International Journal of Veterinary Sciences and Animal Husbandry 2024; 9(6): 94-102

International Journal of Veterinary Sciences and Animal Husbandry

ISSN: 2456-2912
VET 2024; 9(6): 94-102
© 2024 VET
www.veterinarypaper.com
Received: 19-09-2024
Accepted: 27-10-2024

P Abinaya
Department of Veterinary Anatomy, Madras Veterinary College, TANUVAS, Chennai, Tamil Nadu, India

K Dharani
Department of Veterinary Anatomy, Madras Veterinary College, TANUVAS, Chennai, Tamil Nadu, India

R Gnanadevi
Department of Veterinary Anatomy, Madras Veterinary College, TANUVAS, Chennai, Tamil Nadu, India

TA Kannan
Department of Veterinary Anatomy, Madras Veterinary College, TANUVAS, Chennai, Tamil Nadu, India

Corresponding Author:
P Abinaya
Department of Veterinary Anatomy, Madras Veterinary College, TANUVAS, Chennai, Tamil Nadu, India

Beyond the dissection table: AI powered virtual anatomy for veterinary students

P Abinaya, K Dharani, R Gnanadevi and TA Kannan

DOI: https://doi.org/10.22271/veterinary.2024.v9.i6b.1843

Abstract

The integration of artificial intelligence (AI) into anatomy education offers transformative potential, providing resources that enhance both deep and logical understanding through immersive, three-dimensional virtual reality experiences. These tools simulate the exploration of a living, breathing animal body, contributing significantly to the comprehensive knowledge required for clinical practices in veterinary medicine and surgery. However, several challenges must be addressed for successful implementation. Logistical concerns, such as the costs associated with servers, educational tool development, and technical support, pose barriers. Additionally, issues of access and equity arise, as some students may lack adequate computer resources or reliable internet connectivity, limiting their ability to fully engage with these technologies. Furthermore, the design of AI-based educational programs must be inclusive, accommodating diverse curricula and various cultural, racial, and ethnic contexts. Addressing these considerations is essential to ensuring AI's effective integration into anatomy and medical education, enhancing learning while overcoming practical and accessibility obstacles.

Keywords: Accessibility, connectivity, transformative, veterinary and virtual

1. Introduction

Intelligence encompasses the capacity to think critically, analyse information, learn from past experiences, and adapt to new situations (Tirri & Nokelainen, 2011) [60]. It plays a crucial role in shaping human experiences, involving cognitive abilities such as understanding, reasoning, recognition, invention, planning, crisis management and communication (Colom *et al*., 2010) [14]. When these cognitive functions are replicated by machines, it is known as artificial intelligence (AI) (Collins, 2021) [13].

Artificial intelligence is a field of science focused on developing computer algorithms that perform tasks typically requiring human intelligence. Significant advancements in AI have been driven by innovations in artificial neural networks and deep learning. AI is broadly defined as the creation of machines capable of exhibiting intelligent behaviour and performing tasks that were traditionally executed by humans (McCarthy, 1955; Chan & Zary, 2019; Russell & Norvig, 2010) [37, 9, 49]. This involves creating systems that can think, learn and make decisions autonomously, aiming to replicate or surpass human cognitive functions.

2. Domains of AI

Artificial Intelligence (AI) comprises three primary domains:

1. Symbolic, Logic-based, and Knowledge-based AI
2. Statistical AI, which encompasses probabilistic methods and machine learning
3. Sub-symbolic AI, which includes embodied intelligence and search algorithms (Abdellatif *et al*., 2022) [1].

Each of these domains addresses different facets of problems, such as perception, planning, knowledge, reasoning, and communication (Russell & Norvig, 2010). [49] Today, AI is applied across various sectors, including finance, automotive engineering, economics, medicine, and education (Chan & Zary, 2019) [9].

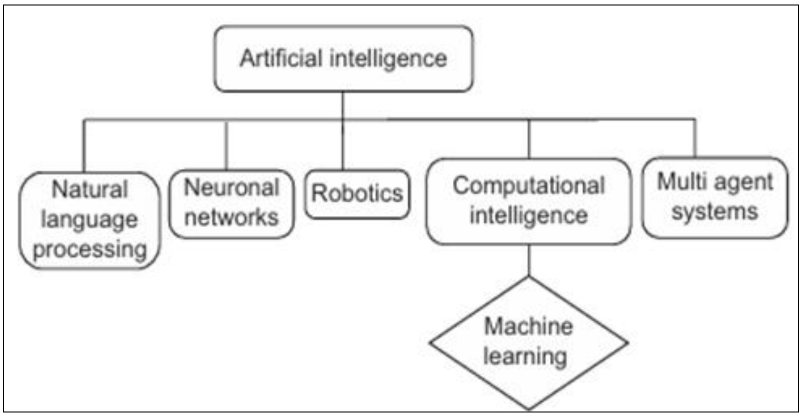

Fig 1: Main elements of AI (Pushpa *et al*.,2022) [44].

