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GAMIFICAÇÃO E ENSINO DE BIOLOGIA: ENTENDENDO OS ARTRÓPODES POR MEIO DE UM JOGO DE CARTAS EDUCATIVO

Lucas Faustino, Danielle Peretti, Jean Carlos Dantas de Oliveira

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ARTIGO

GAMIFICATION AND BIOLOGY EDUCATION: UNDERSTANDING ARTHROPODS THROUGH AN EDUCATIONAL CARD GAME

LUCAS VINICIUS FAUSTINO[1]
ORCID https://orcid.org/0009-0006-7778-2057
proflucasfaustino@gmail.com
DANIELLE PERETTI[1]
ORCID: https://orcid.org/0000-0002-5333-9812
perettidani@gmail.com
JEAN CARLOS DANTAS DE OLIVEIRA
ORCID: https://orcid.org/0000-0002-6665-7393
jeanceac2020@gmail.com

[1] Universidade do Estado do Rio Grande do Norte. Mossoró, Rio Grande do Norte (RN), Brasil.

ABSTRACT: The phylum Arthropoda contains the largest number of species in the Animalia kingdom, providing essential ecosystem services. According to the Brazilian National Common Core Curriculum, topics such as zoology and ecology should be taught in a contextualized way throughout various stages of basic education. In this context, this study aimed to develop an educational card game that addresses the morphology, ecology, and classification of arthropods. Seven arthropod species of notable relevance were selected for the card game. A total of 21 response cards were produced, divided into three levels (easy, medium, and hard), along with 7 cards featuring ecological habits that allow groups to earn extra points and cards with arthropod body segments. At a cognitive level, the game is expected to foster the development of critical thinking and problem-solving skills when applied. The card game has the potential to assist in learning the morphological and ecological aspects of arthropods, while also promoting the development of cognitive skills.

Keywords: active methodology, educational games, ecology, zoology

GAMIFICAÇÃO E ENSINO DE BIOLOGIA: ENTENDENDO OS ARTRÓPODES POR MEIO DE UM JOGO DE CARTAS EDUCATIVO

RESUMO: O filo Arthropoda possui o maior número de espécies do reino Animalia, assegurando importantes serviços. De acordo com a Base Nacional Comum Curricular, conteúdos como zoologia e ecologia devem ser trabalhados de forma contextualizada durante várias etapas da educação básica. Nesse sentido, este trabalho buscou desenvolver um jogo de cartas educativo que aborda a morfologia, ecologia e classificação dos artrópodes. Para o jogo de cartas, foram selecionas sete espécies de artrópodes com notada relevância. Obteve-se 21 cartas-respostas divididas em três níveis (fácil, médio e difícil), 7 cartas de hábitos ecológicos que possibilitam que os grupos acumulem pontos-extras e segmentos corporais de artrópodes. Em nível cognitivo, espera-se que o jogo, quando aplicado, colabore no desenvolvimento de habilidades de pensamento crítico e resolução de problemas. O jogo de cartas tem potencial para auxiliar no aprendizado dos aspectos morfológicos e ecológicos dos artrópodes, além de promover o desenvolvimento de habilidades cognitivas.

Palavras-chave: metodologia ativa, jogos didáticos, ecologia. zoologia.

GAMIFICACIÓN Y ENSEÑANZA DE LA BIOLOGÍA: ENTENDIENDO LOS ARTRÓPODOS A TRAVÉS DE UN JUEGO DE CARTAS EDUCATIVO

RESUMEN: El filo Arthropoda contiene el mayor número de especies del reino Animalia, proporcionando servicios ecosistémicos esenciales. Según el Currículo Básico Común Nacional de Brasil, temas como zoología y ecología deben enseñarse de forma contextualizada a lo largo de las distintas etapas de la educación básica. En este contexto, este estudio tuvo como objetivo desarrollar un juego de cartas educativo que aborda la morfología, la ecología y la clasificación de los artrópodos. Se seleccionaron siete especies de artrópodos de notable relevancia para el juego. Se elaboraron 21 tarjetas de respuesta, divididas en tres niveles (fácil, medio y difícil), junto con 7 tarjetas con hábitos ecológicos que permiten a los grupos ganar puntos adicionales y tarjetas con segmentos corporales de artrópodos. A nivel cognitivo, se espera que el juego fomente el desarrollo del pensamiento crítico y la resolución de problemas. El juego de cartas tiene el potencial de ayudar a aprender los aspectos morfológicos y ecológicos de los artrópodos, a la vez que promueve el desarrollo de habilidades cognitivas.

