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Drawing our garden's insects: a didactic sequence to improve pre-service teachers' knowledge and appreciation of insect diversity

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ABSTRACT
Insects form a highly diverse taxonomic group, which has fundamental ecological functions, but is currently in a process of mass extinction. Here, we present the first cycle of design, implementation, and assessment of a didactic sequence oriented towards improving pre-service teachers' knowledge and appreciation of insect diversity. A methodological approach aiming to promote rigorous observation was followed, for which activities consisting of scientific and naturalistic drawing, among others, were included. The sequence was contextualised at a university organic garden, both to make learning meaningful and to promote new personal experiences with alive insects. We present the empirical results of the first implementation with a group of 28 pre-school (3–6 years) pre-service teachers at a Spanish university. Assessment was based on the analysis of drawings with a purposely designed instrument to assess constructive accuracy, and on the qualitative analysis of open questions that were posed before and after the implementation. Positive results were obtained regarding participants' knowledge of insect diversity, and positive impacts were observed also on their attitudes. Improvements to some activities are suggested before subsequent implementations of the didactic sequence. Finally, our study supports the effectiveness of maintaining organically managed gardens as facilities for biological education.

KEYWORDS
Art education; design-based research (DBR); drawing; garden-based learning; insects

Introduction

Biological education aims to promote and enhance knowledge and appreciation of biodiversity. This is a key educational topic (Gaston and Spicer 2004; Van Weelie and Wals 2002), the understanding of which requires basic knowledge about species, their identification, and life history (Lindemann-Mathies, 2022; Randler 2008). For this purpose, the need to incorporate direct experiences with nature and living beings involving cognitive, affective, and evaluative modes of learning has been emphasised (Drissner, Haase, and Hille 2010; Hummel and Randler 2012). Insects are the most abundant and biologically diverse group of organisms on the planet (Chapman 2009). They are a fundamental part of trophic networks and key elements in ecological processes, such as pollination and nutrient recycling (Black, Shepard, and Allen 2001), and are currently undergoing an unprecedented decline, with 40% of species at risk of extinction, with disappearance rates being eight times higher than those of mammals, birds, and reptiles (Sánchez-Bayo and Wyckhuys 2019).

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Including insects both in early years education (pre-school and primary school stages) and at initial teacher training, has been repeatedly recommended by literature on biological education (Hummel, Randler, and Prokop 2012; Wagler and Wagler 2011). One of the main reasons for this is the consistent evidence showing scarce knowledge and appreciation of insect biodiversity, even in well-educated populations such as undergraduate students (Shipley and Bixler 2017). Practical work on insects at school may increase knowledge and reduce rejection and fear of insects (Hummel and Randler 2012; Hummel, Randler, and Prokop 2012), since specific fears or phobias are known to develop during childhood (Marks and Gelder 1966). Moreover, it has been argued that the maintenance and educational use of insects as model organisms for teaching sciences supports instruction on important scientific ideas (Golick and Heng-Moss 2013). Finally, it has been suggested that insects exhibit a range of unexpected anatomical traits that can be fascinating for children (Shipley and Bixler 2017).

Including insects in scientific education at initial teacher training may, in turn, promote their consideration at pre-school and primary school stages (Gómez Prado, Puig, and Evagorou 2020; Wagler 2010; Wagler and Wagler 2011), which would be a desirable goal of biological education given the current scenario of insects' decline. Thus, the main purpose of this work is to present a didactic sequence including cognitive, procedural, and attitudinal content in relation to insect diversity. In its design, we followed a strategy based on promoting observation, and posed pre-service teachers (PST) the final challenge of drawing insects living in our university garden. We also present empirical evidence derived from the assessment of its implementation with a group of pre-school PST, based on a pre-post information gathering scheme.

Theoretical framework

Research approach: teaching-learning sequences and design-based research

Didactic sequences, or teaching-learning sequences (TLSs), are a key tool for teachers to plan teaching and learning processes. They consist of small- or medium-scale curricular products that cover the teaching and learning of a specific scientific topic (Guisasola and Oliva 2020). Designing TLSs involves making design decisions at two levels: the macro - to ensure the consistency of the entire sequence, and the micro - for each session (Artigue, 1992). Such decisions include (1) selecting, clarifying and organising contents for a particular educational level, including the consideration of their scientific significance, and of their educational significance from the perspective of *science for all* (Fensham 1985) or *scientific literacy* (Millar and Osborne 1998); (2) defining the objectives; (3) inquiring about and considering learners' alternative frameworks to anticipate the learning difficulties that may appear; (4) selecting one of the various possible methodological strategies, (5) choosing or designing activities according to *learning demands* (Leach and Scott 2002) or *zone of proximal development* (Vigotsky 1978); (6) deciding how to assess each activity according to both the objectives and chosen methodological strategy; (7) and finally, sequencing activities (Couso 2012; Zabala and Arnau 2007).

Importantly, the design of TLSs includes one or several cycles of design, implementation, assessment, and refinement (Méheut and Psillos 2004). It is therefore essential to evaluate the learning results achieved, and then to connect them again with the design (Guisasola et al. 2017), in line with the methodological approach of Design-Based Research (DBR) (Andersson et al. 2005; Cobb et al. 2003). In the current framework of science education oriented towards promoting scientific competence (OCDE 2006), the interest in TLSs and DBR has been reinforced, particularly in relation to contextualisation in real situations that are significant for students' personal, social, or future professional lives (Gilbert, Bulte, and Pilot 2010; Muñoz-Campos, Franco-Mariscal, and Blasco-López 2020).

Of the variety of existing proposals to guide the design of TLSs, we chose that of Giné and Parcerisa (2003) and Zabala and Arnau (2007), who follow a constructivist perspective that is close to Vygotsky's (1978) socio-constructivist vision, and recommend a structure in three phases:

(1) the initial or opening phase, which involves introducing the topic, motivating students towards learning it, and identifying students' interests, motivations, and initial knowledge, which need to be considered to promote greater adaptation of activities.

(2) the development phase, focused on the reconstruction of knowledge; this must include activities of different types and with different social organisations (individual, group, class). During this phase, teachers will need to adapt to the needs, problems, and situations that may arise.

(3) the final or closing phase, which includes activities to review and synthetise content, and to apply knowledge. A final evaluation is also encouraged, aiming to measure the distance between students' initial and final knowledge.

