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Modelización tridimensional como innovación metodológica para la enseñanza de la zoología y educación ambiental

Three-dimensional modeling as a methodological innovation for teaching zoology and environmental education

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RESUMEN.

La gran diversidad de animales y la relación entre sus características morfológicas, adaptaciones y estrategias de vida se abordan en la enseñanza de la zoología. El uso de metodologías innovadoras y alternativas, como el modelado zoológico, son herramientas que pueden contribuir a un alto interés en el estudio de la zoología, y se utilizan en una estrategia de educación ambiental. En este estudio, la modelación zoológica cumple un importante papel en el proceso de enseñanza-aprendizaje en los estudiantes de pregrado de la carrera de Ciencias Biológicas, y en la conexión de las prácticas docentes con las actividades de extensión ambiental. Para evaluar el papel de los modelados zoológicos sobre el proceso de enseñanza-aprendizaje, se construyeron 22 modelos zoológicos con representantes del Filo Arthropoda, Mollusca, Cnidaria y Echinodermata, donde se abordaron aspectos de morfología externa, interna y ciclo de vida. Se analizó el proceso de percepción, viabilidad y asimilación de la construcción del modelado zoológico a través de entrevistas a 40 estudiantes de pregrado, 100 niños y adolescentes, público objetivo de los talleres. Los resultados mostraron que el modelado tridimensional estimula a los estudiantes ambientales en el proceso de enseñanza-aprendizaje, y que su uso en actividades educativas son eficientes debido a que despiertan curiosidad, permiten la divulgación de conocimiento cientifico sobre la importancia de la conservación de la biodiversidad y también ayudan a cambiar los conceptos errados que se puedan tener sobre algunos grupos de animales y la difusión de sus servicios ecosistémicos esenciales para la conservación de la biodiversidad.

PALABRAS CLAVE.

Prácticas pedagógicas, metodologías, modelado zoológico, educación ambiental

ABSTRACT.

The great diversity of animals and the relationship between their morphological characteristics, adaptations and life strategies are approached in the teaching of zoology. The use of innovative and alternative methodologies, such as zoological modeling, are tools that can contribute to a high interest in the study of zoology and it is use in an environmental education strategy. In this study, the zoological modeling intermediated the teaching-learning

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process in undergraduate students of the Biological Sciences course and the connection of teaching practices with environmental extension activities. Twenty-two animal models were built with representatives of the Phylum Arthropoda, Mollusca, Cnidaria and Echinodermata, approaching aspects of external, internal morphology and life cycle. The process of perception, viability and assimilation of the construction of the zoological modeling was analyzed through interviews with 40 undergraduates and 100 children and teenagers, the target audience of the workshops. The results showed that the three-dimensional modeling stimulates environmental students in the teaching-learning process and it is use in education activities were efficient, awakening curiosity, enabling the demystification of animals and the dissemination of their essential ecosystem services for the conservation of biodiversity.

KEY WORDS.
Pedagogical practices, methodologies, zoological modeling, environmental education

1. Introduction.

The diversity of fauna and it is spatial and temporal distribution is applied to the teaching of zoology, which for to characterize the corporeal plane of organisms, their form and structure to their function and adaptation to different evolutionary arenas (Almeida, 2009; Richter et al., 2017; Silva et al., 2021). Descriptive and traditional analyzes in zoology teaching methodologies are considered to be of continuous use, which can perpetuate conservative experiences at elementary, secondary and university levels (Marandino et al., 2009; Krasilchik, 2011; Richter et al., 2017).

The teaching of zoology based on technical and ideological assumptions in a traditional way can reflect the individual thoughts and conceptions of each teacher (Richter et al., 2017). With the evolution of science and the emergence of new information and communication technologies, teachers have questioned the construction models of the teaching-learning process and sought changes and updates in pedagogical practices. The education is based between theory and practice, which considers intellectual and manual work, encourages the student to think and build knowledge (Freire, 2001; Pereira & Carneiro, 2014). The educational challenges involve the development of new strategic methodological tools that enable interactivity and enable the student to contextualize the resume with their social, cultural and environmental experiences (Romanowski & Wachowicz, 2003; Duso, 2009; Pereira & Carneiro, 2014; Sousa et al., 2015).

One of the recent methodological innovations is the use of zoological modeling, which has shown positive results, increased student interactivity and practical contextualization between morphological structures of living beings and their adaptive functions (Przybysz & Cunha, 2011; Coimbra & Taddei, 2017). Studies evaluated using zoological modeling demonstrated high ability to understand the general biology of the animal, such as anatomy, life cycle, evolution and behavior. Students involved in the practice of zoological modeling shown that the construction of models requires the exchange of knowledge, theoretical foundations and the ability to create. In addition, zoological models replace the use of corrected biological material, making it more dynamic and flexible as practical zoology classes (Pietrocola, 1999; Cavalcante & Silva, 2008; Matos et al., 2009; Vale & Silva, 2019; Almeida, 2021). Didactic

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methods based on zoological modeling have become increasingly popular and are shown an important tool for practices in several disciplines, whether in the biological area such as zoology, botany and cell biology (Amorim, 2008; Matos et. al., 2009; Almeida et al., 2021) or in exacts, such as chemistry, physics and mathematics (Nicot & Souza, 2016; Acevedo-Díaz et al., 2017; Kato & Olivera, 2020; Nunes et al., 2020; Viana & Vertuan, 2021). Teaching invertebrate zoology involves a high diversity of species, some of them difficult to sample, which makes it impossible to observe these data in practical classes, making the models even more promising for the learning process.

