Teaching zoosemiotics as an educational framework for understanding animal sound communication

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Received: 30 August 2025; Revised: 23 October 2025; Accepted: 20 November 2025; Published: 20 December 2025

Abstract

Teaching animal communication processes known as zoosemiotics provides an interdisciplinary framework for helping learners understand how animals create, perceive, and understand sounds. Drawing on bioacoustics, semiotics, ethology, and communication studies, zoosemiotics education encourages students to move beyond anthropocentrism and recognize the communication of animal sounds as intentional and meaningful communication within an ecological and social framework. This model enables learners to consider animal vocalizations as a unique semiotic system, and to analyze how various signals convey information about identity, social and emotional states, and social, and environmental changes. Including studies in zoosemiotics also promotes scientific literacy, critical thought and ethics in human–animal relations. In all, teaching zoosemiotics provides students with the tools to understand the intricate, multimodal, sound communication systems used in various forms of animal life, while fostering an appreciation for the understanding of animal agency and biodiversity.

Keywords: Zoosemiotics, Animal communication, Sound communication, Semiotics, Ethology, Animal behavior, Environmental education, Communication systems

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DOI: 10.70102/IJARES/V5I2/5-2-80

Introduction

As part of interdisciplinary bioacoustics, ethology, linguistics, and semiotics, the study of animal sounds and their communications have recently become a focus of investigation as a component of domestic and wild animal behavior modelling. While human language and communication have faced centuries of scrutiny, the multiple nuances of animal sounds have subsequently been regarded without the attention they deserve (Pain, 2011). Due to novel, interdisciplinary approaches of bioacoustics and zoosemiotics, the study of non-human communications and their sign systems, we are beginning to understand that animal sounds are much more intricate and nuanced than they functional responses to variable environments (Lewis, 2021). They are a form of contextual, multifunctional communication that conveys essential information about a species' social structure, emotional state, territorial defense, reproductive behavior, and critical information for interspecies survival (Mudiono, Gipayana and Madyono, 2016).

The integration of the teaching of zoosemiotics within the classroom provides a basis whereby students are enabled to understand the systems animals are employed to encode meaningful messages, ultimately and interact with their ecological systems (Nowak, 2021). The fundamental semiotic systems of animal sound communication can be taught to students, allowing them to appreciate the more nuanced understanding of the behavior of animals, moving away from the anthropocentric interpretation of the communication and the functional intercommunication among animals (Tarrikas, 2024).

Zoosemiotics provides students the opportunity to examine the interrelatedness of the biological phenomenon of animal communication and the systems of meaning encoded in signs. Like human languages, the calls of animals can also be interpreted as semiotic systems, as sounds and other visual cues are encoded in a code that animals decipher to navigate their environment. The warning calls of vervet monkeys, the songs of courting birds, and the echolocation c licks of bats all illustrate the use of sounds as symbols to convey animal messages (Khyade, Pawar and Khilare, 2018).

Moreover, one benefit of constructing educational frameworks around zoosemiotics is the promotion of affective and cognitive appreciation of other animals. The promotion of ethical reasoning derived from these frameworks encourages reflection on the social and moral dimensions of human-animal relations and anthropocentric communication (Tierney, 2024). The promotion of ecological understanding empowers the students to defend the unprotected communication interbreeding of species. The construction of educational frameworks around zoosemiotics empowers the students to understand the communication of non-human animals. These fosters understanding of the relations between animals and their environment and the practice of ecological ethics (Sabah, Kroon and Liunokas, 2025).

Key contribution

- Zoosemiotics underlines that animal vocalizations are not just reflexes but deliberate, meaningful signals. It showcases the complexity and variety of sound communication among species, providing insights into how animals utilize sounds to express identity, emotions, social roles, and more environments.
- By combining bioacoustics, ethology, linguistics, and semiotics, zoosemiotics offers a comprehensive educational framework that encourages students to examine animal communication from various perspectives.
- It questions human-centered perspectives and prompts students to reflect on the ethical consequences of human actions, like habitat destruction or noise pollution, which interfere with animal communication well-being.
- It promotes critical thinking by having students examine how animals use sounds in particular ecological and social settings, helping them develop a more detailed understanding of animal behavior communication.