Students' initial ideas

Considering learners' misconceptions or alternative frameworks is a well-established requirement (Couso 2012). It involves inquiring about students' views, conceptions, and affective variables of the scientific topic, and considering them to make design decisions. In our case, it was necessary to consider that insects are often perceived in terms of aversion, dislike, disgust, and fear (Kellert 1993; Schlegel, Breuer, and Rupf 2015; Wagler and Wagler 2011), which is probably due to: (1) their morphology (Gómez Prado, Puig, and Evagorou 2020; Wagler and Wagler 2012), (2) individuals' personal and cultural experiences (Lockwood 2013; Lemelin et al. 2016), (3) gender – males report disliking them less (Byrne et al. 1984; Schlegel, Breuer, and Rupf 2015), and (4) knowledge – enhanced knowledge results in improved attitudes (Breuer et al. 2015; Schlegel, Breuer, and Rupf 2015). Moreover, it is common to consider the terms 'bugs' and 'insects' as synonymous. 'Bugs' is in fact a folk taxonomy, i.e. a culturally constructed way of classifying biodiversity (Berlin, Breedlove, and Raven 1973), which includes a variety of invertebrates such as worms, some molluscs, and most arthropods. Thus, when children are asked to draw an insect, they also draw other invertebrates, such as spiders, scorpions, centipedes, millipedes, and snails (Snaddon and Turner 2007).

In Spanish compulsory education, invertebrates are studied during the first year of secondary school (12-year-old), when two sessions are devoted to arthropods (Romero and Romero Rosales 2015). Insects are not purposely addressed either in compulsory or post-compulsory secondary education and thus, Spanish PST' knowledge on insect anatomy, taxonomy, and diversity is scant, as has also been reported for other countries (Snaddon and Turner 2007; Shipley and Bixler 2017). The most common didactic proposal on insects at pre-school stage in the country consists of observing the life cycle of the silkworm (*Bombyx mori*), which can be purchased and maintained with minimal care (mulberry leaves for adults), and whose butterfly is of a great beauty. The curricular inclusion of insects at pre-school education may thus be diversified and enriched by promoting pre-school teachers' knowledge and positive attitudes towards insects, which constitutes the main purpose of this work.

Teaching approach

Insect morphology being one of the main reasons for negative attitudes (Gómez Prado, Puig, and Evagorou 2020; Wagler and Wagler 2012) made us select a visual teaching strategy aimed at promoting rigorous observation and including scientific and naturalistic drawing. Scientific drawing and naturalistic drawing are two approaches closely linked to scientific activity that differ in important characteristics. Naturalistic drawing aims to convey a general impression of the subject and is more freely and quickly developed. It is frequently used to complement handwritten notes, that need to be taken fast. On the contrary, scientific drawing involves slow work and, sometimes, an additional documentation process.

Drawing is known to contribute to a deeper understanding of scientific topics, since it stimulates intense observation processes and allows for effective data recording and subsequent study (Katz 2017). Several theoretical frameworks have dealt with the role of drawing in learning, such as the *dual coding theory*, which considers that integrating verbal and non-verbal information facilitates the construction of a coherent mental representation, and that a combination of images and text promotes recalling (Paivio 2014), and the later *theory of generative learning*, which considers that drawing promotes the connection of previous knowledge and new content, contributing to the construction of mental models and encouraging higher levels of understanding and recall (Fiorella and Mayer 2016). In addition, there is a general agreement about spontaneous drawing as a useful tool to detect inner conceptions about scientific topics (Giordan and de Vecchi 1988; Katz 2017). However, there are several associated difficulties: drawing is a complicated task for many people, requiring spatial abilities that are hard to develop, and is time-consuming and cognitively demanding (Fiorella and Zhang 2018). Drawing insects is challenging for additional reasons, such as the variety of shapes, complexity of structures, and small size (Rouaux 2014). In this respect, the role of the teacher is known to be of key importance; when students draw without close guidance, they can easily feel discouraged and may not invest the required effort (Schmidgall, Eitel, and Scheiter 2019), but under specialist guidance, their graphic progression can develop surprisingly fast (Edwards 2012).

Our sequence also included activities to familiarise participants with identification books and dichotomous keys, which are also based on rigorous observation of organisms and are appropriate to promote methodological skills and life-long learning in taxonomy (Randler and Bogner 2006; Randler and Knape 2007). According to Moline (2012), merely using images for learning purposes can be very demanding. Since 'a diagram simplifies, generalises, highlights defining facts, and omits minor details' (Moline 2012, 49), good scientific illustrations need to adopt an explanatory and constructive approach, in which case, they would be even better for learning purposes than photographs, which 'can show how a particular insect may look, but not how it works' (Moline 2012, 48).

Learning contextualisation

The contextualisation of TLSs in real situations that are significant at the personal, social, or professional level is considered of major importance in the framework of science education oriented towards promoting students' scientific competence (Gilbert, Bulte, and Pilot 2010; Muñoz-Campos, Franco-Mariscal, and Blasco-López 2020). We used an organically managed garden that is located on campus to contextualise our sequence; its focus was to improve knowledge and appreciation of our garden's insect diversity, with a final challenge being to draw and identify insects from the garden during an outdoor session at the garden. Integrating science content and outdoor experiences is encouraged in biological education, to promote cognitive and attitudinal learning (Drissner, Haase, and Hille 2010; Hummel and Randler 2012), as well as evaluative development, i.e. the development of values, beliefs, and moral perspectives in children (Kellert, 2002; Askerlund and Almers 2016). Moreover, in the case of PST, such outdoor learning experiences act as a model for their future professional practice (Lindemann-Matthies 2006; Torquati et al., 2013). Learning gardens provide the chance to offer outdoor experiences to students (Williams and Dixon, 2013), and moreover constitute ecological systems whose elements, relations between elements, and processes can be scientifically approached. The use of learning gardens to increase students' awareness of the presence, roles, and importance of insects in ecosystems has been encouraged, and related to the implementation of sustainable agricultural practices, such as installing insect refuges or planting melliferous plants (Eugenio-Gozalbo, Aragón, and Ortega-Cubero 2020). Despite the increasing body of literature on garden-based learning, examples of didactic implementations with this orientation are scarce (Fisher-Maltese and Zimmerman 2015).

Objectives

The main purpose of this work is to present the first cycle of design, implementation, and assessment of a TLS for pre-school (3–6 years) PST aiming to improve their knowledge and appreciation of insect diversity. The TLS was designed considering PST' views, conceptions, and affective variables of this scientific topic (Figure 1) and following a socio-constructivist approach. To assess it, information was gathered based on a pre-post scheme, and afterwards analysed. We aimed to empirically answer the three following questions: 'Has the didactic implementation improved . . . ': (1) anatomical knowledge of insects? (2) taxonomical knowledge of insects? And (3) attitudes towards insects in PST?