The encouragement and insertion of creativity in the educational process is recognized through modeling, which is considered a way of connecting local and global knowledge, transforming realities through science (Kato & Oliveira, 2020; Gonçalves, 2021). A study with graduates of Bachelor of Science courses evaluated the perception of students and teachers about significant creativity activities experienced during their training (Vertuan & Setti,018). The study showed that there is a different perception and conflict about competences between teachers and students, pointing out as necessary the increase of flexible activities that allow the student autonomy and protagonism in the development of ideas and creative construction of knowledge.

The practices that involve the teaching of zoology, especially arthropods, represent a great challenge in teaching at all levels, from basic to undergraduate, not only because they represent the largest group of animals, but also because they are culturally seen in a pejorative way by society (Costa Neto, 2004). The descriptive study commonly attributed in textbooks does not facilitate the student to contextualize adaptations of the animal's bodily plan with its ecosystem services, often discouraging the student and its potential multiplier of environmental knowledge with its interactants (Giordan & Vecchi, 1996; Almeida et al., 2021). The conceptions outlined by the student in modeling the creative construction process can integrate learning with scientific knowledge, making didactic models an effective and accessible tool in the modern educational context (Nunes et al., 2020; Viana & Vertuan, 2021).

In this study, the zoological modeling was developed with the objective to awakening interest in the study of invertebrates and enable high capacity for assimilating the architecture and body characters of the animals. In addition, the constructed models were used as instruments for environmental education and scientific dissemination activities with children and teenagers from public schools.

2. Methods.

Zoological modeling was developed during four academic semesters (2017-2019) as part of the evaluation requirements of the Zoology II subject, associated to the Biological Sciences Course of the Institute of Biodiversity and Sustainability, Federal University of Rio de Janeiro, Brazil. 22 models were built by 44 students, who were free to choose the taxa within the resume of the discipline, as well as in the material used to build the corporeal plan associated with the didactic models. Students were guided by the professor and monitors during the semester and used zoological bibliography (Brusca et al. 2017) updated for theoretical support in the morphological representation of models.

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Zoological modeling involved different aspects of taxa biology, such as external and internal morphology, development and life cycle. The method adopted was based on the figurative system that reproduces reality in a schematic and concrete way, representing a structure that allows materializing the idea or concept, making them easy for learning and later being used as reference materials (Justina & Ferla, 2005).

The modeling was developed with several types of materials, such as fabrics, clay modeling, recycled material such as plastic and wire, papier mache, cardboard, polystyrene, rubber and ink-based material. All models were collectively discussed and aspects of faithfully in the representation of morphological characteristics, originality, visual aspect and capacity for use in zoology and environmental education practices were discussed.

To evaluate the use of zoological modeling in the teaching-learning process of zoology, two questionnaires were applied: (1) sampling with 40 undergraduate students to evaluate the perception, viability and assimilation of knowledge during the process of building the zoological modeling and (2) for 100 children and teenagers from public schools in the municipality of Macaé, Rio de Janeiro, Brazil, who participated in educational environmental workshops involving the models constructed in this study (Table 1).

Table 1. Questionnaire on perception, viability, assimilation of zoological modeling by undergraduates during the construction process and by children and teenagers during the environmental education workshops.

Undergraduates Questionnaire		
01-	How do you analyze the importance of the Modeling Model flowchart in the idea construction and materialization process?	A - Very important (n = 32; 80%) B - Important (n = 08; 20%) C - Not Important D - Irrelevant
02-	Did zoological modeling represent a methodological process considered innovative in the discipline of zoology?	A - Yes (n = 40; 100%) B - In Parts C - No D - Indifferent
03-	Was the zoological modeling process a viable practice to be carried out during the practices of the discipline of zoology, considering the theoretical context and possible materials used for confection?	A - Yes (n = 27; 67,5%) B - In Parts (n = 13; 32,5%) C - No D - Indifferent
04-	Did the zoological modeling allow greater assimilation of theoretical content?	A - Yes (n = 40; 100%) B - In Parts C - No D - Indifferent
05-	What is the biggest motivation for building zoological models?	A - Innovative method (n = 07; 17,5%) B - Facility C - Potential use in Environmental Education (n = 22; 55%) D - Theoretical assimilation (n = 11; 27,5%)

Questionnaire Environmental Workshops for Children and Teenagers		
01-	Do animal models allow the recognition of organisms?	A - Yes (n = 100; 100%) B - In Parts C - No D - Indifferent
02-	Which of the animals do you consider beneficial to the environment?	A - Bee (n = 83; 83%) B - Shrimp (n = 09; 9%) C - Starfish (n = 05; 5%) D - Crab (n = 3; 3%)
03-	Which of the animals do you consider harmful to the environment?	A - Ant (n = 79; 79%) B - Tick (n = 09; 9%) C - Spider (n = 07; 7%) D - Snail (n = 05; 5%)
04-	Which animal did you not know?	A - Palpigradi (n = 64; 64%) B - Opiliones (n = 17; 17%) C - Sea slug (n = 11; 11%) D - Sea anemone (n = 08; 8%)
05-	Do you think that knowing animals makes you more will to help protect them and defend nature?	A - Yes (n = 93; 93%) B - In Parts (n = 06; 6%) C – No (n = 01; 1%) D – Indifferent