Literature Review

Semiotic analysis of intra-specific signaling is termed Zoosemiotics, and pertains to the integration of various domains concerned with the study of communication among non-human animals. In relation to the communication of non-human animals, the different types of studies are traditionally analytical at the level of the animal and bioacoustics, or analyze the communication of animals as an ancillary of primary research, such as ecology or ethology. In contrast, zoosemiotics views the communication of animals as a signifying collection of components within the animals' psychological and social ecology (Kass, 2024). Furthermore, it acknowledges that there is complex, purposefully articulated communication, including vocalizations and other social and signaling means, directed to other members of the species. Zoosemiotics serves as the principle for viewing animal communication in its primary sound system. This system is not merely a biofeedback apparatus but conveys social structure and signals for interaction/survival/reproduction signal exchange. There exists an intra-species communication structure. In zoosemiotics, the concept of is fundamental. This is defined as an organism's specific perception of its surroundings (Esfandiari and Ghanbari, 2018).

The necessity of performing communication analysis based on the individual animal's possible sensory, ecological, and social frameworks must be addressed with the utmost caution. The analysis of communication parameters in nonhuman animals is a significant contribution of zoosemiotics to the study of nonhuman signalling systems (Briefer *et al.*, 2024).

Different forms of communication exist across the living world. There are very few species that communicate in the same way humans do. Humans are capable of using vocal sounds in very complex ways that go beyond basic speech. Humans use complex spoken communication for wayfinding, courtship, emotional expression, and social stratification. The ability to warn

and announce, defend territories, and close social groups is a fundamental social function that vocal communication serves. With the passage of time and aided by evolution, the tasks of communication signals become refined, preserving the ability to anticipate and predict the responses of the communication's intended audience. Creating sounds that are strung together in speech for communication can be limited by biology and the environment. Alterations in frequency, amplitude, and modulation of the voice are among the ways some species adjust their vocal communication to suit habitat challenges better. This provides valuable information about the animal communication systems in relation to the animals' physical environment (Bharathi and Senbagam, 2025).

Including zoosemiotics in educational programs broadens understanding of communication in the animal world. This perspective does inspire one to transcend the conventional biologically oriented thinking. It allows students to engage in more meaningful explorations of how animals utilize particular signs (Muir *et al.*, 2025). When students learn to think about animal noises in terms of coherent, structured systems of signification, they can address questions about how specific sounds function as signs, which signs are received, and which sounds are relevant to the particular ecosystem and social context (Verma *et al.*, 2025). The pedagogy of zoosemiotics broadens students' appreciative understanding towards the extensive systems animals use to communicate. It combats the anthropocentric notion and associated ethical perspective that animal systems of communication are primitive and inferior to human communication. This way, students understand animal systems as a specialized and distinct forms of communication. This way of thinking fosters critical reasoning as students are required to interrogate social constructs associated with animal communication, thereby promoting scientific literacy and ecological awareness (Del Olmo, Schmal and Herzel, 2025).

Methodology

3.1 Overall Architecture Diagram for Reaching Zoosemiotics as an Educational Framework for Understanding Animal Sound Communication

The Most Priori Figure 1. Entitled, Teaching Zoosemiotics and Educational Perspectives, and Animal Sound Communication, Depicts the Basic Steps Necessary to Integrate Zoosemiotics into the Educational Framework in the Field Introducing Zoosemiotics, Which Describes the Field, Its Purpose, and the Place of Semiotics in the Study of Animal Communication. This Is Followed by the Essentials, Namely the Sign Systems in the Communication of Animals, Code and Signal Systems, the Animal's Umwelt, and the Communication in its Various Modalities: Vocal, Visual, and Chemical. The Diagram Then Proceeds to the Educational Framework for the Teaching of Zoosemiotics, Which Is Advocated for the Interdisciplinarity of, Especially Bioacoustics, Ethology, and Linguistics, Integrated with Scientific and Ethical Literacy, Especially Bioacoustics, Environmental, and Animal Sympathy.

Finally, This Incorporates Educational Conservation Frameworks Related to the Effects of Environmental Noise on animal communication and the Ethical Aspects of Human Interference.