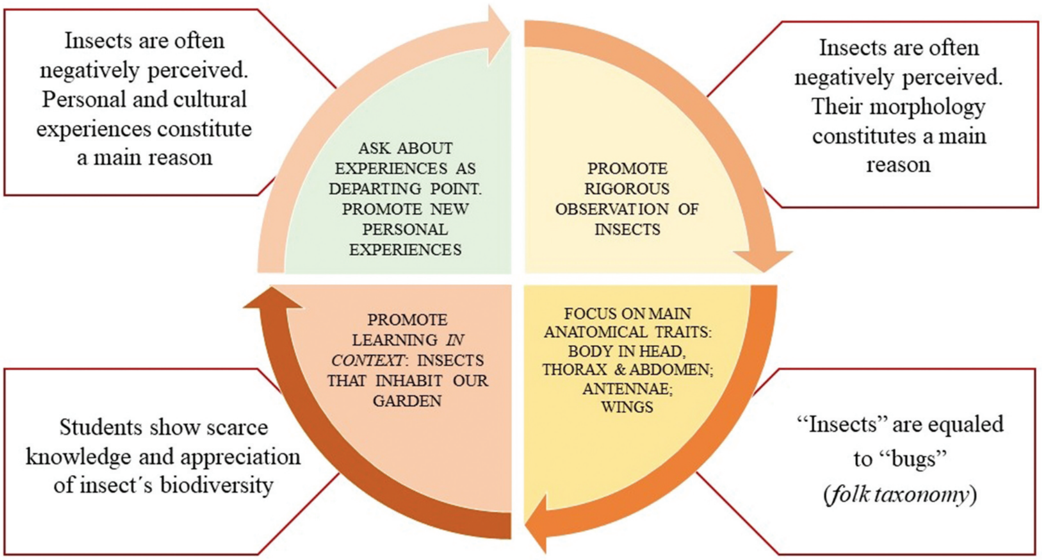

Figure 1. Main relations between literature inquiry on student's initial ideas and design decisions.

Description of the educational context and the teaching-learning sequence

The TLS was designed in the framework of an educational innovation project dealing with the use of organic gardens at university to promote PST' scientific competence. It was implemented during the academic year 2018–2019 with 28 PST (mean age = 21.8 years, 96% women), as part of a compulsory course on Natural Sciences taught during the third year of the education degree. The organic learning garden of the Campus of Soria (University of Valladolid, Spain) is a fenced area surrounded by a natural landscape where the upper course of the river Duero runs between hills and gorges. Cultivation techniques are sustainable: composting and vermicomposting organic waste, mulching, associating plants, and avoiding biocides and fertilisers, among others (Figure 2 and Figure 3).

Implementing the TLS took 13 hours of lectures, plus an estimated time of 3 hours of work at home. It was structured in seven sessions of between 1 h 35' and 2 h 30'. Our didactic objectives are presented in Table 1, content in Table 2, and activities in Table 3. The TLS included hands-on activities combined with more theoretical work; activities to be conducted individually, in work groups, and in the whole class context; as well as outdoor learning at the garden. Activities related to visual information were numerous (such as observing living and non-living insects, drawing them, watching a documentary, and using identification books and dichotomous keys), as we had decided to follow a teaching strategy based on observation.

Table 1. Didactic objectives of the TLS: 'Drawing our garden's insects'.

a) To improve taxonomic knowledge about insects	b) To improve anatomic knowledge about insects	c) To improve attitudes towards insects
a.1. To distinguish Insects from other invertebrates such as worms and molluscs	b.1. To distinguish the three sections in which the body of arthropods is segmented	c.1. To know which insects sting or bite, and which ones do not
a.2. To know the existence of 4 big groups of arthropods (Chelicerated, Myriapods, Crustaceans, and Hexapods), and their main characteristics	b.2. To realise that arthropods have articulated parts consisting of appendages	c.2. To manipulate real insects, both dead and alive (without shouting)
a.3. To distinguish Insects from other arthropods	b.3. To realise characteristics of the body of Insects which are used to classify them, such as antennae, wings, compound eyes, and a variety of mouthparts	c.3. To realise how abundant and important insects are
a.4. To know 8 important orders of insects and their main characteristics (Odonates, Hemiptera, Lepidoptera, Diptera, Hymenoptera, Coleoptera)	b.4. To use these observations to classify insects	c.4. To understand the roles and ecological importance of insects

Table 2. Conceptual, procedural, and attitudinal contents of the TLS: 'Drawing our garden's insects'.

Concepts	Procedures	Attitudes
- Invertebrates-arthropods-hexapods-insects	- Observation of body characteristics	-Reducing fear and disgust towards insects
- Thorax, abdomen, head	- Scientific and field drawing of insects	-Increasing appreciation of insect diversity and ecological importance
- Antennae, wings, compound eyes, mouthparts	- Use of identification books and dichotomous keys	
- Insects' lifecycles, habitats, environmental requirements, reproduction	- Classification of common insects	

Methods

The TLS assessment followed a pre-post design and was based on a self-administered open questionnaire that PST answered individually, both on-line (in a Word document) and on paper (for drawings) (Act. 2 and Act. 12, Table 3), comprising the following questions:

Q1. What insects do you know? On a separate sheet, draw 5 of those insects.

Q2. Of these, are there any that trigger your rejection? Which ones? Could you explain why?

Q3. Of these, do any scare you? Which ones? Could you explain why?

Q4. Of these, do you feel inclined to like any of them? Which ones? Could you explain why?

Q5. Could you match the following common names of insects with the groups or taxa to which they belong? Bee, dragonfly, bedbug, grasshopper, butterfly, dung beetle, moth, ladybug, damselfly, ant, fly, firefly, cricket, wasp, bumblebee, mosquito (Odonata, Hemiptera, Lepidoptera, Diptera, Hymenoptera, Coleoptera)

Additionally, PST were asked two questions in the final examination for the course (Act. 13, Table 3):

Q6. Say to which taxa the organisms in the photographs belong, and relate them to their most relevant characteristics from the list (butterfly, kestrel fly, ladybird, true bug, grasshopper – pictures taken of garden insects)

Q7. Could you relate the following common names of insects to the groups or taxa that appear below? (Dragonfly, grasshopper, dung beetle, damselfly, ant, firefly, cricket, wasp, bumblebee, mosquito)

Table 3. Structure and activities of the TLS: 'Drawing our garden's insects'.