Palabras clave: metodología activa, juegos educativos, ecología, zoología.

INTRODUÇÃO

The phylum Arthropoda comprises approximately 1,025,000 known species worldwide, though estimates suggest there could be as many as 10 million (Reyes et al., 2021). This phylum includes

segmented organisms with an exoskeleton and jointed appendages (Carvalho & Pereira, 2022), which has enabled the group to develop diverse modes of locomotion and feeding, as well as the specialization of body regions and appendages (Brusca; Moore; Shuster, 2018).

Arthropods are key elements in the functioning of most ecosystems, as they provide essential ecosystem services (Nogueira, 2023). They sustain food webs, act as pollinators and seed dispersers, and contribute to the cycling of organic matter (França et al., 2018). They also play diverse roles in human society (Buss & Iared, 2022); for example, some arthropods are used as food, such as crustaceans, while others provide resources like honey, propolis, and silk (França et al., 2018).

Despite the frequent presence of arthropods in daily life and early exposure during childhood, human society generally associates the phylum Arthropoda with fear or disease (Buss & Iared, 2020). According to Moura, Valois, and Lima (2016), domestic animals and small to large mammals tend to be more appreciated by children compared to arthropods, as these children often have toys representing such animals and regularly see them on television.

In this context, the role of formal education is crucial, as the science taught in schools is imbued with values aimed at promoting specific behaviors, such as valuing and preserving the environment (Brasil, 2017). The National Common Curricular Base (BNCC), a document that defines essential learning content (Brasil, 2017), provides guidelines for the teaching of zoology and ecology, which are covered in both primary and secondary education. These components emphasize morphological and physiological characteristics, the organization of the phylum, its biodiversity, and ecosystem services.

In this scenario, basic education institutions must provide the means for students to fully develop their understanding of the morphology and ecological roles of arthropods. The BNCC highlights that meaningful learning requires content to be taught in a contextualized manner (Brasil, 2017). Therefore, it is up to educators to design alternative methodologies for teaching science in a concise and didactic way (Moura, 2020).

Given the need for methodologies that foster comprehensive knowledge development among primary education students, innovative approaches should be adopted by educators (Curvo; Mello; Leão, 2023). One possibility is the implementation of active methodologies, which emphasize the student as the central figure in the teaching-learning process (Lovato et al., 2018), encouraging them to adopt a critical and reflective stance (Guarda et al., 2023).

Examples of active methodologies include flipped classrooms, station rotation, and gamification. The use of gamification in education is becoming increasingly common (Zayas et al., 2019). Students who feel challenged become active agents of their own learning, establishing connections and interactions with other participants (Pimentel; Moura, 2022). Gamification involves the use of game elements to actively engage students in solving social challenges across various fields (Larré; Relvas; Oliveira, 2023).

Brian Burke (2015) highlights that gamification features characteristics such as the use of rewards and leaderboards; specific rules and steps to follow; interaction through technological or non-technological means; encouragement of changes in participants' attitudes; clearly defined rules; progressive difficulty levels; elements of conflict, competition, and cooperation; scoring, rewards, and feedback; and the development of innovative skills among participants.

From this perspective, this study aimed to develop an educational card game that covers concepts related to the morphology, ecology, and classification of representatives of the phylum Arthropoda. This game is intended for application in various stages of primary, secondary, and higher education. By incorporating playful and interactive elements, the aim is to provide students with a more positive learning experience, enhancing their performance in science and biology courses. Additionally, this proposal seeks to dispel misconceptions about the group, address fears, and challenge the utilitarian perspective that some students might have towards certain organisms.

METHODOLOGY

Development of the Card Game

- **Selection of Game Dynamics**

The game's dynamics were designed to incorporate the characteristics of gamification, as outlined in the book "Gamify: How Gamification Motivates People to Do Extraordinary Things" by Brian Burke (2015). This approach also aligns with the general objective of the natural sciences curriculum for primary education, as stated in the National Common Curricular Base (BNCC). According to the BNCC, the investigative process should be understood as a central component in the education of students, with its development tied to didactic scenarios planned throughout all stages of basic education (Brasil, 2017).