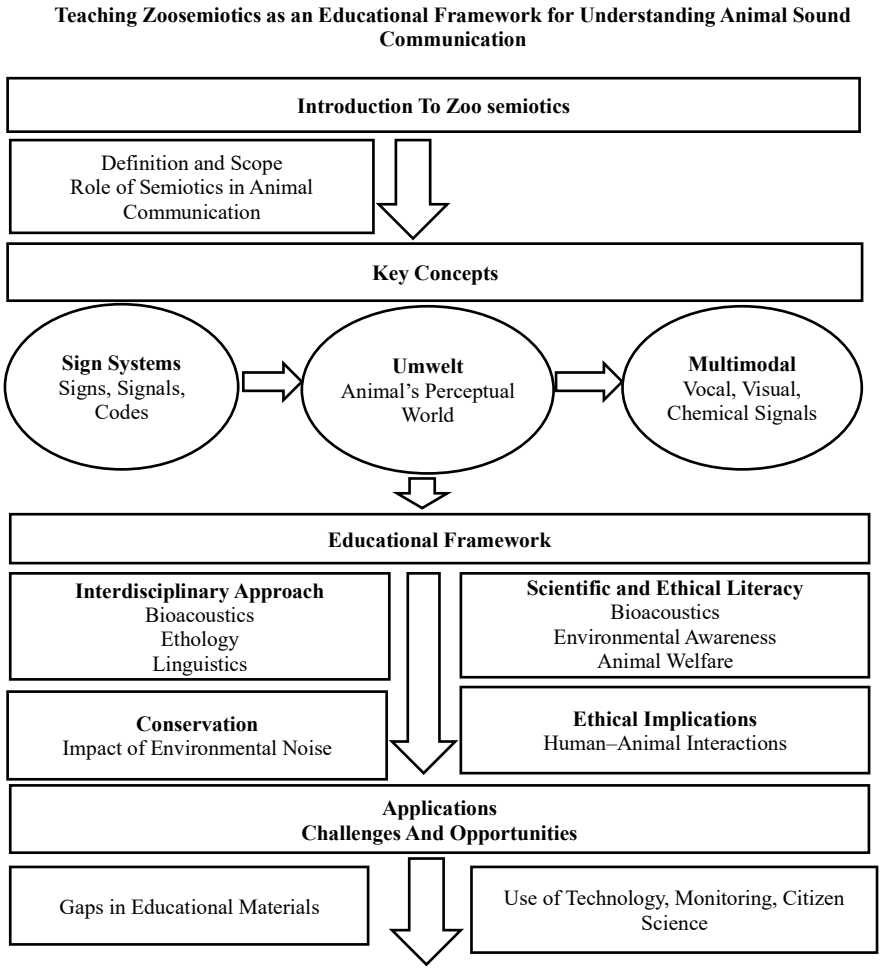

Figure 1: Framework for understanding animal sound communication.

The final Applications section details the significance of this framework in understanding the value of conservation, the ethics of using animals, and the treatment of animals. In the Challenges and Opportunities section, the focus is on gaps in available educational resources, the integration of technology and monitoring, and citizen science to further advance education in the field of zoosemiotics.

Table 1: Materials and methods for animal communication.

Category	Details
Materials	Animal Sound Recordings, Vidos, Spectrogram Software, Case study packets, online resources, and recording devices.
Key concepts	Audio/Video clips, case studies based on small species, and visual diagrams to explain semiotic concepts.
Interdisciplinary approach	Bioacoustics, ethology, linguistics, and case studies integrate with these disciplines, and multimedia resources demonstrate the different animal behaviors.
Applications	Bioacoustics software, field work documentation, and monitoring technology

3.2 Materials and Methods

The section summarizes Table 1, the techniques, and the tools used to examine for the first time the communicative abilities of animals. Resources included the animals' sounds and videos, spectrograms, case study packets, and various recording instruments. Major topics under examination involved the analysis of audio and video materials, illustrations of semiotics, and the study of small animals. This work engaged cross-disciplinary collaboration, comprising bioacoustics and ethology. linguistics and case study analysis for an integrated presentation of the animal's behavior. The techniques involved using various bioacoustics programs, fieldwork instruments, and surveillance equipment to study animal interactions.

3.3 Educational Framework for Understanding Animal Sound Communication

The cross-disciplines of animal studies and sound communication is governed by Educational Frameworks for Understanding Animal Sound Communication. This inquiry describes and examines sign systems that animals use, such as alarm and mating calls and sounds. 'Umwelt' is also described, which is the unique perceptual universe of a given species and controls how that species produces and hears a sound. The framework also elaborates on the concept of animals being one-dimensional, multi-modal communicators. This is because animals are known to use and combine vocal, visual, and chemical signals simultaneously. This Framework integrates aspects of bioacoustics, ethology, and linguistics by investigating the parameters and characteristics of sound, animal behavior, and the environment, and the meanings of animals' sounds. The framework also defends the study of animals' sounds in their environments based on scholarly ethics and scientific literacy. This assessment employs sound and spectrogram software and instruments while factoring in the environmental consequences of animal research techniques that could potentially lead to electrically mediated noise pollution. Within the theoretical framework, the use of sound communication theory in conservation efforts and the application of sound to monitor and trace the location of endangered species illustrate human-animal communication. The framework illustrates research to the public by detailing the use of bioacoustics sensors and public sound data collection efforts involving citizen science.