2.1 Machine learning (ML)

Machine learning (ML) is a subset of AI that is often used interchangeably with the term AI. It allows machines to learn from datasets without being explicitly programmed for a specific task. (Raymond & Medina, 2018; Kulkarni *et al*., 2021) [47,31].

ML operates in three main ways: supervised, unsupervised, and reinforcement learning. In supervised learning, the system is trained using labelled data provided by humans to achieve the desired outcomes. Unsupervised learning, on the other hand, involves the system working with unlabelled data, uncovering patterns or structures within the data. The combination of these two approaches forms the basis of reinforcement learning, which aims to maximize precision and accuracy by learning from feedback and rewards (Raymond & Medina, 2018; Kulkarni *et al*., 2021) [47,31].

2.2 Deep learning (DL)

Deep learning (DL) is a highly advanced subset of machine learning and a sophisticated branch of artificial intelligence (AI) (Hu *et al*., 2020) [25]. It employs intricate neural networks to process and interpret unstructured data, allowing systems to address complex problems with remarkable accuracy. In DL, algorithms are trained using extensive datasets, enabling them to achieve outputs that closely mimic human cognitive abilities. Key applications of deep learning include autonomous decision-making systems, sophisticated web search engines, AI-powered robots, advanced natural language processing tools, and disease mapping. This technology is pivotal in advancing numerous fields by providing more precise and efficient solutions to complex challenges (Bengio *et al*., 2013) [6].

2.3 Chat GPT (Generative Pretrained Transformer)

ChatGPT, developed by OpenAI and based in San Francisco, CA, USA, represents a significant leap in artificial intelligence technology. Released in November 2022, ChatGPT quickly attracted one million users within a few days (Liebrenz *et al*., 2023; Sedaghat, 2023) [34,52].This cutting-edge language model harnesses deep learning techniques to generate human-like responses to text inputs. It has been trained on a comprehensive dataset derived from the internet, allowing it to understand and address a diverse range of queries in natural language. This capability enables ChatGPT to participate in coherent, contextually relevant conversations and offer meaningful interactions.

3. Anatomy in the veterinary profession

Anatomy has been a cornerstone of medical education for centuries (Singh *et al*., 2015) [55]. Often referred to as the "mother of medical education," anatomy serves as the foundation for all clinical medical sciences. When asked about its importance, medical professionals consistently rank gross anatomy as being of paramount fundamental significance (Singh *et al*., 2015; Pabst & Rothkotter, 1997) [55, 42]. Numerous studies have shown that both medical students (Singh *et al*., 2015; Moxham & Plaisant, 2007) [54, 39]. and postgraduate students recognize the critical importance of anatomy (Singh *et al*., 2015; Cottam, 1999) [55, 15].

A thorough understanding of anatomy is essential for medical professionals in patient examination, understanding and diagnosing diseases, and communicating effectively with patients and other healthcare providers. Additionally, knowledge of anatomy is crucial for performing surgical and other invasive procedures. It plays a pivotal role in both diagnosis and treatment, as a clear comprehension of normal anatomical structures and the deviations caused by disease informs therapeutic approaches (Singh *et al*., 2015) [55].

4. Teaching of veterinary anatomy

The approach to teaching anatomy has undergone significant changes over time. Challenges such as limited instructional time and insufficient faculty have long been concerns for university educators and administrators. While some institutions maintain traditional teaching methods, many have updated their curricula to adopt an integrated approach. Students often perceive anatomy lectures as monotonous and unengaging, critiquing them for using outdated teaching techniques. Research has not identified a single superior teaching model; instead, the most effective strategy appears to involve the integration of multimodal methods into the learning process (Wilson, 2018) [63]. This diversified approach is considered more engaging and effective for students (Estai & Bunt, 2016) [20].

4.1 Conventional methods of teaching anatomy

Traditional methods of teaching anatomy encompass a variety of approaches, including didactic lectures, cadaveric dissection, examination of prosected specimens, use of anatomical models, surface anatomy, and radiological anatomy.

- Dissection involves students actively exploring anatomical structures in cadavers, sectioning the body along various planes to identify specific anatomical features. This hands-on method, often paired with lectures and master classes, has been a fundamental teaching tool for over 400 years (Azer and Eizenberg, 2007) [4], employing both regional and systemic approaches. However, it has faced criticism for being time-consuming and costly (Aziz *et al*.,2002) [5], and some medical schools have replaced it with alternative methods such as prosection combined with other teaching modalities (Drake *et al*.,2009) [19].