Additionally, the natural sciences objectives for secondary education, as set out by the BNCC, were considered. These objectives emphasize the expansion and systematization of knowledge acquired during primary education as a foundation for secondary education. This goal encompasses conceptual knowledge in the field, as well as the social, cultural, environmental, and historical contexts of this knowledge, along with investigative processes, practices, and the specialized languages of the natural sciences (Brasil, 2017).

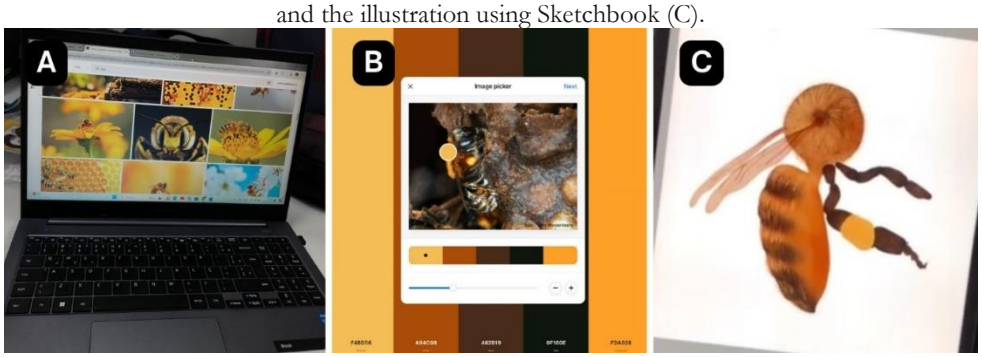
- **Research and Content Selection**

The development of the cards began with a research phase to select the most suitable representatives of the phylum Arthropoda for the game's objectives. The selection criteria included the diversity of ecological relationships established by the groups, their proximity to human-altered environments, their cultural, medicinal, and economic impact, their vulnerability to habitat loss due to human actions, the general population's knowledge base about them, and the emotions they evoke, such as fear, disgust, or fascination. To gather relevant information, the index databases ScienceDirect, SciElo, Google Scholar, and CAPES Journals were consulted, along with platforms like iNaturalist and Biodiversity4All. Using these sources ensured that the information was based on solid and up-to-date scientific evidence, providing a clearer understanding of the educational needs related to the group.

- **Game Design and Structure**

Once the selection of arthropods was complete, a photo screening process was conducted using Google Images and other image search tools (Figure 1 - A), prioritizing images that best represented living organisms in their natural environments, maintaining their colors and characteristics. With the help of the Coolors platform (Figure 1 - B), color palettes were created from the selected photographs, ensuring that the positions, body characteristics, and colors depicted in the game closely resembled the natural appearance of the arthropods. Next, using the digital illustration software Sketchbook (Figure 1 - C), scientific illustrations of each arthropod were manually created. The final cards were designed using Canva, with a layout structured to be visually appealing, pedagogically effective, and to present clear and relevant information for the game's dynamics.

Figure 1: Steps in the card game development, including the image selection process (A), the creation of color palettes (B), and the illustration using Sketchbook (C).



Source: created by the authors.

RESULTS AND DISCUSSION

Selection of Arthropod Groups for the Game

After conducting detailed research on arthropod groups suitable for the game's objectives, seven species were chosen (Figure 2) for the development of the material. These species were selected due to their ecological significance and educational value: the butterfly Heraclides thoas (Linnaeus, 1771), the crab Callinectes sapidus (Rathbun, 1896), the stingless bee Melipona subnitida (Ducke, 1910), a spider from the Theraphosidae family, a representative of the order Odonata, an arachnid from the subclass Acari, and a beetle from the genus Nicrophorus spp.

Figure 2: Selected species for digital illustration. A: Heraclides thoas (Linnaeus, 1771); B: Melipona subnitida (Ducke, 1910); C: Representative of the order Odonata; D: Acarina subclass arachnid; E: Theraphosidae family spider; F: Callinectes sapidus (Rathbun, 1896); G: Nicrophorus spp. beetle.

Source: Almir Candido de Almeida [A]; Blog Um Mossoroense Itinerante [B]; DepositPhotos [C]; BugGuide [D]; Cobasi Blog [E]; Jarek Tuszyński/WikiCommons [F]; NatureSpot [G].