The framework wraps up by contemplating issues and prospects in education, including resource limitations and the implementation of cutting-edge technology, and urges learners to thoughtfully consider the balance among scientific inquiry, conservation, and the ethics of studying communication in non-human animals. In all, the framework aims to provide an all-encompassing perspective on the communication of sounds in non-human animals across scientific, ethical, and technological dimensions.

3.4 Game Theory in Animal Communication

Sometimes communication through sounds made by animals may be studied like communication in game theory, viewing animals as players in a game of strategy. This is useful for analyzing the

evolution and mechanisms of game-theoretic communication. For instance, one may model a signaling game where the Sender (the sound producing animal) possesses a message. Receiver (the sound perceiving animal) takes some decision related to action a based on the received signal (the one perceived). The signal is one of the control variables in the game and the action from the receiver is the other control variable of the game. The outcome for these players in the game (the sender and the receiver) is determined by a game called the payoff matrix.

$$\begin{matrix} A & B \\ P1 & P2 \\ P3 & P4 \end{matrix} \quad (1)$$

The above Eqn (1) describes the P1, P2, P3, and P4, which represent the payoff for the different sender and receiver combinations.

3.5 Network Theory for Group Communication

In certain social animals such as elephants or wolves, communication extends beyond dyads to include entire troops. Network theory can be harnessed to outline the communication phenomena at the group level. In such a network representation, the vertices are animals and the edges are the communication signals. The network topology (i.e., the structure of the social communication network, such as who communicates with whom) can be used to trace the flow of information in the group. Metrics of interest may include Degree centrality: how central a given animal may be in the communication network. Clustering coefficient: the rate at which animals in a group communicate with one another. The information (e.g. alarm calls) can be modeled as a communication or epidemic phenomenon.

$$\frac{dI(t)}{dt} \ \beta S(t)I(t) \ \gamma I(t) \quad (2)$$

From the above Eqn (2) describes the susceptible population, I(t) is the infected or communicated population. β and γ Represents the infection and recovery.

Results And Discussion

4.1 Dataset Description

This comprehensive resource devoted to the study and instruction of the interdisciplinary field of animal sound communication integrates bioacoustics, ethology, linguistics, and semiotics: The Zoosemiotics Educational Framework Dataset. The dataset is designed to contain a diverse collection of animal vocalization samples, spectrograms, behavior descriptions, semiotic analyses, and species profiles, and, provincial and ethical information. Its intended purpose is to function within educational contexts, such as university-level classes, workshops, and/or citizen science initiatives. The dataset comprises field recordings of animal sounds, such as the songs of birds, whales, and primates, and is organized by various ecological contexts. Each recording is accompanied by extensive metadata, including species, field recording location, date, time, and context of the call (e.g., alarm, mating). These recordings are also accompanied by spectrograms and detailed pitch and frequency analyses of the sounds for which the recordings are provided.

4.2 Performance Comparison for Various Metric Analysis

The analysis of scores according to different criteria within the Zoosemiotics

Educational Framework for Understanding Animal Sound Communication (table 2 and figure 2) indicates heterogeneous distribution which shows that respondents have different levels of knowledge and skills, and to some extent, indicates the presence of a problem that needs to be accounted for. The highest score goes to Communication & Presentation Skills (92%). This shows that the students could present the results of their research activities verbally and/or in writing. Therefore, the goals of teaching students to develop presentation skills have definitely been achieved. Also, Technical Sound Analysis (90%) and Technological Integration (88%) scores were high which means that students could analyze the sounds of the animals and use modern tools and technologies such as bioacoustics sensors and spectrogram software.

Table 2: Performance comparison for various metric analyses.