- Prosection allows students to study pre-dissected cadavers, offering an opportunity to observe real anatomical structures without the extensive time commitment required for dissection (Dinsmore *et al*.,1999) [17].These specimens are typically displayed in anatomy museums and morphology laboratories.
- Plastination is a technique developed by Gunther von Hagens at Heidelberg University in 1977(Estai and Bunt,2016) [20]. It involves the preservation of dissected cadaver structures, and even entire bodies, using chemical materials. This method provides odourless, durable anatomical preparations that do not require traditional chemical preservatives, thus reducing the need for continuous dissections. Plastinated specimens are easier to handle and store, making them a practical alternative in anatomy education(Fruhstorfer *et al*.,2011) [21].

4.2 Modern methods of teaching anatomy

- **3D Interactive Anatomy Teaching**

Early advancements in computer-based technology for anatomy education introduced three-dimensional interactive platforms. These tools enable students to navigate through various layers of anatomical structures and rotate images to view them from different angles and perspectives. (Pushpa *et al*., 2022) [44].

- **Digital Dissection**

A recent innovation in anatomy education is "digital dissection," which allows students to virtually dissect the body by sequentially removing layers or specific structures. This method simulates the experience of real-time dissection sessions, offering a more interactive and accessible learning experience (Pushpa *et al*.,2022) [44].

- **3D Printing Technology**

The advent of 3D printing technology has provided anatomy educators with a new resource. 3D printed anatomical models are increasingly used in anatomy labs to complement traditional methods such as dissection, prosections, and commercially available models (McMenamin *et al*., 2014) [38]. As 3D printers become more affordable and widely available, their use in anatomical teaching is expected to grow. These models are particularly beneficial for teaching intricate anatomical structures, illustrating anomalies, and simulating surgical interventions (Jaksa *et al*., 2021; Vatankhah *et al*., 2021; Yuan *et al*, 2021) [28, 61, 64].

- **Virtual Reality (VR) and Augmented Reality (AR)**

Augmented Reality (AR) overlays digital information onto the real world, accessible through devices such as cameras, tablets, or mobile phones. In contrast, Virtual Reality (VR) immerses users in a completely artificial environment, effectively isolating them from the physical world (Huang *et al*., 2019) [26]. Both technologies offer immersive and interactive experiences that enhance the understanding of complex anatomical concepts.

5. Role of ai: novel uses of artificial intelligence in facilitating anatomy teaching, learning, and assessment

- Artificial Intelligence (AI), once considered a futuristic concept, is now an integral part of everyday life. Its applications range from voice recognition systems like Alexa to the precise analysis and reporting of medical investigations, as well as predicting disease outcomes and management strategies for individual patients. AI technologies, such as Artificial Neural Networks (ANN) and the more advanced Convolutional Neural Networks (CNN), are designed to mimic the neural networks of the human brain. These systems not only store, process, analyse, and compute data, but also improve their machine learning capabilities over time, effectively "thinking" and exploring optimal solutions.
- In the realm of anatomy education, AI's capabilities extend to facilitating teaching, learning, and assessment. AI systems can simulate complex anatomical structures and processes, offering personalized learning experiences that adapt to the needs of individual students. Additionally, AI's ability to analyse large datasets and recognize patterns enhances the accuracy of anatomical assessments. The advanced functionality of AI even allows for remote-controlled robotic surgeries, showcasing its potential to revolutionize practice (Ramesh, 2004) [46].

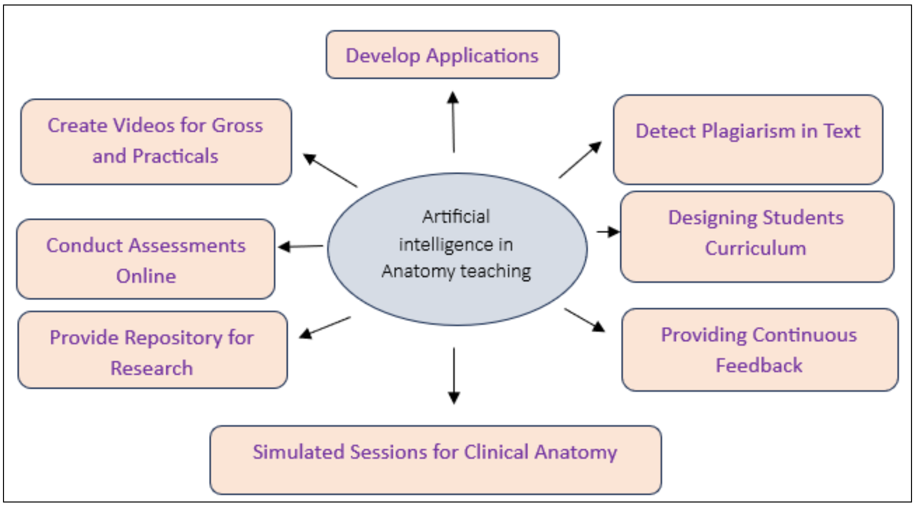

Fig 2: Schematic diagram showing how artificial intelligence can be incorporated in anatomy teaching (Abdellatif *et al*., 2022) [1]