Heraclides thoas (Linnaeus, 1771), known commonly as the caixão-de-defunto butterfly, is relatively common in Brazil and belongs to the family Papilionidae, considered a bioindicator due to its sensitivity to rapid environmental changes (Mare, Corseuil; Schwartz, 2004). This butterfly is frequently found in human-altered environments, laying its eggs on Citrus spp. and other rutaceous plants (Rafael et al., 2024), and it prefers to pollinate Lantanas, Asclepias, and Ixoras (iNaturalist).

Callinectes sapidus (Rathbun, 1896), the blue crab, is a key species in benthic ecosystems, controlling the abundance of other species and exhibiting an omnivorous and generalist diet (Tagatz, 1968). Fishing activities involving this crab hold significant social and economic importance in various Brazilian coastal communities (Brasil, 2019), although overfishing has had negative impacts on this species (Aguilar et al., 2008; Colton et al., 2013).

Stingless bees, known as native bees or indigenous bees (Aquino, 2006), are social bees with atrophied stingers, constructing their nests in tree trunks or underground. Among them, Melipona subnitida (Ducke, 1910), popularly known as Jandaíra, stands out as an important pollinator of native plant species. It is widely known among meliponiculturists (Vaz et al., 2021) and produces honey with healing properties (Alves et al., 2008), such as antidepressant effects, weight-loss support, and improvement of biochemical parameters affected by obesity in rodents (Bezerra et al., 2023).

Although the public has some knowledge of arachnids, they are often mistakenly classified as insects, leading to extermination due to fear and aversion (Santana; Neto; Silva, 2023), despite their

importance as top predators in food webs (Triplehorn; Johnson, 2011). Although many spiders have venom, not all pose serious threats to humans due to factors like low toxicity, small chelicerae, or living in areas seldom visited by people (Guerra et al., 2020). For instance, tarantulas, when threatened, release only their urticating hairs, which may cause inflammatory responses, rarely leading to severe clinical conditions (Filho et al., 2021).

Representatives of the order Odonata, commonly known as dragonflies, are among the most charismatic insects, partly due to their elegant, highly maneuverable flight, vibrant colors, and relatively large size (Pinto, 2024). These organisms have a close relationship with both aquatic and terrestrial environments (Farias et al., 2023), as they develop as nymphs in water bodies and, when adults, complete their life cycle on land (Borror et al., 1989). Dragonflies are excellent bioindicators of environmental quality (Costa et al., 2021) and help control populations of other invertebrates harmful to human health, preventing disease vector proliferation (Botero et al., 2022).

Mites, belonging to the Arachnida class, have a compact body and small size, leading to a wide range of species with diverse lifestyles (Brusca; Moore; Shuster, 2018). Part of their ecological diversity comes from their ability to "hitchhike" on larger animals (Seeman; Walter, 2023). For example, they may "ride" on bees, attacking colonies and parasitizing larvae (Silva et al., 2023), or "hitch a ride" on Nicrophorus beetles, establishing a phoretic relationship without parasitizing their larvae (iNaturalist).

The order Coleoptera exhibits a vast diversity of shapes, sizes, ecological strategies, and habitats (Silva et al., 2024). Beetles are quick to respond to anthropogenic pressures in natural environments (Texeira; Hoffmann; Silva-Filho, 2009). Beetles of the genus Nicrophorus bury the corpses of small vertebrates, such as birds or rodents, to serve as food for their larvae (Biodiversity4All), engaging in various ecological relationships such as competition and mutualism (Liu et al., 2020).

Response Cards

At the end of the process of selecting photographs, digital illustrations, and designing the layout of the cards, a total of 21 cards were produced (Figure 3), divided into three difficulty levels: easy, in green; medium, in yellow; and hard, in red. This division into levels allows the game to be adapted for different educational stages, with the easy level (Figure 4A) suitable for elementary education, the medium level (Figure 4B) for high school, and the hard level (Figure 4C) for higher education. Additionally, another way to use the game is through a progressive methodology based on difficulty levels, allowing for a gradual learning experience that makes the game more challenging as students advance in their understanding of arthropods.

Figure 3: Game cards showing difficulty levels: easy (green), medium (yellow), and hard (red).

Source: prepared by the authors.

The cards were designed with a balance between minimalist aesthetics and functional effectiveness (Figure 4D), focusing on the arthropod specimen by placing it centrally and prominently within a white circle. In contrast, the main illustration does not reveal some important body characteristics, thus preventing them from being used to identify the pieces that need to be collected during assembly. This approach encourages the use of previously acquired knowledge and the reading of additional information provided on the cards, promoting more active learning, where students need to apply their knowledge to solve the game's challenges.