Phase	#	Description	Social Org.	Resources	Time
Initial	1	Short oral introduction	Class	None	10′
	2	Initial ideas' elicitation	Individual	Open questionnaire	1 h 30′
Development	3	Scientific drawing seminar	Work groups	-Expert presentation -Insect collection -Drawing materials	2 h/20 students
	4	Documentary display	Class	CD 'Microcosmos'	1 h 20′
	5	Master lecture: a primer to insect taxonomy	Class	Expert presentation	45′
	6	Laboratory practice: identification of our gardens' soil fauna	Work groups	-Soil samples -Binocular loupes, tweezes -Adapted dichotomous keys	1 h
	7	Work at home: Elaborate a presentation on a taxonomic group of insects	Work groups	Computer Internet Books	2 h
	8	Present it to the class	Work groups	Presentations	15′/work group
	9	Master lectures: (1) Insects found at our garden, and (2) Field insect drawing	Class	2 Experts' presentations	30′
	10	Garden practice: drawing and identifying our gardens' insects	Work groups	-Drawing materials -Hats and sun glasses -Identification books and dichotomous keys	2 h/20 students
	11	Work at home: read the latest scientific news	Individual	2 scientific reports on insects decline	1 h
Final	12	Final ideas' elicitation	Individual	Open questionnaire	1 h 30′
	13	Examination	Individual	2 Questions	20′

All these data were analysed by calculating basic descriptive statistics, and by qualitatively analysing content through the definition of content categories.

To assess PST' graphic progression based on products of Act. 3 and Act. 10, an instrument was specifically designed which focused on constructive aspects of drawings, in line with theoretical recommendations about diagrammatic representations. It considered eight dimensions related to constructive accuracy: 1) symmetry of insects, 2) body segmentation, 3) general proportion, 4) number of legs, 5) resemblance of legs (if they are segmented or not, general legs-body proportion, and relative proportion between different parts of the legs), 6) careful observation of antennae, 7) careful observation of wings, and 8) deep understanding of characteristic head features, such as eyes or jaws. All the dimensions, except the number of legs, were scored from 1 to 4 points, with 4 points representing excellent resemblance and deep understanding of a certain feature, and 1 point a total lack of resemblance. Additionally, three other dimensions: 9) texture, 10) colour, and 11) graphic motifs are directly related to fine surface details, while one more dimension, 12) volume, is half-way between the construction and the artistic finish of the drawing. Similarly, these four additional dimensions were scored from 1 to 4 points. For Act. 10, two additional descriptive dimensions were considered: 13) elements of context and 14) perspective.

Results and discussion

Anatomical knowledge of insects

A total of 122 spontaneous drawings were initially collected after Act. 2, Q1 (five per student), which were used to map PST' conceptions of how an insect looks (Giordan and de Vecchi 1988; Katz 2017). Such drawings mainly showed formal schemes which could be regarded as *child art*, a type of graphical expression connatural to children and adults who have not received artistic training, like our PST (Edwards 2012). Initial representations tend to exaggerate the significant elements of a specific morphology, and omitted traits that may be structurally relevant but do not play a role in visual recognition. For example, the division of the body into sections varied greatly and was unrealistic, although it did convey a general idea of the animal's shape. Thus, many drawings exhibited a central shape, surrounded by an indeterminate number of legs (not necessarily six, but always an even number), while others presented a kind of human-like figure structure, perhaps with a cartoon face, as well as insect features such as many legs, wings, stingers and, especially, antennae (Supplementary Material, SM hereafter: Figure 1). The typical syncretism of children and adults without artistic training: 'is a constant, both in the tendency to synthesise structurally complex aspects in simple structural solutions, as well as in the integration and reduction of significant complexes' (Martínez 2004, 91). From an arts education perspective, it is known that the human figure is used as a template to draw animals, to which children incorporate new and characteristic details for their effective identification (Lowenfeld and Brittain 1985; Luquet and Depouilly 1981). This explains the reminiscence of human traits along with the outstanding presence of antennae or other characteristic elements, such as many legs. Thus, since antennae are characteristic of insects, our PST turned other types of creatures into insects by merely adding them. In this initial group of drawings, a combination of different perspectives was common, particularly in butterflies or bees, as a strategy to reveal distinctive aspects. Butterflies' bodies were seen from the front, while wings were shown from above; and bees were viewed from the side, so the stinger could easily be appreciated. Finally, it is worth noting that drawings of other animals, such as spiders (8), centipedes (2), worms (7), and slugs (1), were also found. Note that animals such as worms present a completely different appearance for a careful observer (soft, long, with a tubular body divided into rings), yet some of them were 'adorned' with legs and antennae (SM: Fig 2).

After just the 2 hours of training that were invested in Act. 3, our students produced a dramatically different corpus of 28 drawings (1 per student). Beautiful insects were drawn from above, symmetry was always present, and 100% of insect bodies were correctly segmented into three sections and had six legs which in most cases were articulated (93%). Correct proportions between the different parts of the body were observed in 27 out of the 28 drawings. Notably, it seemed easier for PST to accurately perceive proportions between solid parts than between solid parts and longitudinal elements such as legs-, likely due to lack of practice in observing negative space as part of an image (Edwards 2012). Significant details of the head and other features, like antennae or wings, were carefully observed and consistently included in drawings (SM: Figs 3 to 6). Such impressive improvement in insect representation is related to the quick graphic progression that is known to occur when specific, focused drawing practice occurs under well-oriented teaching (Edwards 2012), and clearly shows the potential of drawing to reveal structural information (Wilson and Bradbury 2016). However, artistic features, such as colour, texture, or sense of volume, were more difficult to include for PST simultaneously to structure: thus, 43% of drawings used colour or exhibited the model´s characteristic graphic motifs, 43% conveyed a sense of volume, and 32% captured texture. This is because PST focused exclusively on those artistic features that contributed to species recognition: beetle drawings emphasised volume (SM: Fig. 7), true bugs had detailed colour patterns (SM: Fig. 8), and a bumblebee was given a delicate hairy texture (SM: Fig. 9). Only two drawings can be considered complete in the artistic sense (SM: Fig. 10).

Figure 2. Organic Learning Garden at Campus of Soria (University of Valladolid, Spain).

Figure 3. Organic Learning Garden at Campus of Soria (University of Valladolid, Spain).