3. Results.

Twenty-two animal models from different taxonomic categories were constructed using zoological modeling. Most of the taxa approached were representatives of the largest group of animals in the current fauna, Phylum Arthropoda, representing 03 subphylum (Figs 1-4). The models of the subphylum Crustacea demonstrated external morphological characteristics for popularly known specimens of the order Decapoda, such as crabs (Figs. 1A and 1B) lobster (Fig. 1C) and shrimp (Fig. 1D). Structures such as appendix, antennae, body tagmas, eyes and specific adaptive structures were evidenced. For the crabs, modeling was developed to study the external anatomy (Figs. 1b and 1E) and internal (Fig. 1F), indicating morphophysiological structures such as heart, gills and gonads. To approach the development of the crustaceans, the modeling of immature phases was carried out in different stages of the trochophore larva (Figs. 1G-H).

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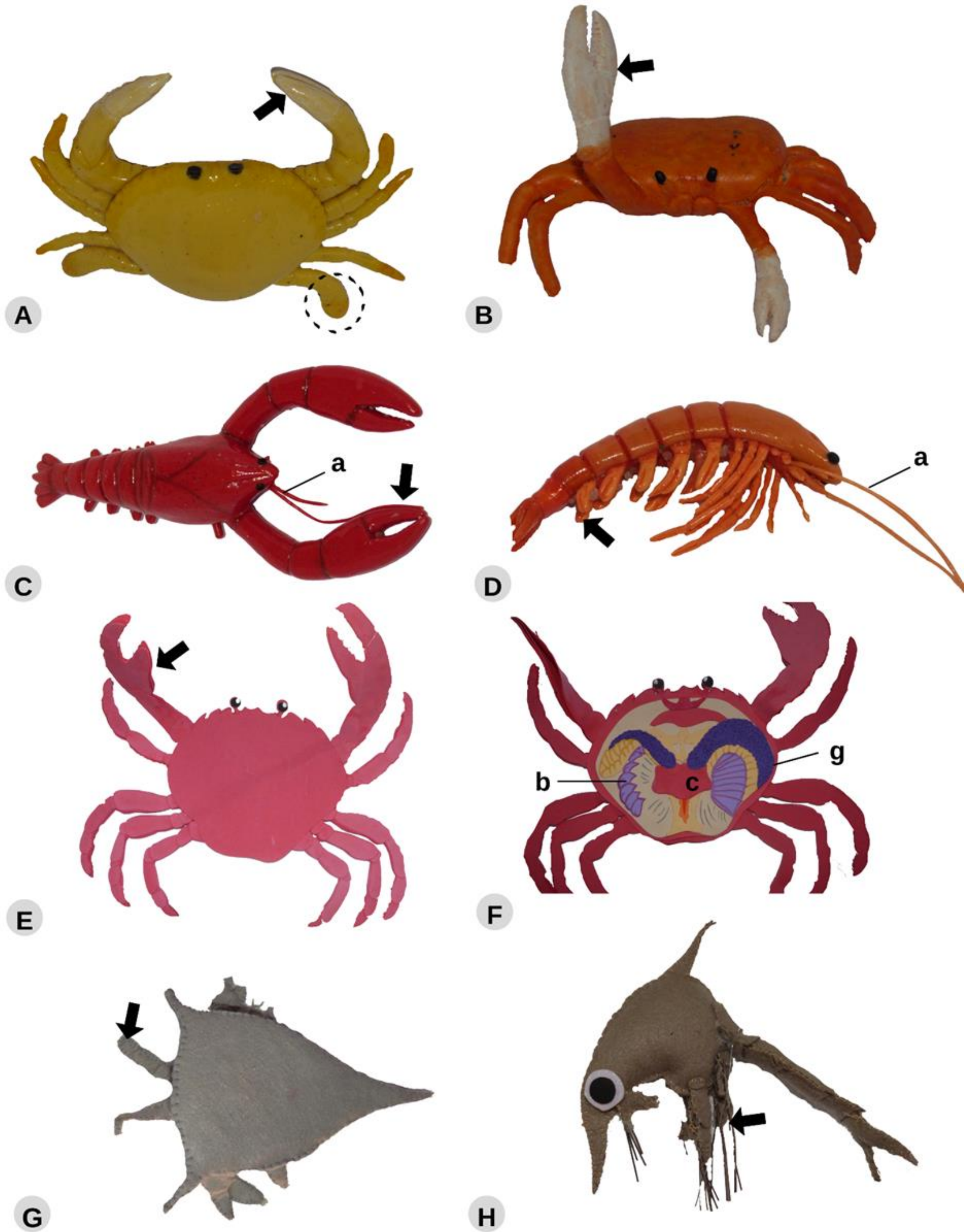

Figure 1. Modeling with representatives of the Phylum Arthropoda, Subphylum Crustacea. A-D. Decapoda Order. Crabs (A and B) and lobster (C), the arrow shows the cheliped and the dashed circle the adaptation of the last pair of last legs for swimming. D. Shrimp showing antennae (a) and pleopods, legs adapted for swimming and digging. E-F. Crab modeling to study the external (E) and internal (F) anatomy, showing the heart (c), gills (b) and gonads (g). G-H. Modeling of immature stages, trochophore larvae, arrows show antennae in (G) and pleopods in (H).