The background colors clearly indicate the game's difficulty level, helping to quickly distinguish the cards. At the bottom center, accompanied by a book icon (Figure 4E), is the information about its phylogenetic classification. Below that, accompanied by a leaf icon (Figure 4F), are some body characteristics such as the number of legs and wings, relevant traits for distinguishing between groups. The organization of the information on the cards, with phylogenetic classification and body traits highlighted by specific icons, facilitates understanding and quick access to necessary information for each round.

On the bottom right side, the point values for each category are displayed. In the easy and medium-level cards, the maximum score is 25 points (Figure 4G and 4H). In the hard-level cards, the maximum score is 45 points (Figure 4I). In all levels, it is possible to accumulate extra points through curiosity cards. The scoring system serves as a motivator, encouraging students to delve into the details of arthropods to achieve the highest possible score.

Figure 4: Game cards showing difficulty levels: easy (A), medium (B), and hard (C). Card details (D) showing phylogenetic classification information (E) and body characteristics (F). Easy-level scoring values (G), medium-level scoring values (H),

and hard-level scoring values (I).

Source: prepared by the authors.

In the easy level, scoring criteria include the central axis of the body specific to each group, as well as the number of appendages the organism has. For example, to achieve the maximum score with a Melipona subnitida (Ducke, 1910) bee card at the easy level, the group must use a head, thorax, and abdomen from Hymenoptera, along with two pairs of wings and three pairs of legs from any arthropod group. Thus, the easy level should be seen as an introduction to the topic, allowing for initial familiarization with the morphology of arthropods, as the main focus at this level is recognizing the group based on its primary characteristics, such as body segmentation and number of appendages.

At the medium level, all body segments of arthropods must be specific to the organism to achieve maximum points, meaning it should be used when students already have more detailed knowledge and are ready for more complex challenges. At the hard level, in addition to the specific body of the arthropod, classification plates for class and order/subclass must also be used, expecting students to demonstrate a deeper and more detailed understanding of arthropods.

Table 1 – Highlighted information on scoring criteria for the educational game cards

	Easy Level	Pt	Medium Level	Pt	Hard Level	Pt
***Callinectes sapidus* (Rathbun, 1896)**	Class: Malacostraca	0	Class: Malacostraca	0	Class: Malacostraca	10
	Order: Decapoda;	0	Order: Decapoda	0	Order: Decapoda	10
	Decapod carapace	5	Decapod carapace	5	Decapod carapace	5
	1 pair of claws	5	1 pair of Decapod claws	5	1 pair of Decapod claws	5
	1 pair of swimming legs	5	1 pair of Decapod swimming legs	5	1 pair of Decapod swimming legs	5
	3 pairs of simple legs	10	3 pairs of Decapod legs	10	3 pairs of Decapod legs	10
***Mellipona subnitda* (Ducke, 1910)**	Class: Insecta;	0	Class: Insecta	0	Class: Insecta	10
	Order: Hymenoptera;	0	Order: Hymenoptera	0	Order: Hymenoptera	10
	Hymenoptera head	5	Hymenoptera head	5	Hymenoptera head	5
	3 pairs of legs	5	3 pairs of Hymenoptera legs	5	3 pairs of Hymenoptera legs	5
	Thorax	5	Hymenoptera thorax	5	Hymenoptera thorax	5
	Abdomen	5	Hymenoptera abdomen	5	Hymenoptera abdomen	5
	2 pairs of wings	5	2 pairs of Hymenoptera wings	5	2 pairs of Hymenoptera wings	5
Theraphosidae	Class: Arachnida;	0	Class: Arachnida	0	Class: Arachnida	10
	Ordem: Araneae;	0	Order: Araneae	0	Order: Araneae	10
	Araneae cephalothorax	5	Araneae cephalothorax	5	Araneae cephalothorax	5
	Abdomen	5	Araneae abdomen	5	Araneae abdomen	5
	4 pairs of legs	10	4 pairs of Araneae legs	10	4 pairs of Araneae legs	10
	1 pair of pedipalps	5	1 pair of pedipalps	5	1 pair of pedipalps	5
Heraclides thoas	Class: Insecta;	0	Class: Insecta	0	Class: Insecta	10
	Order: Lepidoptera;	0	Order: Lepidoptera	0	Order: Lepidoptera	10