5.1 Teaching and learning

AI plays a pivotal role in modern medical education through intelligent tutoring systems (Qayumi & Qayumi, 1999; Primal Pictures, 2022) [45, 43]. It bridges the gap between traditional teaching methods and the digital preferences of contemporary students by offering personalized support. AI-driven systems can identify knowledge gaps, provide targeted feedback, and facilitate personalized learning experiences. They also handle administrative tasks such as attendance tracking and assignment grading, tasks traditionally performed manually by educators (Interact Elsevier, 2022) [27]. Despite the advantages of AI, it is crucial to address ethical and moral considerations when designing computer-based learning systems and AI algorithms (Anatomage Inc., 2022; Martín, 2018) [2,35].Ensuring that these systems are transparent, credible, auditable, and reliable is essential.

Deep learning, a subset of machine learning can analyse and reproduce anatomical structures with high accuracy, especially in complex areas such as the brain, head and neck, and limb musculature. For instance, the Bayesian U-Net framework has demonstrated the ability to segment musculoskel*et al* anatomy from CT images with exceptional precision (Nara Institute of Science and Technology, 2019) [40].This technology, if tailored to anatomical course requirements, could serve as a valuable educational tool. Interactive teaching aids, such as Anatomy Chatbots (Li *et al*., 2021) [33], formative assessment tools, and clinical application quizzes, can be integrated into deep learning AI frameworks to foster deeper, logical learning and enhance students' application of knowledge in clinical settings (Chan & Wiseman, 2011) [10]

5.2 Personalized learning

AI-powered adaptive learning systems can pinpoint specific areas where individual students face difficulties and offer targeted remediation. For example, if a student struggles with understanding the musculoskeletal system of equines, the AI system can suggest additional resources or interactive exercises tailored to address those specific challenges. These AI-based learning platforms analyse student performance data to customize learning pathways, adapting to each student's needs. This personalized approach enhances comprehension and retention, ultimately leading to improved academic outcomes (Anil Choudary 2024) [3].

5.3 Image analysis

In veterinary medicine, the accurate interpretation of medical images is essential for diagnosing and treating animals. AI algorithms, trained on extensive datasets, assist veterinarians in identifying anatomical structures and pathological conditions with greater efficiency. AI-based image analysis software supports the interpretation of radiographs and ultrasound images, helping students develop the skills required for diagnosing various conditions in clinical practice (Anil Choudary 2024) [3].

5.3.1 Ultrasonography

Ultrasonography is a non-invasive diagnostic technique used to assess various physiological and pathological conditions of the reproductive organs in ruminants. It serves as an effective tool for diagnosing abnormalities in the udder, including inflammation, mucosal lesions, tissue proliferation, foreign bodies, milk stones, congenital changes, abscesses, and hematomas. This technique is valued for its simplicity, safety for both the subject and operator, portability, and rapid results. It allows for immediate interpretation and diagnosis in most cases (Szencziova and Strapak, 2012) [57].

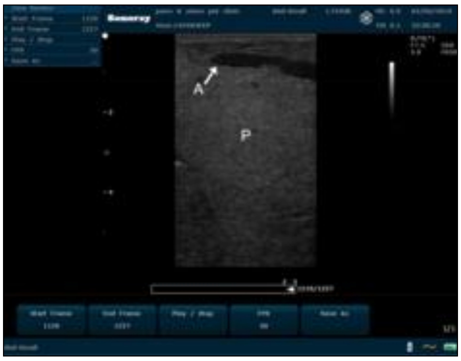

Fig 3: Two dimensional ultrasonographic image of mammary gland of lactating adult Madras Red ewe showing homogenous parenchyma(P) A-Alveoli (Senthilkumar, 2019) [53]

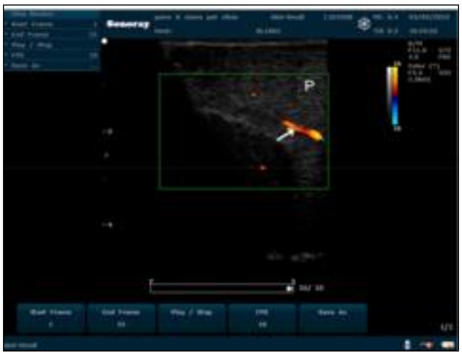

Fig 4: Two dimensional ultrasonographical image of mammary gland of lactating adult Boer local she-goat showing blood flow in a blood vessel(arrow) P-Parenchyma (Senthilkumar,2019) [53]

5.3.2 Electrocardiography

The clinical application of electrocardiography (ECG) in dogs began with Norr's pioneering work in 1922 (Norr,1922; Lannek,1949) [41, 32]. ECG is a non-invasive, relatively inexpensive method used to diagnose cardiac arrhythmias and assess myocardial health. It detects disturbances in cardiac rate and rhythm, as well as chamber enlargement, myocardial disease, ischemia, pericardial disease, electrolyte imbalances, and certain drug toxicities. Consequently, ECG is a valuable tool in cardiac evaluation, aiding in the diagnosis of anatomical and physiological conditions and in prognostication (Tilley, 1992) [59].