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For the subphylum Hexapoda, a class Insecta was represented approaching the external morphology of representatives of different taxa (Fig. 2). For Coleoptera order, a modeling was made with a Beetle (Fig. 2A) and for Hymenoptera with Ant (Fig. 2B) and Bee (Fig. 2C), in which the tagmas and structures such as antennae, eyes, wings in the shape of elytrum were indicated (Fig. 2A), membranous wings (Fig. 2C-D), in addition to jaws and legs. The modeling to study the internal anatomy was done with a bee, showing the location and shape of structures such as the brain, thoracic muscles, dorsal blood vessel, ventral nerve cord and gonad (Fig. 2E).

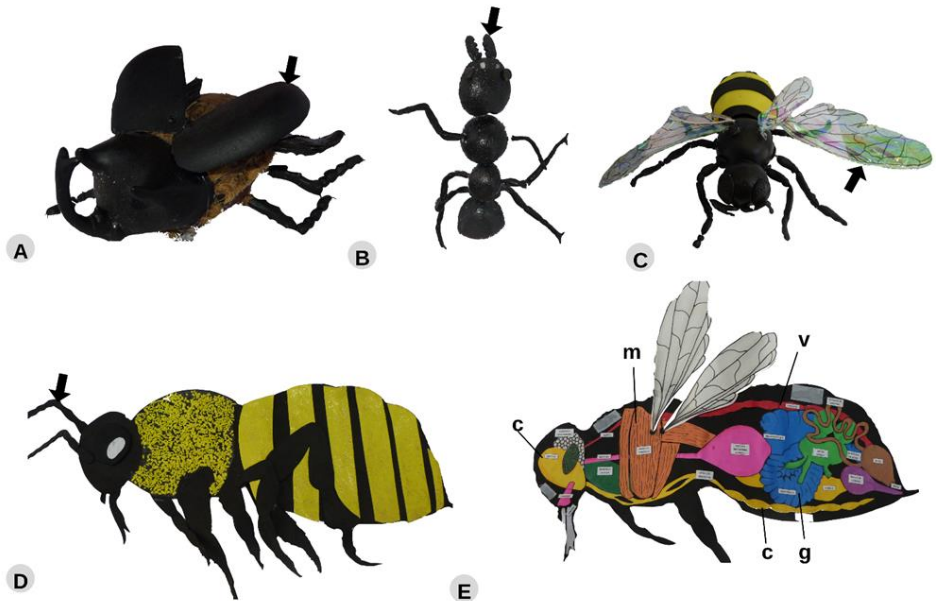

Figure 2. Modeling with representatives of the Phylum Arthropoda, Subphylum Hexapoda, Class Insecta. A. Order Coleoptera, beetle, arrow indicates anterior wing in elytra form. B-E. Hymenoptera order. B. Ant, the arrow indicates the pair of jaws. C.-E. Bee, in (C) the arrow points to the membranous wing and in (D) the antennae. E. Modeling to study the internal anatomy, showing the location and shape of structures such as the brain (c), thoracic muscles (m), dorsal blood vessel (v), ventral nerve cord (c) and gonad (g).

A scheme was proposed to represent the development cycle of a beetle, showing the different phases of a holometabolic insect: egg, larva, pupa and adult (Fig. 3).
Modeling for representatives of the subphylum Chelicerata involved different orders such as Aranae (Fig. 4A), Acari (Fig. 4B), Opiliones (Fig. 4C), Uropyghi (Fig. 4D) and Palpigradi (Fig. 4D) and indicated synapomorphic structures of the group such as chelicerae and pedipalps, locomotor appendix, tagma division and the telson. Representatives of the Phylum Mollusca belonging to the Gastropoda class were schematized in modeling involving snail (Fig. 5A-C) and indicated in the external morphology the shell that covers the body, the muscular foot and the head. The internal anatomy evidenced the position and shape of the brain, intestine and branchial vessels (Fig. 5C). The external anatomy of a nudibranch representative showed body shape and structures such as antennae and tentacles. (Fig. 5D).