(Linnaeus, 1771)	Lepidoptera head	5	Lepidoptera head	5	Lepidoptera head	5
	3 pairs of legs	5	3 pairs of Lepidoptera legs	5	3 pairs of Lepidoptera legs	5
	Thorax	5	Lepidoptera thorax	5	Lepidoptera thorax	5
	Abdomen	5	Lepidoptera abdomen	5	Lepidoptera abdomen	5
	2 pairs of Lepidoptera wings	5	2 pairs of Lepidoptera wings	5	2 pairs of Lepidoptera wings	5
Odonata	Class: Insecta;	0	Class: Insecta	0	Class: Insecta	10
	Order: Odonata;	0	Order: Odonata	0	Order: Odonata	10
	Odonata head	5	Odonata head	5	Odonata head	5
	3 pairs of legs	5	3 pairs of Odonata legs	5	3 pairs of Odonata legs	5
	Thorax	5	Odonata thorax	5	Odonata thorax	5
	Abdomen	5	Odonata abdomen	5	Odonata abdomen	5
	2 pairs of Odonata wings	5	2 pairs of Odonata wings	5	2 pairs of Odonata wings	5
Acari	Class: Arachnida;	0	Class: Arachnida	0	Class: Arachnida	10
	Subclass: Acarina;	0	Subclass: Acarina	0	Subclass: Acarina	10
	Acarina gnathosoma	5	Acarina gnathosoma	5	Acarina gnathosoma	5
	Abdomen	5	Acarina idiosoma	5	Acarina idiosoma	5
	4 pairs of legs	10	8 Acarina legs	10	8 Acarina legs	10
	1 pair of pedipalps	5	2 Acarina pedipalps	5	2 Acarina pedipalps	5
Nicrophorus spp.	Class: Insecta;	0	Class: Insecta	0	Class: Insecta	10
	Order: Coleoptera;	0	Order: Coleoptera	0	Order: Coleoptera	10
	Insecta head	5	Coleoptera head	5	Coleoptera head	5
	3 pairs of legs	5	3 pairs of Coleoptera legs	5	3 pairs of Coleoptera legs	5
	Thorax	10	Coleoptera thorax	10	Coleoptera thorax	10
	Abdomen and Coleoptera wings	5	Coleoptera abdomen and wings	5	Coleoptera abdomen and wings	5

Source: prepared by the authors.

The card game, as a form of gamification, has the potential to assist in learning about the morphological and ecological aspects of arthropods, as well as significantly promoting the development of cognitive skills, including for individuals with disabilities or developmental disorders (Botelho; Oliveira; Giglio, 2017; Najjar; Salhab, 2022). In this way, important cognitive skills such as logical reasoning, decision-making, and problem-solving can be developed (Costa et al., 2020; Viana et al., 2013), contributing to the development of competencies and skills as outlined in the National Common Curriculum Base.

Gamification, through the card game, makes the study of arthropods more dynamic and engaging, contrasting with traditional teaching methods, which can be less interactive and emphasize content quantity over critical thinking development (Pereira et al., 2020). This playful aspect of gamification can increase students' motivation and interest in biology, leading to improved learning outcomes.

Ecological Habits Cards

The ecological habits cards (Figure 5) allow groups to accumulate extra points. To this end, the main ecological habits of each arthropod representative selected for the game were described in a simplified manner (Table 2).

Ecological habits and curiosity cards illustrate the complexity of ecological interactions among the various arthropod species. They emphasize the importance of these groups in maintaining ecological balance, whether through pollination, pest control, decomposition, or mutualistic interactions

(França et al., 2018). The opportunity to earn extra points aims to encourage students to understand the interdependence between organisms and their roles in ecosystems.

Figure 5: Cards depicting the ecological habits of each species.

Source: prepared by the authors.

Table 2 – Highlighted information on the ecological habits of arthropods, extracted from the ecological habits cards in the educational game.

