyses' focusing on distinctions between plants (Scharf, 2009), our result suggests that young Betsileo might identify plants following a model proposed by gestalt psychology. Gestalt psychology considers that the processes of perception and mental representation treat phenomena as a coherent whole, a system, emphasizing less on the elementary units of this system than on the relations that unite them (Kohler, 2015; Wagemans et al., 2012). This aligns with a significant body of research suggesting that local ecological knowledge is holistic in nature (Berkes & Berkes, 2009; Latour, 2012; Tagalik, 2018). Thus, this consideration justifies our holistic approach using drawing interviews, giving a glimpse of the rich and complex knowledge system held by teenagers to identify plant species.

We found that 35.5% of the criteria used to identify plants were non-morphological. Indeed, we regularly found different species of lemur and birds represented with sexual dimorphism (see Appendix S1). For example, the red fody male (*Foudia madagascariensis*) builds the nest in a Malagasy bleu berry bush (*Vaccinium secundiflorum* Hook.) (Figure 2b). Similarly, we frequently found lemur from the genus *Eulemur* (probably *Eulemur rufifrons* (Bennett, 1833)) feeding on *Syzygium* (Figure 5ai). Finally, plant-insect interactions were also represented, particularly host plants' relationship with undetermined Lepidoptera with *Passiflora* and Malagasy silkworm (*Borocera cajani* Vinson, 1863) with *Aphloia theiformis* (Vahl) Benn. The use of other species to identify or spot the desired species (or other elements of nature) have been observed in other small-scale societies such as Hadza people using the honeyguide bird to find beehives among others (Cram et al., 2022). The ecology and the vegetation where the WEP grow was also very detailed during interviews. This important rate of non-morphological criteria involved highlights the importance of the context in the plant identification process and suggests a complex holistic understanding. Moreover, the great precision in the representation and identification of plant species by their morphology and ecological environment suggests that young Betsileo have a great capacity to observe and recall their surroundings. Indeed, children's and adolescent's observation ability has been recorded in several small-scale societies across the world. For example, an Eveny Siberian pastoralist adolescent is able to recognize each reindeer in a herd of several hundred (Willerslev & Ulturgasheva, 2012), and Aché (Paraguayan forest foragers) and Khanky (Siberian pastoralist) children can follow tracks and not get lost using fine detail such as broken twigs, and moss on trees (Golovnev & Golovneva, 2016; Hill & Hurtado, 2009).

4.3 | Gender and age variability

Our most striking result is that the criteria and the level of precision used to identify plants vary according to gender and age. Indeed, we found that boys used more criteria than girls but also distinct ones. Our PCA showed that girls were less likely to use non-morphological criteria such as landscape items or biotic interactions. Boys were also more precise than girls and became more precise as they grow up, meanwhile, girls' precision does not evolve with age. This distinct pattern in identification knowledge can be discussed through the lenses of socio-cultural and ecological context. In most small-scale societies, adolescence is a pivotal period when socio-cultural norms such as the gendered division of labour are adopted and guide the daily activities of individuals in different ways (Fehr et al., 2008; Gallois et al., 2018; Lew-Levy et al., 2020). In the Betsileo context, the gendered division of labour results in a specialization of ethnobotanical knowledge but also a great contrast in the mobility of individuals (Porcher et al., 2022). Boys, who are more likely to be involved in herding, are expected to move more frequently and widely through different ecological habitats than girls, whose mobility is restricted to the domestic sphere and crop fields. Therefore, girls and boys interact with different plant species in different ecological and sensory contexts. This could explain why boys use more criteria related to biological interaction than girls. The long days spent watching over the herds might allow them to keep a close eye on the ecological cradle where the edible plants they collect grow. In addition, young Betsileo boys are in their childhood formidable bird hunters suggesting a wide spectrum of complementary ecological knowledge (Viano, 2004). Together our results suggest that girls and boys have different exposure to nature for which they might have developed different strategies to identify WEP species, strategies that are adapted to the social-ecological context in which they grow. In ecosystems such as moist altitude dense forests—surrounding the valley, identifying plants might require being more precise and multiplying the number of criteria used to ensure a correct plant identification among the great diversity of plant species occurring in this habitat. However, in the village surrounding where girls mainly live and work (e.g. crop field, home garden), the WEP diversity is well-known, named and used by most of the Betsileo (Porcher et al., 2022), the probability to misidentify or being confused with another plant might be lower than in any other ecosystems, which might not imply to develop or use the same criteria to identify plants. Both Betsileo girls and boys increase their mobility while growing, but boys are more mobile which exposes them to many distinct ecosystems while herding. Therefore, the increasing precision with age we found in boys might be correlated to their increasing mobility and thus, the need to improve and adapt their identification knowledge to a wider ecological context.

In addition, by looking at teenagers' ability to represent a criterion with high level of precision for a given species, we found that there is also some species-dependent pattern according to gender (Figure 4). Indeed, for the same species tested, girls and boys do not focus on the same criteria, with the same precision. This finding supports our precedent idea showing that girls and boys experience the plant species differently and suggest that they developed their sense of observation and build knowledge in a different context reflecting a gendered socialization. That also might be the case for other sensory modalities which need to be addressed in further research (Shepard Jr, 2004). Finally, our findings indicate that girls represented a greater number of WEPs compared to boys, suggesting a more comprehensive understanding of the diversity of WEPs. This result is consistent with our prior research, which demonstrated that girls exhibit greater knowledge of WEPs and, more specifically, on the herbaceous plants used in daily side dishes than boys (Porcher et al., 2022). This intracultural variability in LEK (i.e. boys' identification skills and girls extended knowledge of WEP's diversity and uses) supports previous evidence on the importance of the role of the socio-ecological environment in understanding LEK variability in children. Variability in children's LEK is also linked with the knowledge acquisition and transfer process, where an important share of LEK in small-scale societies might be transferred horizontally, from child to child (Gallois et al., 2018) but also with siblings and parents of their respective gender and the place where they learn that LEK (Jaun-Holderegger et al., 2021; Porcher et al., 2022; Soga et al., 2018).