After the garden practice (Act. 10), PST produced 148 drawings (five per student). Notably, they related many insects to the specific context of the garden: 37% included handwritten notes about the environment, and 34% included drawings of different aspects of the garden. PST chose very general terms to refer to the places where insects were found, like 'soil' or 'plants', but their drawings usually included significant details (SM: Fig. 11). Thus, the descriptive power of drawings was not only due to the representation of insects but also to complementary images of plants and other elements of the environment, which could allow further study and research and thus contribute to PST' scientific literacy (Coleman, McTigue, and Smolkin 2011; Katz 2017).

In this group of drawings, proportions were correct in 58% of cases, while 16% were clearly disproportionate, and 24% were well rendered. Most drawings showed the correct segmentations into three main sections (78%), and many added further details: 68% captured significant head details (eyes, jaws, etc.), 95% included antennae, and 96% presented the correct number of legs. The fact that PST represented a body divided into three sections and with six legs is extremely significant, since the constant movement of live animals (Ortega-Alonso 2018) and their small size (Rouaux 2014) makes it difficult to capture these characteristics. Namely, these two traits must be considered a positive result of previous training at the classroom seminar. The same stands for the representation of articulated legs.

Most drawings from this group (80%) were pictured from above, following the same scheme used in Act. 3. Thus, our evidence revealed a certain tension between such recently acquired formula for representing insects and the natural tendency to represent objects from the most revealing point of view (Ehrlén 2009; Luquet and Depouilly 1981). For instance, butterflies were now viewed from the side, as when perched on plants, so body structure and legs were difficult to see, although these were usually artistically drawn (SM: Fig. 12). Grasshoppers were both pictured from above and from the side, and structure was perfectly reflected in the first case (SM: Fig. 13) but tended to be incomplete or incorrect in the second one, which is the perspective that allows to better appreciate back legs (SM: Fig. 14). A final example: the structure of an ant was correct when represented from above, but not when represented from the side (SM: Fig. 14). In conclusion, there were errors related to the choice of drawing perspective, a topic that had not been approached during the classroom seminar on scientific drawing, which indicates that a full study of models, including all their perspectives, is necessary before drawing living and moving animals (naturalistic drawing). Finally, and regarding artistic features, colour was the most frequently used resource (65%), a sense of volume was present in 26% of drawings, and only 10% showed texture. The widespread use of colour is consistent with the quick drawing style that is necessary when portraying living creatures, so there is an interesting and natural adjustment between the needs of expression and the artistic medium (Eisner 2002). Above all, this group of drawings made at the university garden reveal how quickly PST generated a new, more sophisticated internal model, based on academic practice. This is clearly shown by the fact that depicting the structure of a small element which is not stationary is difficult nearly impossible; thus, in this case, there must be a mental change about what insects are like. In drawing as a discipline, it is also considered that the drawer works from an inner model when he/she is not copying, using a clichéd representation, or directly observing a physical model in three dimensions (Luquet and Depouilly 1981). In addition, they show how drawing is not simply a way to access students' conceptual learning (Chang et al. 2020), but a constructive learning process (Fiorella and Mayer 2016) that can provide an opportunity 'to construct the science concept' itself (Chang 2017, 136).

Taxonomical knowledge of insects

Initially, 24 PST gave a complete list of all the insects they knew (Act. 2). A list of 27 generic names of insects emerged (butterfly, ladybird, bee, mosquito, wasp, beetle, dragonfly, grasshopper, cricket, ant, fly, flea, cockroach, moth, stick insect, firefly, bumblebee, praying mantis, louse, gadfly, earwig, bug, cicada, aphid, termite, leaf insect, and shoemaker[1]), plus three that were more specific (dung beetle, bull beetle, and blow flies[2]). The most frequently mentioned were butterfly and ladybird (100% of PST), bee and mosquito (95.8%), wasp, beetle, and dragonfly (91.7%), cricket (87.5%), ant and fly (83.3%), and flea (75%). Each student mentioned between five and 29 organisms, with mean value being 15.75 ± 1.13 (mean ± SD) insects per student. Other arthropods also appeared (generic names, such as spider, centipede, tick, ball bug, mite, and scorpion, and more specific names such as tarantula), together with molluscs (snail and slug), and organisms with a worm's body, including, but not exclusively, worms (worm, silkworm, caterpillar, earthworm). Of these, the most frequently mentioned were spider (70.8%), worm (58.3%), centipede (54.2%), and tick (50%). Each student mentioned between 1 and 14 other organisms, with mean value being 4.13 ± 0.69 (mean ± SD) per student. The inclusion of other arthropods, and of some worms and molluscs can be attributed to the use of the folk taxonomy 'bugs' (Berlin et al., 1973) as a synonymous for 'insects', which may occur not only in children (Snaddon and Turner 2007) but also in our PST, when specific training on insects has not been enough, as it seems to be our case. On average, each student mentioned 16 insects and four other organisms. Similarly, a previous study on a larger sample of US university students (N = 236) found that each student listed a mean number of 13 insects and underlined that even such a well-educated population was unaware of a vast number of them (Shipley and Bixler 2017). This finding, in turn, is a key argument to further include insects in science curricula, particularly for PST (Sammet, Andres, and Dreesmann 2015; Wagler and Wagler 2012).

After the didactic intervention, 24 PST again gave a list of all the insects they knew (Act. 12). A list of 31 generic names of insects emerged (the initial ones plus damselfly, cycad, locust, and water strider), plus 29 that were more specific: 11 types of beetles, 10 types of flies, three types of ladybirds, two types of grasshoppers, and one type of wasp, bug, and cricket. Of these, the most frequently mentioned were bee and butterfly (87.5% of PST), wasp, dragonfly, fly, mosquito, and grasshopper (83.3%), ladybird (79.2%), and bug (75%). Each student mentioned between 7 and 29 insects, with mean value being 18.25 ± 1.11 (mean ± SD) per student. As a novelty, two PST also gave the scientific names of the taxonomic groups to which some of the insects belong. Again, PST also mentioned other organisms: the initial ones plus millipede. Of these, the most frequently mentioned were ball bug (37.5% of PST), tick (33.3%), and centipede (25%). Each student mentioned between one and four other organisms, with mean value being 1.29 ± 0.22 (mean ± SD) per PST.