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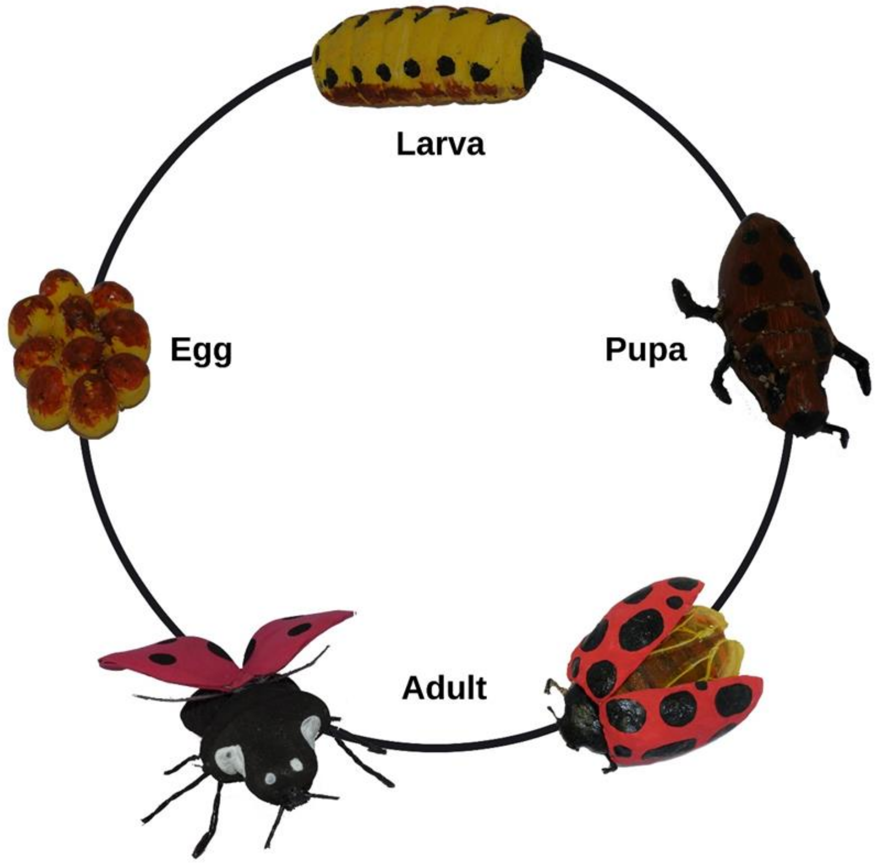

Figure 3. Modeling with representatives of the Phylum Arthropoda, Subphylum Hexapoda, Class Insecta, Order Coleoptera. Diagram representing the developmental cycle of a beetle, showing the phases of a holometabolous insect, with egg, larva, pupa and adult.

Modeling was elaborated with different representatives of the Phylum Echinodermata, such as a starfish, covering its external and internal morphology with indication of the ambulatory feet, aquifer vascular channel, circular channel and gonads (Fig 6A-C). For sea urchins the external anatomy showed the spines (Fig 6D) and the internal anatomy the Aristotle's lantern and the gonads (Fig 6E). A modeling with the representative of the Phylum Cnidaria, sea anemone, showed the external morphology, showing the tentacles (Fig 6E).
Undergraduates considered for the use of the modeling flowchart proposed by Justi & Gilbert (2002) as important in the construction process of zoological modeling and evaluated as an innovative methodology for teaching zoology. Most respondents (n = 27; 67,5%) shown as viable the making of the model and all considered that this activity increased the assimilation of theoretical content, with it is potential use in environmental education being the high incentive for this practice (Table 01 and Fig. 7).