Augustus D. Waller first demonstrated in 1887 that electrical impulses from the heart could be recorded from the body's surface. Einthoven later described the P-QRS-T deflections associated with the heart's excitation waves. The P wave corresponds to atrial depolarization or contraction originating from the sinoatrial (SA) node to the atrioventricular (AV) node, the QRS complex represents ventricular depolarization or contraction, and the T wave signifies ventricular repolarization or relaxation. ECG essentially reflects the summation of multiple action potentials generated by cardiac cells across the entire heart. To view the heart from different perspectives, multiple lead systems are used, with the standard leads (I, II, and III) being fundamental since the inception of electrocardiography (Tilley, 1992) [59].

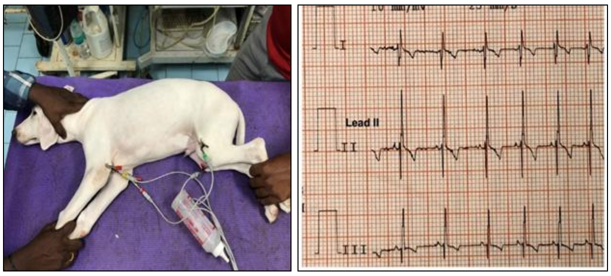

Fig 5: Ecg Strip of Adult Chippiparai dog showing P-QRS-T Deflections (Bhargavi, 2019) [7]

5.3.3 Echocardiography

Two-dimensional real-time echocardiography (2DE), extensively studied in humans, has only recently been applied in veterinary medicine. Thomas (1984) proposed that a comprehensive anatomical evaluation of the canine heart using 2DE was feasible with a standardized, systematic examination technique. This method captures both long-axis (longitudinal) and short-axis (cross-sectional) views of the heart. It identifies three transducer orientations that provide consistent images of key cardiac structures, including all four cardiac chambers, atrioventricular and semilunar valves, and the proximal portions of major blood vessels. Thus, 2DE has shown significant potential for evaluating cardiac anatomy and physiology in dogs. Echocardiography, or cardiac ultrasound, is now considered an essential diagnostic tool in veterinary medicine. (Henik, 1995) [22].

Fig 6: Two-Dimensional Echocardiographic Image- Right Long Axis View of Left Ventricle of Rajapalayam Dog IVS-Interventricular Septum; LVD-Left Ventricle Diameter; LVPW-Left Ventricular Posterior Wall (Bhargavi,2018) [7]

Fig 7: Two-Dimensional Echocardiographic Image-Right Long Axis View of Rajapalayam Dog AOD- Aortic Root Diameter; LAD-Left Atrial Diameter (Bhargavi,2018) [7]

5.3.4 Computed tomography

Computed Tomography (CT) is one of the most prevalent cross-sectional imaging techniques in medicine. The term "computed tomography" combines "computed" (referring to the use of computers), "tomo" (meaning "to cut"), and "graph" (meaning "pictures"). This technique employs ionizing radiation (X-rays) in conjunction with an electronic detector array to capture patterns of tissue densities, thereby generating images of slices of tissue (Villifana, 1987) [62].

A CT scan produces cross-sectional images by scanning a flat, transverse slice of the body while the patient lies on a stationary table (Thrall, 2002) [58]. According to Rivero *et al*. (2009) [48], veterinary computed tomography has become the preferred modality for abdominal imaging in cats and dogs, providing a reliable depiction of cross-sectional anatomy.

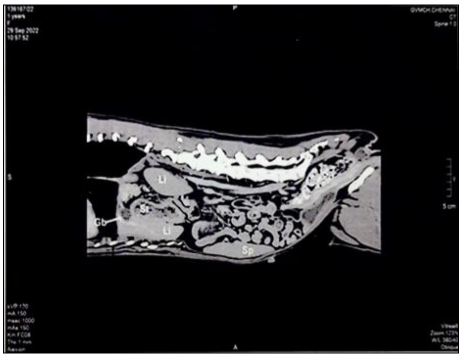

Fig 8: Computed tomographic image of adult male Rajapalayam dog showing the stomach(St) separated by the liver (Li)from the ventral abdominal wall and entirely located within the intra-thoracic part of the abdominal cavity. Gb-Gall bladder Sp-Spleen (Senthilkumar,2023) [53]

Fig 9: Computed tomographic image of adult female Rajapalayam dog showing the lumbar vertebrae articulated cranially with thoracic vertebra and caudally with sacrum (Senthilkumar, 2023) [53]

5.3.5 Radiography

X-rays are a form of high-energy radiation within the electromagnetic spectrum, characterized by their short wavelength and ability to ionize cells and tissues as they pass through the body. In radiography, X-rays are generated through the rapid deceleration of fast-moving electrons within an X-ray tube. The intensity and size of the X-ray beam are controlled by adjusting the voltage and amperage applied to the tube. Radiographic images are two-dimensional (2-D) representations of three-dimensional structures (Dixon, 2008) [18].