Thus, taxonomical knowledge of insect diversity notably improved after the didactic intervention: mean values increased to 18 common generic names of insects and decreased to one name of other organisms per student. Notably, the total number of more specific common names greatly increased, from 3 to 29. Thus, PST' knowledge of insect diversity improved in level of detail; what was initially a beetle became either a dung beetle, a graveyard beetle, a cuirassier beetle, or a stag beetle, among others. This happened for the cases of beetles, flies, ladybirds, and grasshoppers. In other words, our data evidenced an enhanced perception of insect diversity in PST, which moreover was organised, and not chaotic. Another example is given by the results of the final exercises. Initially (Act. 2, Q5), PST were asked to classify a list of 16 common insects into a set of given orders, with 46% of them not answering at all, or answering 'I don't know' or 'I would need to look for this information on Internet'. Of the proposed cases, 69% were not attributed at all, 18% of cases were correctly attributed to the corresponding order, and 13% were incorrectly attributed. After the didactic intervention, PST were asked to classify a list of 10 such insects into a set of given orders (Act. 13, Q7); only 2% of cases were not attributed, 96% of cases were correctly attributed to the corresponding order, and 3% were incorrectly attributed. Finally, PST were also asked to visually recognise insects in pictures (Act. 13, Q6): in 87% of cases, such insects were correctly attributed to their corresponding order, and in 79% of cases, such organisms were correctly related with their most relevant anatomic characteristics from a list. We consider that approaching the study of

Table 4. List of insects identified at the learning garden by pre-service teachers.

Order	Family	Common name	Species	Common name
Coleoptera	*Cantharidae*	Soldier beetles	*Cantharis spp.1*	
			Cantharis spp. 2	
	Carabidae	Ground beetles	*Pterostichus spp.*	
			Cicindela campestris	Green cicindela
	Chrysomelidae	Leaf beetles	*Chrysomela populi*	Poplar leaf beetle
	Coccinellidae	Ladybirds	*Coccinella 7 – punctata*	Seven-spot ladybird
	Scarabaeidae	Scarab beetles	*Oxythyrea funesta*	White spotted rose beetle
	Tenebrionidae	Darkling beetles	*Helliotaurus ruficollis*	
Diptera	*Muscidae*	House flies	*Musca domestica*	Domestic fly
	Tipulidae	Large crane flies		
Hemiptera – Suborder Heteroptera	*Corsidae*		*Syromastus rhombeus*	
	Pentatomidae	Stink bugs	*Pyrrhocoris apterus*	
			Eysarcoris fabricii	
			Elasmucha grisea	Parent bug
Hemiptera – Suborder Homoptera	*Aphididae*	Aphids		
Hymenoptera	*Formicidae*	Ants		
Lepidoptera	*Lycaenidae*	Gossamer-wings		
	Pieridae	Pierid butterflies	*Gonepteryx rhamni*	Common brimstone
Neuroptera	*Chrysopidae*	Green lacewings	*Chrysopa spp.*	
Orthoptera	*Acrididae*	Grasshoppers	*Chorthippus spp.*	Field grasshopper
			Podisma spp.	Locust

insects from a strategy that trained PST in the scientific skill of rigorously observing their anatomical characteristics had a significant positive impact on these achievements. Since previous works have shown a limited understanding of insect characteristics (Barrow 2002; Cinici 2013), this should be considered a useful and valuable approach. The list of all insects identified by PST during the garden practice (Act. 10) is presented in Table 4.

Attitudes towards insects

Table 5 presents the main information related with Q2 and Q3.

Table 5. Main results related to aversion and fear.

Aversion			Fear		
Insects	% Before	% After	Insects	% Before	% After
Wasps	40.7	34.6	Spiders	37	0
Bees	30	23.1	Bees	33.3	23
Spiders	30	0	Wasps	33.3	54
Cockroaches	19	0	Ticks	14.8	0
Fleas	19	11.5	Gadflies	0	12
Gadflies	19	0			
Lices	15	0			
Grasshopers	11	0			
Main Reasons	**% Before**	**% After**	**Main Reasons**	**% Before**	**% After**
Sting/bite	56	39	Sting/bite	56	58
Transmit illnesses	11	15	Personal experiences	26	19
Personal experiences	7	12	Transmit illnesses	11	4
Their anatomy	7		'They are poisonous'	4	4
'I do not know why'	7				
'They are dirty'	7				
Reported feelings	**% Before**	**% After**	**Reported feelings**	**% Before**	**% After**
Fear	15	0	No fear	18.5	30.8
Panic/phobia	11	0	Panic/phobia	14.8	0
Disgust	11	12			
Hate	4	0			
'Makes me sick'	4	0			

Regarding feelings of aversion (Q2), a list of 14 insects and seven other organisms (spider, slug, centipede, tick, worm, earthworm, and tarantula) was obtained. Whereas 12% of PST declared that they felt aversion to 'all insects', 4% said to 'most of them', and 4% said to 'none'. One student gave the following reason:

> Flies are the most unpleasant insects for me because they land on any kind of surface. These insects usually look for unpleasant places (organic waste and excrements). This makes these insects gross. [st2]

Regarding fears, a list of 11 insects and four other organisms (spiders, ticks, caterpillars, tarantulas) were considered frightening, the main reason being summarised by the following student:

> In general, I'm afraid of any creature that can sting or hurt me. [st18]

Personal experiences were given by one-quarter of PST:

> . . . when I was a child, I remember running through my grandmother's garden and I got stuck in a huge spider's web. Since then, I haven't been able to stand them. [st1]

Whereas 18.5% of PST reported to not feel fear of any insect, 14.8% of PST declared to feel panic or phobia towards certain organisms, particularly spiders:

> I have arachnophobia, fear of spiders; I get shivers down my spine when I see them. [st20]

Thus, whereas studies show a lack of correlation between aversion and fear (Breuer et al. 2015), in our case, the most frequently mentioned organisms were similar: wasps and bees, and spiders. In relation to the list of 'most disliked' bugs by North American undergraduate students (Shipley and Bixler 2017), wasps, spiders and mosquitoes appeared with high percentages in both cases, whereas in ours, bees were more frequently mentioned, cockroaches were less frequently mentioned, and ants were not mentioned at all. The fact that spiders induce high levels of both fear and disgust has been widely discussed elsewhere (Gerdes, Uhla, and Alpers 2009; Vetter 2013). In studies assessing fear and disgust based on colour photographs, inconsistent results have been obtained regarding bees, which may be influenced by the presence or absence of wasps (Breuer et al. 2015; Gerdes, Uhla, and Alpers 2009). In our case, bees appeared both in aversion and fear categories in 30% of PST' responses, similar to wasps (which caused aversion up to 40% of PST).