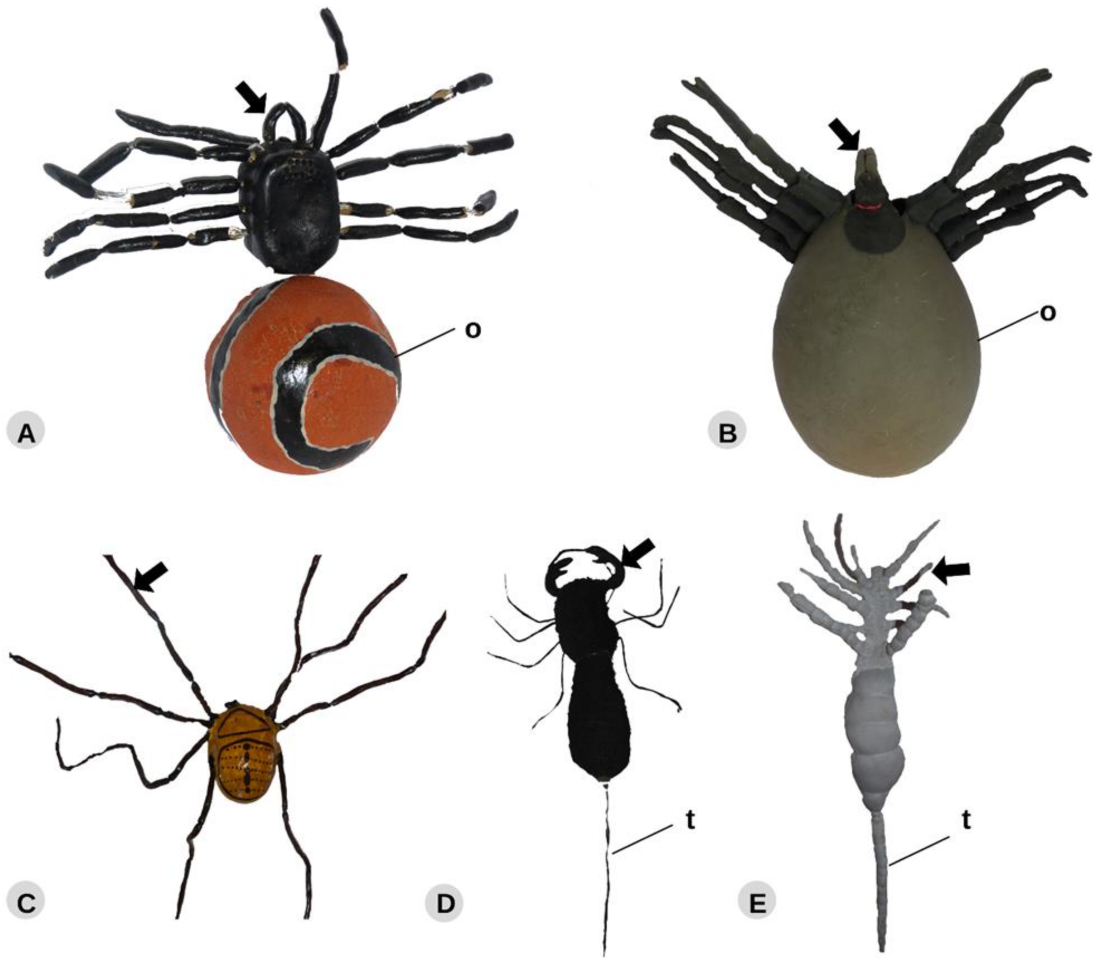

Figure 4. Modeling with representatives of the Phylum Arthropoda, Subphylum Chelicerata. A. Order Aranae, spider and in (B) Order Acari, mite, the arrows indicate the chelicerae and the division of different tagmas the opistosome (o). C. Order Opiliones, an arrow indicates the first pair of legs. D. Order Uropighi, vinegar scorpion, an arrow indicates the chelicerae and (t) points the telson elongated. E. Order Palpigradi, the arrow indicates the first pair of legs and in (t) the multi-articulated telson.

The target audience of the environmental education workshops, children and teenagers, were unanimous in evaluating the models allowed the bodies to be recognized. During the environmental workshop activities, most respondents (n = 83; 83%) a shown bees as the most beneficial animals and (n = 79; 79%) ants as the most harmful. Among the models worked, the Palpigradi representative (Arachnida) was shown by the majority (n = 64; 64%) such as the unknown animal. The majority (n = 93; 93%) considered that knowledge of the fauna is an important factor to encourage the preservation of the environment and the adoption of sustainable practices that help in the conservation of biodiversity (Table 01; Fig. 8 and 9).

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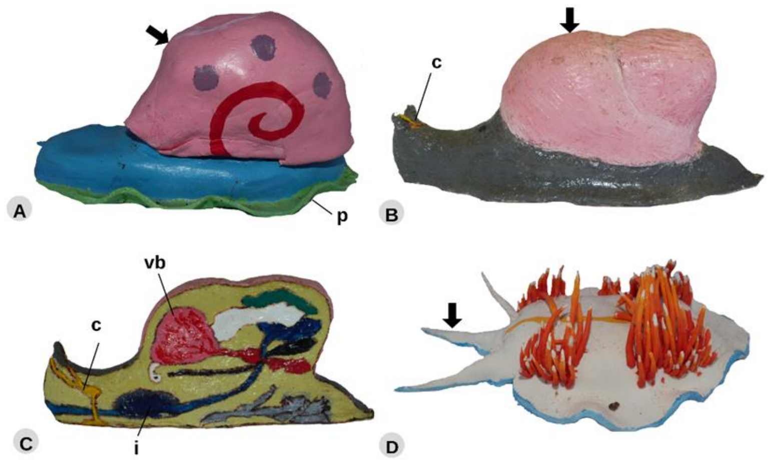

Figure 5. Modeling with representatives of the Phylum Mollusca, Class Gastropoda. B.C. Snail, the arrow shows the shell that covers the body; muscular foot (p) and head (c). C. Modeling to study the internal anatomy showing the position and shape of the brain (c), intestine (i) and branchial vessels (vb). D. Nudibranch, marine representative showing the external anatomy, the arrows point to the antennas.

Figure 6. Modeling with representatives of the Phylum Echinodermata (A-E) and Phylum Cnidaria (F). B.C. Class Asteroidea, starfish, arrows indicate ambulatory feet; the aquifer vascular canal, circular canal (c) and gonads (g). In Class Echinoidea, in (D) external anatomy showing the spines and in (E) internal anatomy showing the aristotle's lantern and gonads. F. Phylum Cnidaria, sea anemone, arrows indicate tentacles.