Callinectes sapidus (Rathbun, 1896)	The blue crab is omnivorous, feeding on algae, organic debris, small fish, mollusks, worms, and other crustaceans. It uses its claws to capture and manipulate food, playing an important role in coastal ecosystems by consuming a variety of organisms and organic matter.
Mellipona subnitda (Ducke, 1910)	Bees are essential insects for pollination and primarily feed on nectar and pollen from flowers. They also serve as food for other animals, such as dragonflies, and some mites that attach to them and feed on their blood.
Heraclides thoas (Linnaeus, 1771)	Butterflies (adults) feed on nectar from flowers, using their mouthparts. Some species may also consume liquids from decaying fruits or tree sap. The larvae (caterpillars) feed on leaves, flowers, or fruit, depending on the species.
Theraphosidae	Spiders are predators that feed on other arthropods. They use their webs to capture prey or hunt actively. Depending on factors such as population density and food availability, some spiders may even feed on other individuals of the same species.
Odonata	Dragonflies (adults) are voracious predators of other insects such as mosquitoes, flies, bees, and butterflies. They hunt while flying, using their excellent vision and maneuvering skills to catch prey mid-air. The larvae (nymphs) are aquatic and feed on small invertebrates such as crustaceans.
Acari	Mites can engage in various ecological relationships, acting as parasites to some arthropods by feeding on their blood, hitching rides on others (phoresy), or even engaging in mutualism with beetles of the genus Nicrophorus spp., keeping the beetle's body free from bacteria without parasitizing its larvae, in exchange for a "ride.".
Nicrophorus spp.	Beetles play important ecological roles. They may feed on small arthropods, pollinate plants, or, in some cases, as in the genus Nicrophorus spp., engage in mutualism with mites of the genus Poecilochirus spp., offering a "ride" in exchange for a clean body and healthy larvae.

Source: prepared by the authors.

Material for Assembly

According to the assembly criteria outlined in the main cards, we obtained the body fragments and the phylogenetic classification plates necessary for the game dynamics (Figure 6). As

shown in Figure 4, the following materials were collected: 2 heads, 2 thoraxes, 2 abdomens, and 12 legs of Lepidoptera; 2 carapaces, 4 clawed legs, 4 swimmer legs, and 12 simple legs of Decapoda; 2 heads, 2 thoraxes, 2 abdomens, 8 wings, 4 hind legs, and 8 simple legs of Hymenoptera; 2 cephalothoraxes, 2 abdomens, 16 legs, and 4 pedipalps of Araneae; 2 heads, 2 thoraxes, 2 abdomens, 12 legs, and 8 wings of Odonata; 2 gnathosomas, 2 idiosomas, 16 legs, and 4 pedipalps of Acarina.

Additionally, the phylogenetic classification plates included: 8 pieces from the class Insecta; 2 pieces from the class Malacostraca; 4 pieces from the class Arachnida; 2 pieces from the order Odonata; 2 pieces from the order Lepidoptera; 2 pieces from the order Decapoda; 2 pieces from the order Hymenoptera; 2 pieces from the order Araneae; 2 pieces from the subclass Acarina; and 2 pieces from the order Coleoptera.

Figure 6: Body segment pieces for the construction of arthropods.

Source: prepared by the authors.

The body segments of the arthropods were designed to promote learning based on the observation of the species' body morphology, allowing students to visualize the invertebrate in greater detail and develop an investigative mindset. In this way, structures that would typically remain secondary when observing a complete arthropod can now be studied in detail, such as the corbiculae—structures located on the hind legs of bees that assist in pollen transport (Gavilanes, Castillo, Zavala, 2023) or the paddle-shaped structure of the posterior legs of a crab.

This methodology enables students to explore the morphological diversity within the Arthropoda phylum. By handling and observing different body parts from organisms such as insects, arachnids, and crustaceans, students can develop a deeper understanding of the variations that occur within this highly diverse group. This approach can foster a greater appreciation of biodiversity and the ecological interactions that these groups participate in. Moreover, the richness of detail in the arthropod fragments requires players to pay attention to the specific characteristics of each specimen, encouraging them to carefully observe the morphological traits of each individual to maximize their points per round.

The assembly process using the body segments of arthropods stimulates the group to identify patterns and differences between species, while also helping them understand how these details relate to the classification and ecological function of the organisms, thus developing skills in observation and analysis. Additionally, the number of body segments has been doubled to ensure that surplus pieces

remain. Therefore, if one group has part of their arthropod "collected" by another group, they will not be penalized, thus ensuring a fairer game flow.

The Rules of the Game

The design of the game rules (Table 3) was carried out in a way that integrates the goals of the work with the competencies and skills outlined in the National Common Curricular Base, utilizing the gamification features described by Burke (2015).

Table 3 – Rules of the educational game on the ecology, morphology, and classification of arthropods.