Interpreting radiographic images requires a thorough understanding of normal anatomical structures, variations, and their radiological appearances. Radiographs produce images in black, white, and various shades of grey, reflecting differences in X-ray beam attenuation by different tissues. The degree of tissue absorption is influenced by the tissue's atomic number, specific gravity, and thickness. Bone, with its higher atomic number and specific gravity, absorbs more X-ray photons, appearing pale or white on the radiograph. Gas, with the lowest specific gravity, absorbs few X-rays and appears black, while fat appears dark grey, soft tissue or fluid appears mid-grey, and m*et al* appears white (Koong, 2012) [30].

Abdominal radiography is particularly useful for diagnosing conditions such as foreign body obstruction, dyschezia, urinary incontinence, anuria, dysuria, organomegaly, and for pregnancy diagnosis in dogs and cats (Hollway and McConnell, 2013). [24]

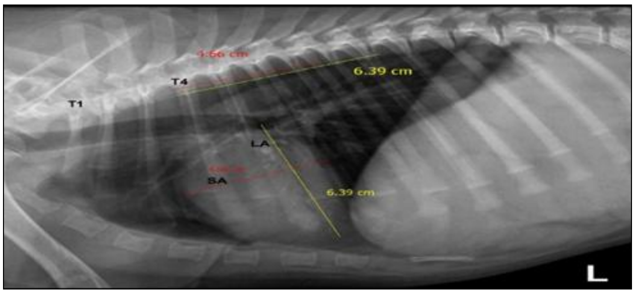

Fig 10: Left lateral digital radiographic image of Chippiparai showing vertebral heart score measurement LA-Long Axis;SA-Short Axis; L-Left; T1,T4-Thoracic vertebra (Bhargavi,2018) [7]

5.4 Interactive learning tools

AI-driven interactive learning tools create engaging educational experiences that captivate student interest and promote active participation. By incorporating elements such as gamification, simulations, and virtual reality, these tools enhance learning by making it both enjoyable and accessible. For example, virtual reality simulations enable veterinary students to explore complex anatomical concepts through immersive experiences. Students can interact with virtual models of animal anatomy, gaining a more profound understanding of physiological processes and anatomical relationships (Anil Choudary 2024) [3].

GPT-powered chatbots further enrich the learning experience by engaging in interactive conversations with students. These chatbots allow students to inquire about specific anatomical structures or systems, providing detailed descriptions, definitions, and explanations. This conversational approach helps students better grasp the complexities of veterinary anatomy (Choudhary *et al*., 2023) [11].

5.5 Accessible reference materials

Chatbots also offer veterinary students easy access to anatomical information. They can quickly provide answers about the location, function, and clinical relevance of specific anatomical structures, which is particularly valuable during study sessions, practical exams, or when preparing for surgeries (Choudhary *et al*., 2023) [11].

5.6 Comparative anatomy

Veterinary anatomy often involves examining anatomical differences across animal species. Chatbots can assist in comparative anatomy by delivering information about specific anatomical variations and emphasizing the unique features of each species. This interactive approach allows students to explore and understand the similarities and differences between various animal anatomies (Choudhary *et al*.,2023) [11].

5.7 Case-based learning

GPT-powered chatbots can facilitate case-based learning by presenting scenarios or clinical cases involving anatomical abnormalities or pathologies. Students can interact with the chatbot to analyse the anatomical implications of these cases, applying their knowledge to diagnose and propose treatment options. This method enhances critical thinking and problem-solving skills within the context of anatomy (Choudhary *et al*.,2023) [11].

5.8 Reinforcement of key concepts

Chatbots can support the reinforcement of key anatomical concepts through interactive tools such as quizzes, flashcards, or review sessions. Students can assess their knowledge, pinpoint areas of weakness, and receive immediate feedback. This repetitive reinforcement helps solidify their understanding of veterinary anatomy. While some features currently available in other chatbots are not yet present in ChatGPT, future updates could incorporate these capabilities to enhance learning (Choudhary *et al*.,2023) [11].

5.9 Research and development

AI is driving advancements in veterinary anatomy by enabling the automated analysis of large datasets and uncovering novel insights. AI-powered tools are used to explore evolutionary trends and investigate disease mechanisms, significantly enriching our understanding of animal anatomy and physiology. For instance, AI algorithms can analyse genomic data to identify genetic variations linked to specific anatomical traits in domestic animals. This research not only advances our knowledge of animal anatomy but also impacts breeding programs and conservation efforts (Anil Choudhary 2024) [3].