Finally, we are aware that gender variation in the children's LEK we observe might also be due to gender-shame (Gazelle et al., 2014), resulting in shyness during drawing activities and interviews, despite the precautions taken by the researchers.

4.4 | The invisible spectrum

It is first worth noting that the diversity of WEP species drawn by Betsileo adolescents represents more than ¾ of the diversity previously found with other methods (84 sp, see Porcher et al., 2022). In that sense, our method is relevant for understanding which criteria are used by the Betsileo for identifying the WEP as it provides information that covers a representative sampling of the WEP in the area. Thus, our drawing-interview method provides both qualitative and quantitative data allowing us to deepen our understanding of local knowledge realms.

However, we are also aware that our method and approach probably caught only a fraction of the criteria really used by young Betsileo, and this is so mainly for three main reasons. First if, as mentioned, young Betsileo identify plants through a multitude of criteria interpreted as a coherent whole, then it is possible that some of the criteria used must also be unconscious, or not empirically perceptible, materialized by sensations or feelings; this would constitute a limitation when using drawings.

Second, we decided to base our analysis on standard criteria well-known from botany, but many other criteria to identify plants, including morphological ones, might escape from traditional botany. For example, plant architecture is a recent discovery in botany and a great tool for identifying and classifying plants (Barthélémy & Caraglio, 2007; Hallé & Oldeman, 1970) and indeed 25% of our sample used plant architecture as criterion. The relevance of this criterion recently added to the botanist toolkit suggests that other criteria not yet considered by botany might be used by local communities and might have escaped our analysis. To minimize this bias, further research might work with local people in co-producing a list of criteria using a multiple-evidence-based approach (Roue & Nakashima, 2018; Tengö et al., 2014).

Finally, we choose to focus on visual criteria through the use of drawing, which limits the plant representation into a two-dimensions figuration, challenging teenagers' figure-ground organization (Wagemans et al., 2012) and forcing them to be creative in their graphical representation of complex criteria. This might bias our data favouring individuals with better capacities in this type of representation. This is the case, for example, in a drawing shown above (Figure 2b), where the child has found a way to represent in two dimensions the margin of the leaf as it rolls up while drying. Moreover, by focusing on visual aspects, our approach does not allow us to elicit other sensory criteria such as sound, textures, smell, taste or other sensory and emotional experience that may play an important role for children in taxa identification, particularly as sensory sphere constantly evolves during childhood (Morris, 2010; Vennerød et al., 2018). Indeed, among these different sensory aspects, the chemosensory—that is, smell and taste—has been the subject of studies demonstrating its key role in the identification of tree species and medicinal properties by both local people (Jernigan, 2006; Shepard Jr, 2004) and botanists (Schatz & Wilmé, 2001). Less studied, proprioception and touch, by the feet also play a role in tree identification for Maasaï children by feeling the texture, the thorns and the flexibility of the branches to which they climb (Tian & Leÿs, 2021).

Considering our results and their limitations, our work is a first step both unveils a diverse and complex system of criteria to identify plant species and suppose the existence of an *invisible spectrum* of local knowledge driven by sensory modalities and performativity, requiring new approaches and methods to be recorded, adapted to children. Therefore, further research should be devoted to develop new approaches for assessing the identification criteria, and ecological knowledge in general, including not only the cognitive but also the sensory and emotional part of the human-nature relation. Finally, sensory and emotional approaches may have relevant implications in environmental awareness programmes and could be used as embodied learning processes (Downey, 2010; Stagg et al., 2022).

5 | CONCLUSION

Betsileo adolescents hold a broad and sophisticated system of plant identification based on a deep knowledge of plant morphology and ecology, involving a wide spectrum of identification criteria, which vary according to age and gender due to distinct daily experiences with plants and habitats. While this study offers valuable insights into the specific context of the Betsileo community, its implications extend beyond this population, offering important considerations for broader discussions on people and nature relationships developed during childhood. Indeed, plant knowledge, acquired very early in childhood, constitutes the foundation of future interactions with nature and should be at the heart of environmental humanities studies and knowledge co-production projects to tackle socio-ecological concerns. Moreover, this knowledge caught by our drawing-interview method and transdisciplinary approach seems to involve different knowledge dimensions beyond cognitive aspects, suggesting a large spectrum not yet explored. Therefore, we encourage further studies to explore these aspects by developing new children-adapted methods and approaches complementary to conventional ethnoecological tools and by adopting sensory approaches into environmental awareness programmes.

AUTHOR CONTRIBUTIONS

V.P., S.M.C., S.G., V.R.-G. conceived and designed the study. V.P. and S.C.R did the ethnobotanical work; V.P. and S.A.-F. analysed the data; and V.P. wrote the first draft of the paper and prepared figures. All authors discussed the results and commented on the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors have declared that no competing interests exist.

DATA AVAILABILITY STATEMENT

The dataset used to (i) build individual profiles based on identification criteria and (ii) to calculate and compare the precision level score; were deposited in the Zenodo database under https://doi.org/10.5281/zenodo.7844959.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Appendix S1: Coding the plants by criteria and level of complexity.

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