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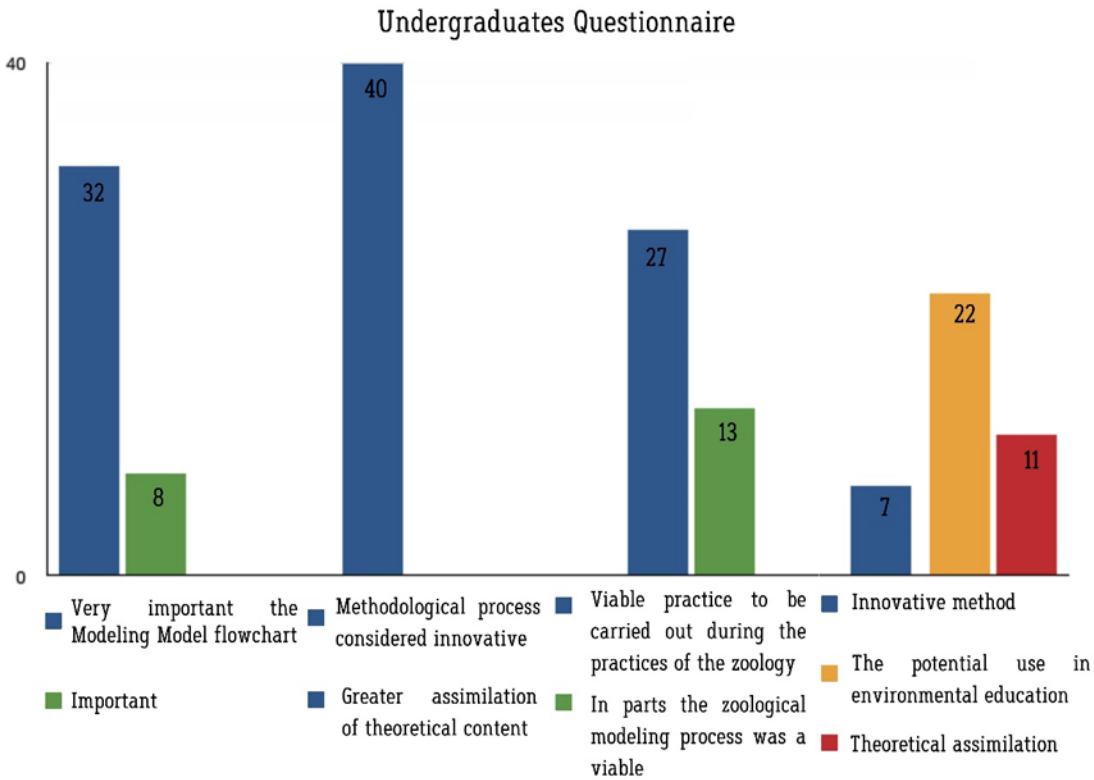

Figure 7. Graphic expressing the most frequent responses of undergraduates to the following questions: (i) important the Modeling Model flowchart in the process of building and materializing ideas. Analyzed how important the Modeling Model flowchart in the process of building and materializing ideas; (ii) if the zoological modeling represented a methodological process considered innovative in the discipline of zoology and allowed greater assimilation of theoretical; (iii) if the process zoological modeling process was a viable practice to be carried out during the practices of the zoology discipline and (iv) which was the biggest motivation for the construction of zoological models.

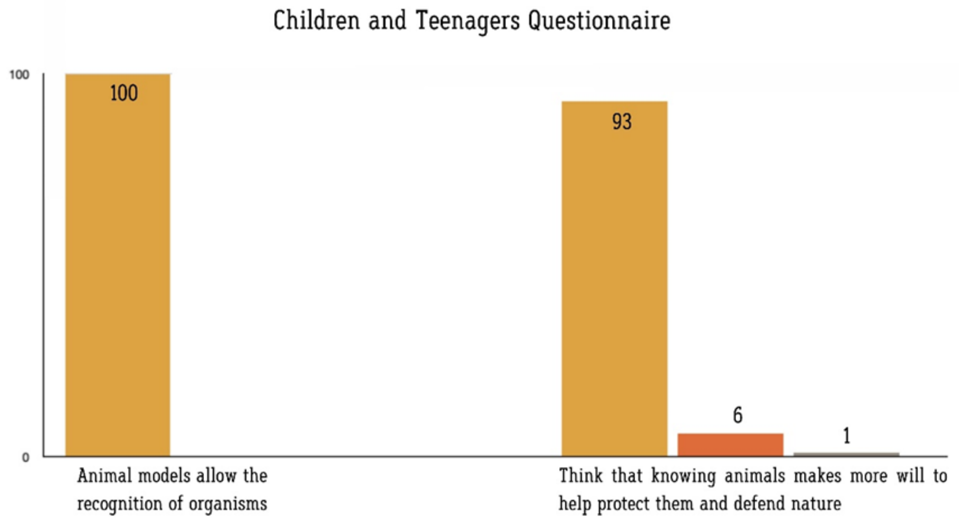

Figure 8. Graphic expressing the most frequent responses of children and teenagers.

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4. Discussion.

Traditionally, the zoology teaching system was based on the description and memorization of internal and external morphological structures of the animals body construction plan (Posner et al. 1982). New approaches seek to reach a socio-educational level that values the ability to integrate knowledge and multiple intelligences with experiences, making the process more interactive and dynamic (Seniciato & Cavassan, 2004; Gardner, 2005; Souza, 2009; Pereira & Carnveiro, 2014). The use of alternative methodologies in the teaching of biology has indicated to be multidisciplinary and zoological modeling is seen as a tool be able of optimizing the assimilation of knowledge, through the creative reconstruction of the animals body plans. (Oliveira 2005; Azevedo & Bezerra, 2006; Araujo-de-Almeida, 2007; Sanvik, 2007; Amorim, 2008; Silva et al., 2021).

Relevant aspects in the use of zoological modeling involve creative and dialogic interactivity, awakening interest and protagonism in the teaching-learning process (Souza, 2009; Seniciato & Cavassan, 2004; Viveiro & Diniz, 2009; Silva et al., 2021). Furthermore, the construction of models is an alternative to the use of fixed biological materials, reducing the need for collection for the purpose of didactic collection. For the teaching of zoology, many specimens have small sizes and the models allow an expanded view of body structures, faithfully reproducing aspects of external morphology and associating them with it is functionality.