Component	Performance Score (%)
Real-World Application	78
Communication & Presentation Skills	92
Technological Integration	88
Ethical & Environmental Understanding	75
Application of Zoosemiotics	80
Technical Sound Analysis	90
Conceptual Understanding	85

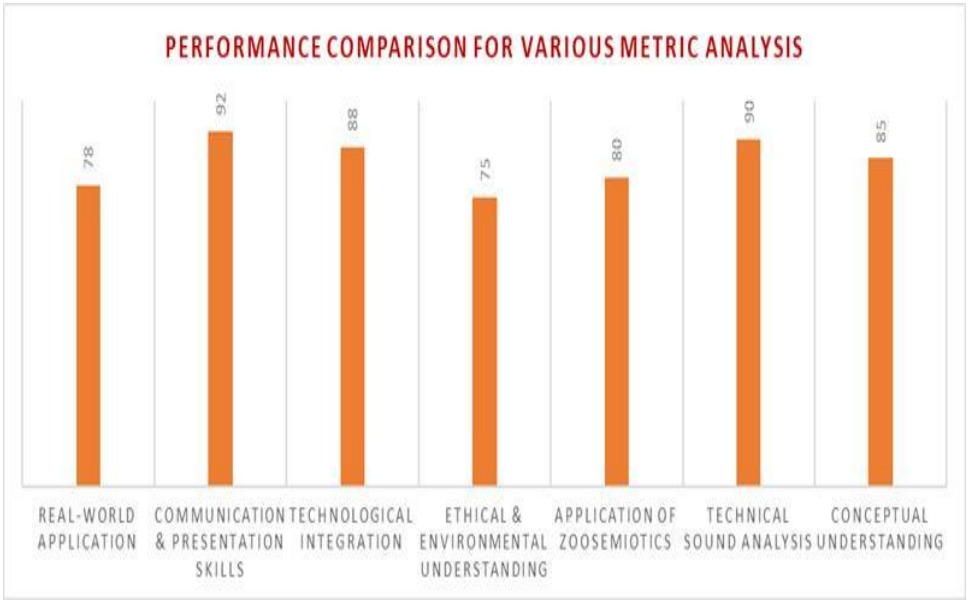

Figure 2: Performance comparison for various metric analysis.

The results prove the successful implementation of technical skills and the appropriate use of the provided technologies. But still, some values seem to require more efforts to be made. The Ethical & Environmental Understanding score of 75% is the lowest which means that students understand the basics of ethics in animal research, but this knowledge is rather superficial logically with the more human-centered discussions regarding the effects of anthropomorphizing communication with animals. Real-World Application

also received the Predictive Indicator Score of 78%. This shows the students know the theory; however, students still need to learn more about theory application in practical conservation efforts. The Predictive Indicator Scores concerning students' Conceptual Understanding and Application of Zoosemiotics were more positive, 85 and 80, respectively. The students knew the essence of other animals' sentiments well. They were also able to apply the knowledge; however, its application could benefit from stronger engagement with more complex topics and a wider diversification of species and taxonomic analysis.

Discussion

Teaching Zoosemiotics as an Educational Framework for Understanding Animal Sound Communication offers an amalgamation of several fields i.e. semiotics, bioacoustics, ethology, and linguistics. This framework allows students to learn the fundamental concepts of animal communication, focusing on animals' vocalizations as signs. It teaches learners to interpret animal vocalizations through the semiotic triangle (signifier, signified, interpretant) and bridges the gap between theory and practice in areas such as conservation and animal behavior. Using bioacoustic sensors and spectrogram software to examine and interpret the communication of various organisms, students acquire useful, practical skills while participating in citizen science. The course also attends to the negative human behavioral and activity ramifications on the communications of animals and the research and advocacy ethics on the research subjects. The design confers to the students a holistically incorporated wisdom on the communications of various organisms and the requisite knowledge and ethics for direct application in the realms of conservation and other disciplines. The synthesis of theoretical knowledge and technology with ethics reflection provide the students tools to offer societal value in bioacoustics, behavioral study of animals and conservation.

Conclusion

Teaching Zoosemiotics as an Educational Framework for Understanding Animal Sound Communication takes an integrated multidisciplinary approach to the study of the sound communicative abilities of animals. The study of the animal vocalization social communication. The complex integration of semiotic\ss, bioacoustics, ethology, and linguistics provide for the ecological and social and ecological understanding the animal vocalizations. The frameworks core focus on theory application is further augmented through instrumentation, technology, bioacoustics sensors, spectrogram software and citizen science projects. The ethical and environmental aspects of the of the frameworks design provide students with a sense and responsibility when studying animals. The frameworks integration of scientific inquiry and conservation overcomes the narrative of despair concerning the ecological and behavioral problems of studying communication in animals. Overall, this framework designs students to be bioacoustics, animal behaviour, conservation science and to appreciate the communication in animals and the enhanced relationship with nature. This is

fundamental in preparing the future seminarians, conservation practitioners and communicators of the animal communication and ecosystem custodianship, of the animals and the ecosystem.

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