After the didactic implementation, the list of organisms that caused aversion decreased to 14 insects and two other organisms (spider and tick). Importantly, 0% of PST declared they were averse to 'all insects', 0% to 'most of them', and 23% to 'none'. Only 12% referred to disgust. New experiences with insects were gained, for instance:

> I have to say that before this sequence I was averse to nearly all bugs, but because of working with them, I only find some dislikeable, like bees, wasps, and bumblebees. [st27]

> In the garden, I have become more familiar with slugs and worms. [st18]

The list of insects that inspired fear also decreased to nine insects and two other organisms (spider and tick). As reported in the literature, the fear-inducing species share pain-creating body features such as stings or pincers (Bixler and Floyd 1999). However, the fear of being stung by a wasp, bee, or spider described by our PST and based on personal experiences or social learning (Breuer et al. 2015) seems to be subsequently triggered by other insects that are less prone to stinging (earwig) or even incapable (real bug) of doing so. It has been pointed that improved lesson content and accurate information may mitigate both aversion and fear towards insects, since students learn to identify species and can distinguish between them (Breuer et al. 2015; Hummel, Randler, and Prokop 2012). Moreover, they better understand insect behaviour and appreciate their functions (Randler 2008). In our case, new experiences with insects, fundamentally at the garden, curbed PST' initial aversion and fear.

Table 6 presents the main information related with Q4.

Table 6. Main results related to sympathy.

Sympathy		
Insects	**% Before**	**% After**
Butterflies	82	77
Ladybirds	82	65
Dragonflies	22.2	35
Fireflies	14.8	12
Grasshoppers	0	12
Reasons	**% Before**	**% After**
Nice appearance	70.4	92
Harmless	44.4	23
Memories of childhood	7	15
Memories of good weather	4	12

On the other hand, PST initially felt sympathy for 13 insects and three other organisms (worm, earthworm, snail). After the didactic implementation, a list of 12 general and two more particular names of insects (corresponding to real bugs), and no other organisms emerged. Whereas insects such as cicada, cricket, ant, praying mantis, fly, and mosquito were initially present and disappeared, others, such as damselfly, bug, leaf insect, stick insect, and moth appeared after the intervention. Some reasons gained importance after the implementation, such as their evoking nice memories:

> When I see any of these creatures, I feel a kind of excited because they remind me of spring. When they appear, the weather is usually good. They bring joy and well-being, because they remind me the sun, warmth and feeling good. [st8]

Our list is quite similar to that of 'most liked' for North American undergraduate students (Shipley and Bixler 2017), at least in the first five positions, with the exception of the praying mantis, which was initially included by a small percentage of our PST and subsequently disappeared, arguably because the PST had no real contact with this insect in the garden. These findings are also broadly consistent with others (Breuer et al. 2015; Gómez Prado, Puig, and Evagorou 2020). Interestingly, memories linking insects to good weather gained importance after the garden session; it is known that personal sketching can take students back to pleasant moments experienced in nature (Ortega-Alonso 2018). It has been suggested that infant memories trigger more positive emotions in the present (Gómez Prado, Puig, and Evagorou 2020), and positive emotions are a good predictor of students' interest, which in turn conditions effective learning and pro-environmental attitudes (Gómez Prado, Puig, and Evagorou 2020; Schlegel, Breuer, and Rupf 2015). Thus, the final challenge, consisting in drawing and identifying insects during a garden practice, provided PST new and positive experiences with insects, and linked them with positive past experiences.

Conclusions

This work presented the first cycle of design, implementation, and assessment of a TLS contextualised at a university organic garden and whose main objective was to enhance knowledge and appreciation of insect diversity. The selected teaching strategy aimed to promote rigorous observation of insects by including practices of both scientific and naturalistic drawing, besides being theoretically informed and including activities characteristic of scientific activity, such as using books and dichotomous keys for insect identification. The TLS was implemented with pre-school PST, a particularly interesting sample population for two reasons: firstly, because PST' knowledge and attitudes will condition the likelihood of insects being included in science education from early ages (Wagler 2010; Wagler and Wagler 2011), and secondly, because 96% of our PST were women, who tend to report greater aversion to insects (Schlegel, Breuer, and Rupf 2015).

Assessment of this first cycle of implementation produced positive results in relation to improving anatomical and taxonomical knowledge, which are due to the inclusion of drawing. Theoretical studies support the idea that there is a two-way relationship between perception and representation: arts promote perceptual refinement (Eisner 2002), and such perceptual refinement enhances drawing skills (Edwards 2012). This is particularly clear in the case of scientific drawing because it is not possible to incorporate the structure of the learning object without comprehension, which involves a careful observation of the different parts and how they join and work together (Moline 2012). Thus, drawing helped our PST to perceive in a conscious and deep sense, helping them notice key constructive features of insects.

Implementing the didactic sequence also improved PST' positive attitudes and appreciation of insect diversity, as intended. Two key elements effectively contributed: drawing as a motor for the open-minded observation and reconstruction of ideas, and the garden as an outdoor context which allowed PST to have new experiences with insects, and acted as a real context, thus supporting authentic science learning. Therefore, our evidence is in line with previous research showing that science units integrating hands-on science exploration with language art skills have potential for increased learning in both areas, science and art education (Wilson and Bradbury 2016), and with previous research emphasising the need to incorporate direct experiences with nature and living beings that involve cognitive, affective, and evaluative modes of learning (Askerlund and Almers 2016; Kellert 2002). Furthermore, the usefulness of maintaining organically managed gardens as facilities for science and environmental education at educational centres, including universities, is supported (Eugenio-Gozalbo, Aragón, and Ortega-Cubero 2020). Finally, it is necessary to mention that, since no delayed post-tests were administered, it is not possible to know how durable PST' knowledge might be.

Regarding TLS design, it is considered that validation is the result of successive implementations, so that the sequence is each time modified according to the specific results obtained (Méheut and Psillos 2004; Couso 2012). In our case, improvements could be introduced in some activities, such as more in-depth work in Act. 4, to identify insects and other organisms that appear in the documentary 'Microcosmos' or working on the choice of drawing perspective before approaching the final naturalistic drawing activity. It should be underlined that it is key to devote time and expertise to drawing activities to obtain successful results, for which close collaboration between science and art teachers is recommended for this TLS. Such efforts are afterwards rewarded in terms of PST' learning, as we have observed in more recent experiences on the topic of pollinators (Eugenio-Gozalbo et al., in press).

Notes

1. this common name is used both for *Gerris lacustris* and for *Pyrrhocoris apterus.*
2. strong flies of the families *Calliphoridae* and *Sarcophagidae.*

Declaration and ethics statements

Ethical review and approval were not required for the study in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

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Supplementary Material

Figure 1.