I. Formation of Groups
• Players must divide into groups of 3 to 4 participants.
II. Selection of the Game Leader
• Each group must elect one of its participants to be the game leader.
• The selected participants must come to a consensus and decide who will be the leader.
III. Distribution of Cards
• The game leader should shuffle the answer cards, select a card for their group, and distribute one answer card to each group without revealing the organism on the card.
• The card can only be flipped to reveal the organism with the authorization of the leader.
IV. Reveal of the Organism
• With the authorization of the leader, groups may flip their cards for ten seconds.
• After this time, the groups must place the cards, with the organism facing down, in a visible location for everyone.
V. Assembly of the Invertebrate
• Groups will have one minute, starting from the leader's authorization, to assemble their organism.
VI. Scoring
• The leader of each group must tally the score for another group using the answer cards.
• At this point, each group must present a brief explanation of their arthropod's ecological role. If successful, they will earn extra points (the leader must verify the ecological role and the corresponding score on the trivia cards).
• In games with up to 3 groups, the group with the lowest score will be eliminated.

- In games with 4 to 6 groups, the two groups with the lowest scores will be eliminated. When 3 groups remain, the previous rule applies.
- In games with more than 6 groups, the three groups with the lowest scores will be eliminated. When 6 groups remain, the previous rule applies.

Source: prepared by the authors.

The division of players into groups of 3 to 4 participants is a strategy aimed at fostering cooperation and teamwork. This format aligns with the active teaching methodology, which seeks to involve students in the learning process in a relevant and participatory way, promoting deeper and more effective learning (Børte, Nesjeb, & Lillejord, 2020). The choice of small groups also facilitates game management and dynamics, making it suitable for use even in classrooms with fewer students.

The process of shuffling and distributing the answer cards by the game leader introduces an element of surprise and fairness to the game. The decision not to immediately reveal the organism on the answer card maintains anticipation and motivates students to focus and pay attention to details. The brief period of ten seconds to visualize the card with the organism before flipping it back down creates a sense of urgency, requiring students to use their observational skills efficiently. Additionally, the one-minute limit for assembling the organism simulates situations encountered in exams or practical activities, preparing students for scenarios where tasks must be completed within a time constraint.

This aspect of the game also demands that groups work cohesively to achieve the objective, encouraging students to actively communicate with their peers. The process aims to develop communication skills as well as the ability to work in teams. As a feature of gamification described by Burke (2015), the scoring process, conducted by a leader from another group, promotes transparency and impartiality within the game. Furthermore, allowing groups to earn extra points by explaining the ecological role of their arthropod encourages discussion and critical thinking about the ecological functions of organisms.

CONSIDERAÇÕES FINAIS

Gamification is an active methodology that aims to make biology teaching more engaging, offering a way to meaningfully involve students (Medeiros, Lima, & Silva, 2021). By integrating game elements into science content, there is an opportunity to maintain student interest through challenges. This strategy can stimulate the development of students' potential, as well as critical thinking and autonomy, in addition to encouraging teamwork (Cohen et al., 2020). Gamification can also increase student engagement during biology classes, serving as a tool to stimulate active participation and collaboration among students. The card game about arthropods, developed in this study, seeks to encourage students to explore, discuss, and apply their knowledge in a gamified context. On a cognitive level, the game is expected to contribute to the development of critical thinking and problem-solving skills.

To evaluate the effectiveness of the card game, it is planned to implement it in a school in the future. This stage will be important to understand how students interact with the game, in which aspects it can contribute academically and socially, and how gamification influences biology learning.

Considering the scientific foundation behind the development of this teaching material, the integration of gamification in biology teaching can engage students, stimulate active participation, and facilitate the understanding of complex concepts. This work has the potential to significantly enhance the educational experience of students in the field of natural sciences, contributing to the development of cognitive skills such as critical thinking, decision-making, and teamwork—essential for academic and social life. Moreover, the teaching material represents a valuable tool for teachers at various educational levels, enabling more contextualized lessons.

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CONTRIBUIÇÃO DOS AUTORES

Autor 1 – Elaboração e desenvolvimento do projeto, análise dos dados, síntese do jogo de cartas e revisão da versão final do artigo.
Autora 2 – Orientação da pesquisa, participação ativa na análise de dados, escrita do texto e revisão da versão final do artigo.
Autor 3 – Coorientação da pesquisa, participação ativa na análise de dados, escrita do texto e revisão da versão final do artigo.

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