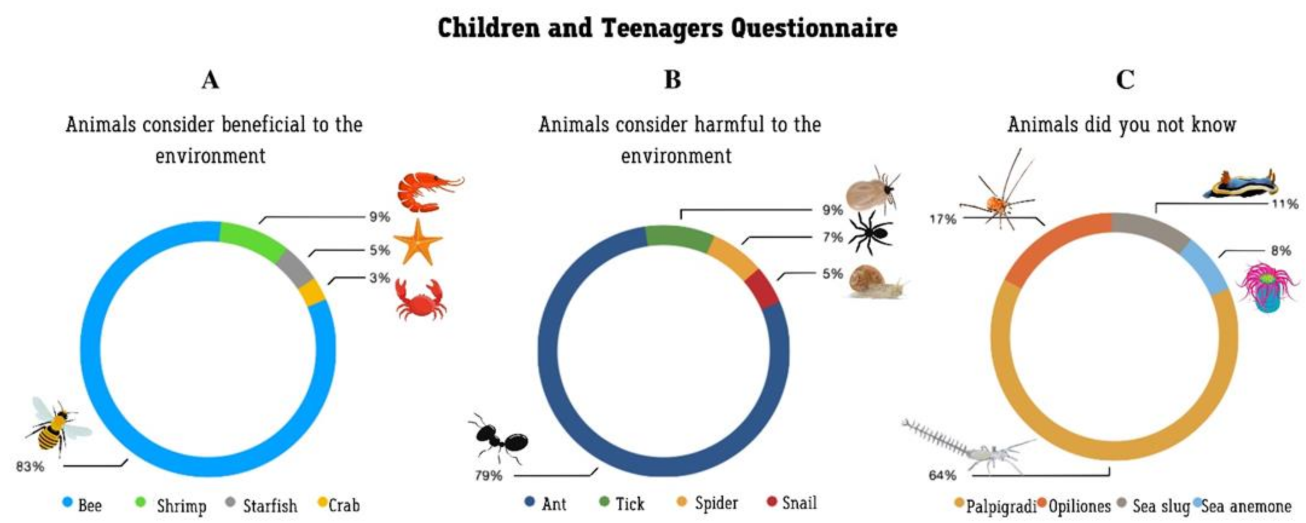

Figure 9. Graphic expressing the most frequent responses of children and teenagers.

In the resume of undergraduate courses in Biology, many animal taxa, especially invertebrates, are difficult to sample, making practical classes and the direct association of morphological aspects impossible, which causes discouragement and can compromise the assimilation and fixation of the contents taught. In addition, it should be considered that for some groups, such as arthropods, biological diversity corresponds to about 85% of the described species (Brusca et al. 2017), which makes practical experimentation with fixed biological models even more difficult. the zoological modeling has the potential to meet the demand for under-sampled taxa, which makes zoology more dynamic by optimizing the connection with ecological, behavioral and evolutionary aspects (Araujo-de-Almeida, 2007; Reis, 2011; Azevedo et al., 2012).

All students involved in the zoological modeling process in this study considered fundamental the collective construction based on the Modeling Model diagram (Justi & Gilbert 2002) which predicts the theoretical basis and individual experiences as a starting point for building an initial mental model. Still, students evaluated the models as an alternative teaching process that encourages learning, instigating the search for knowledge. Pedagogical constructivism is based on the role of students in their own learning process, connecting research and developing reasoning through the emergence of doubts. (Pereira & Carneiro, 2014). Educational constructivism evaluate that the learning process involves prior knowledge that substantiates the contextualization of knowledge (Mathews, 2000; Azevedo et al., 2012; Ferreira et al., 2020; Silva et al., 2021). Another aspect shown by the students was the encouragement of construction through the potential use of models as instruments for environmental education practices. During the workshops, children and teenagers showed interest and curiosity about the models and the biological and environmental aspects approached, and in some cases the animals were associated in a pejorative way and their ecosystem role was not known by the public. One of the main strategies of environmental education is to present biological diversity and the relationships and connectivity between living beings, considering that knowledge is the main way in the formation of new agents and allies in the conservation and dissemination of sustainable practices (Moura et al., 2010; Schroeder, 2013; Mouga et al., 2016).

5. Conclusion.

Zoological modeling is an important and innovative efficient educational strategy for the teaching-learning process, with great capacity for connection between practice and theory. Graduates involved in modeling activities point to a practice that stimulates the search for knowledge and the development of skills and creative talents, which improves learning and streamlines the process among interactants. In addition, zoological models are appointed as an alternative the practice of fixing animals is a highly viable resource due to the low cost and possibility of using recycled materials. The possibility of inserting aspects of practical experiences and connecting the morphological adaptations of animals with their ecological services offers a plurality of knowledge in zoological modeling, making the process dynamic and integrated into the dialogue between students and teachers. Another relevant and innovative aspect is to integrate modeling practices with the use of models in extension activities, where undergraduates will use biological knowledge to develop and apply environmental education strategies in schools and in society in general.

In this study, zoological modeling was used as an alternative methodology for the teaching-learning process of zoology and proved to be an instrument capable of boosting and stimulating students to integrate scientific knowledge, teaching practices and their potential use in extension activities. The use of zoological models are potential tools to streamline the study of zoology and contribute to the formation of biologists committed to the dissemination of knowledge about biological diversity and their role as environmental educators.

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