Students' initial spontaneous drawings

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Figure 2.

Students' initial spontaneous drawings. Note the worm (with legs and antennae).

Figure 3.

Exotic flying stag beetle (Odontolabis sp.).

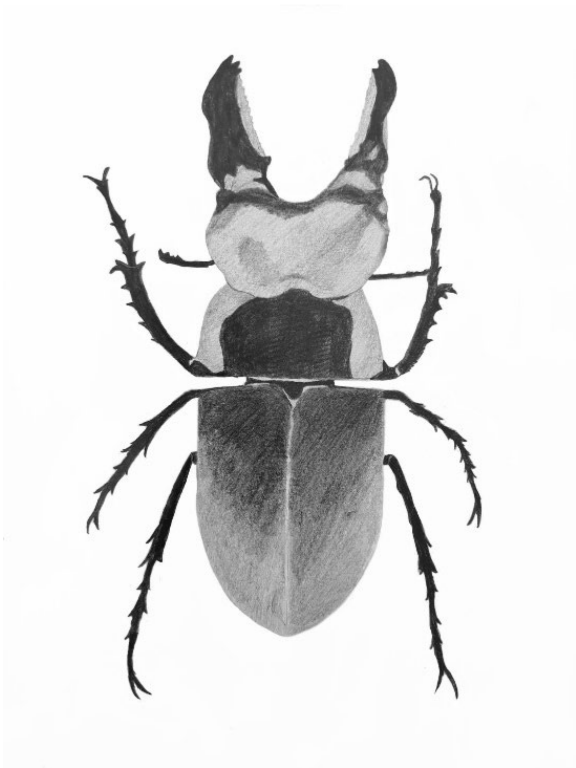

Figure 4.

Giant ant (Camponotus gigas).

Figure 5.

Spotted lanternfly (Lycorma delicatula).

Figure 6.

Asian long-horned beetle (Anoplophora glabripennis).

Figure 7.

Emerald beetle (<u>Romborrhina japonica</u>)

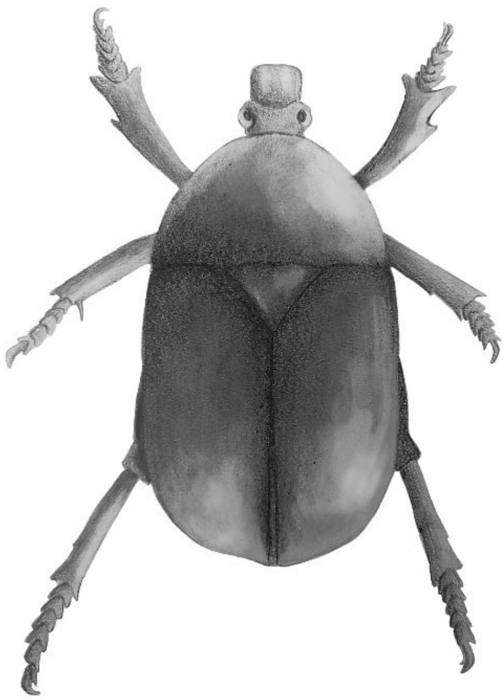

Figure 8.

Oriental shield bug (<u>Catacanthus incarnatus</u>).

Figure 9.

Bumblebee (<u>Bombus lucorum</u>).

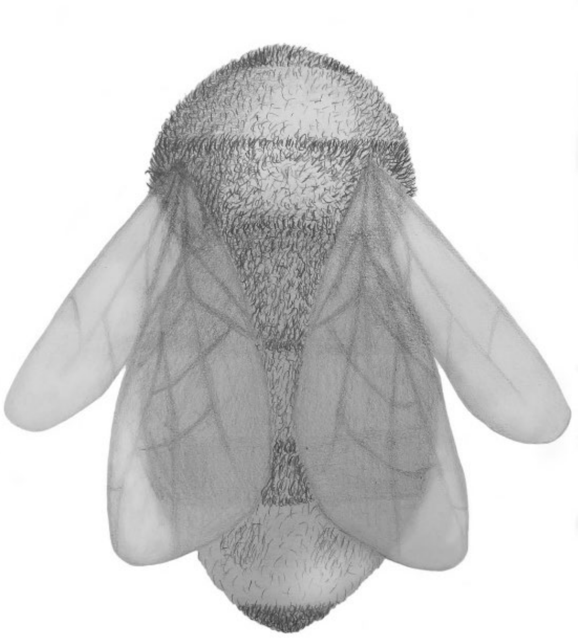

Figure 10.

Asian cicada (<u>Pyrops candelaria</u>).

Figure 11.

Ladybug (<u>Coccinella 7-punctata</u>) and poppy (<u>Papaver rhoeas</u>).

Figure 12.

Butterfly (Lycaenidae), right lateral view.

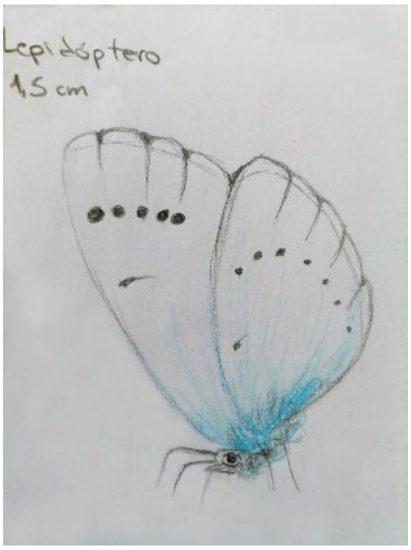

Figure 13.

Grasshopper (<u>Chorthippus spp.</u>), dorsal view.

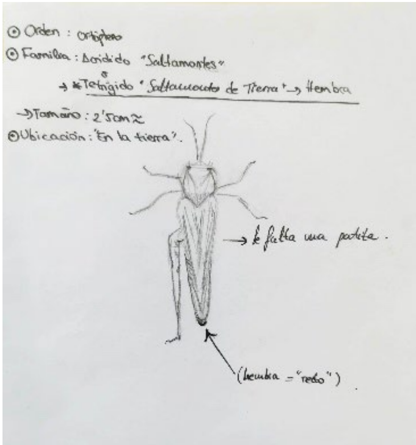

Figure 14.

Grasshopper (<u>Chorthippus spp.</u>), right lateral view.

Figure 15.

Ant (Formicidae), dorsal view and left lateral view.