5.10 Assessment

Assessment is a critical component of medical education, serving as a means to gauge student progress. Research on anatomy assessment methodologies often focuses on indices such as objectivity, validity, reliability, and educational impact (Samarasekera *et al*., 2015) [50]. An assessment method that is uniform across all students, without individual bias, is universally valued. An impartial, objective approach to assessment is appreciated by the student body, as it ensures that all students are evaluated on a consistent basis. Objectivity becomes crucial when different examiners may have varying opinions on students' knowledge and skills. Uniformity in assessment questions and tasks helps achieve this objectivity, leading to greater standardization in the expected responses, skills, and behaviours from students (Brenner, 2014) [8].

Despite efforts to maintain objectivity, human assessments are inherently susceptible to biases related to subject matter and cultural factors such as gender and region. Furthermore, there is considerable diversity in evaluating anatomical knowledge, attitudes toward the subject, and skills. To address these challenges, it is essential to agree on best strategies and methodologies to ensure reliability, consistency, validity, and standardization (Sullivan, 2011) [56]. The integration of AI in assessment processes can enhance these goals by providing automated adjustments in difficulty levels and unbiased evaluations.

The "assessment for learning" paradigm, which focuses on active and authentic assessment approaches, has been widely adopted in medical education. This approach provides learners and educators with insights into their current progress, future goals, and the best methods to achieve them (Klenowski,2009; Dannefer,2013) [29,16].With advancements in anatomy education, including AI, modern assessment strategies have evolved to include competency-based assessments, portfolio-based assessments, and programmatic assessments, which are now prevalent in many contemporary health-related curricula (McBride & Drake, 2018; Hift, 2014) [36,23].However, traditional assessment methods focusing on factual knowledge remain common in some medical and health education disciplines, with an emphasis on summative assessments (Choudhury & Freemont, 2017; Samarasekera *et al*., 2020) [12,51].Consequently, as anatomy curricula evolve, anatomists must reconsider assessment methods to apply an authentic approach that ensures the effective application of knowledge and skills, achieving a recognized level of competency.

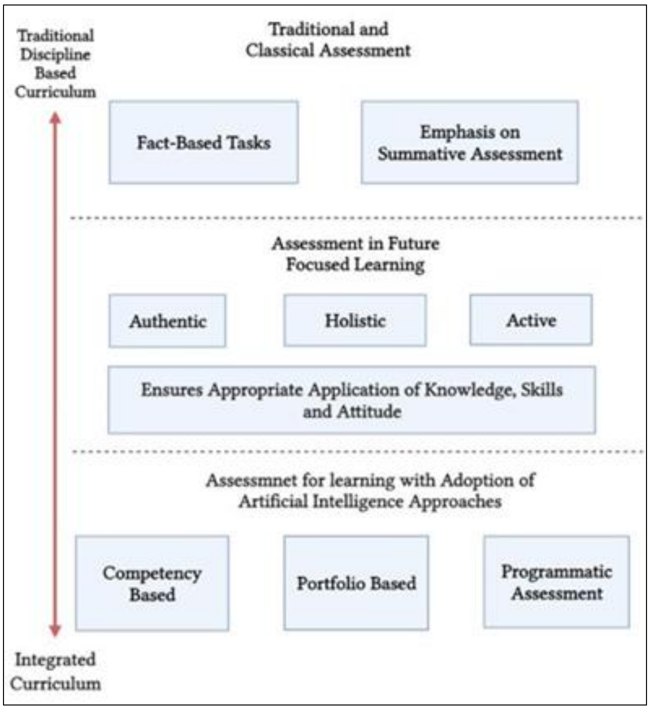

Fig 11: Anatomy Assessment in Era of Artificial Intelligence (Abdellatif *et al*., 2022) [1]

6. Future novel scope of artificial intelligence in anatomy education

As anatomists, we envision several potential developments in AI that could transform anatomy education (Abdellatif *et al*., 2022) [1]:

1. **Virtual Reality (VR) Apps:** The creation of VR applications to provide a deeper understanding of complex anatomical fields such as embryology and neuroscience. These apps could offer immersive experiences to explore intricate anatomical structures and developmental processes.
2. **Advanced Data Analysis:** Tools for analysing, computing, and summarizing complex anatomical data. For instance, in embryology, AI could track and visualize the migration and differentiation of structures across developmental timelines. Similarly, it could map neural pathways in the central nervous system, simplifying complex topics into accessible overviews.
3. **3D Imaging and Printing:** Development of AI tools to enhance visual learning through detailed 3D images and their integration with 3D printing technology. This could produce accurate, physical models of complex anatomical structures that are challenging to dissect.
4. **Deep Learning for Structured Demos:** AI systems that provide detailed demonstrations of intricate anatomical regions, such as the head, face, and neck, functioning as valuable teaching assistants.
5. **Self-Review Resources:** AI systems designed for self-assessment by creating interactive learning programs, including cause-and-effect, multiple-choice questions and problem-based clinical scenarios. These tools would offer immediate feedback and facilitate self-evaluation.
6. **Objective Assessment and Data Compilation:** AI-driven systems to objectively assess student performance, compile statistical data on scores and grades, and compare academic achievements across different cohorts and learning modes.
7. **Interactive Clinical Training:** Development of interactive robots programmed to simulate specific clinical conditions. These robots could respond to interventions, allowing students to practice their clinical and diagnostic skills in a controlled environment.
8. **Complex Interactive Quizzes:** AI-based apps that generate anatomical images and advanced interactive quizzes, enhancing self-learning opportunities and engagement, similar to platforms like Kahoot·

7. Conclusion

To summarize, as we are in digital era, AI may be used as an effective tool in enhancing the learner centred learning in the discipline of Veterinary Anatomy which leads to thorough understanding of the subject and its application in Veterinary Medicine.

8. Acknowledgements

The authors express their gratitude to the Dean of Madras Veterinary College, Chennai, for their encouragement and support.

9. Competing Interests

The authors have declared that they have no competing interests.

10. Authors’ contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

11. References

1. Abdellatif H, Al Mushaiqri M, Albalushi H, Al-Zaabi AA, Roychoudhury S, Das S. Teaching, learning and assessing anatomy with artificial intelligence: the road to a better future. Int J Environ Res Public Health. 2022;19(21):14209.
2. Anatomage Inc. Anatomage Table; c2022. Available from: https://www.anatomage.com/table/ (accessed on 25 August 2022).
3. Choudhary A. Embracing Tomorrow: The Evolution of Veterinary Anatomy Teaching through Artificial Intelligence. Acta Sci Vet Sci. 2024;6(5):1-3.
4. Azer SA, Eizenberg N. Do we need dissection in an integrated problem-based learning medical course? Perceptions of first- and second-year students. Surg Radiol Anat. 2007 Mar;29(2):173-180.
5. Aziz MA, McKenzie JC, Wilson JS, Cowie RJ, Ayeni SA, Dunn BK. The human cadaver in the age of biomedical informatics. Anat Rec. 2002 15;269(1):20-32.
6. Bengio Y, Courville A, Vincent P. Representation learning: A review and new perspectives. IEEE Trans Pattern Anal Mach Intell. 2013;35:1798-828.
7. Bhargavi S. Anatomic Evaluation of Heart using Two-dimensional Echocardiography and Radiography in indigenous breeds of dogs. PG thesis submitted at TANUVAS, India. 2018.

8. Brenner E. Human body preservation - old and new techniques. J Anat. 2014;224:316-44.
9. Chan KS, Zary N. Applications and challenges of implementing artificial intelligence in medical education: integrative review. JMIR Med Educ. 2019;5 Available from: https://mededu.jmir.org/2019/1/e13930
10. Chan LK, Wiseman J. Use of the one-minute preceptor as a teaching tool in the gross anatomy laboratory. Anat Sci Educ. 2011;4:235-238. Available from: https://anatomypubs.onlinelibrary.wiley.com/doi/abs/10.1002/ase.234
11. Choudhary OP, Saini J, Challana A, Choudhary O, Saini J, Challana A. ChatGPT for veterinary anatomy education: an overview of the prospects and drawbacks. Int J Morphol. 2023;41(4):1198-1202.
12. Choudhury B, Freemont A. Assessment of anatomical knowledge: Approaches taken by higher education institutions. Clin Anat. 2017;30:290-9. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/ca.22835
13. Collins C, Dennehy D, Conboy K, Mikalef P. Artificial intelligence in information systems research: a systematic literature review and research agenda. Int J Inf Manag. 2021;60:102383.
14. Colom R, Karama S, Jung RE, Haier RJ. Human intelligence and brain networks. Dialogues Clin Neurosci. 2010;12:489-501.
15. Cottam WW. Adequacy of medical school gross anatomy education as perceived by certain postgraduate residency programs and anatomy course directors. Clin Anat. 1999;12:55-65. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/(SICI)1098-2353(1999)12:1%3C55::AID-CA8%3E3.0.CO;2-O
16. Dannefer EF. Beyond assessment of learning toward assessment for learning: educating tomorrow's physicians. Med Teach. 2013;35:560-563. Available from: https://www.tandfonline.com/doi/abs/10.3109/0142159X.2013.787141
17. Dinsmore CE, Daugherty S, Zeitz HJ. Teaching and learning gross anatomy: dissection, prosection, or both of the above? Clin Anat. 1999;12(2):110-4.
18. Dixon AM. Fundamentals of Diagnostic Imaging: An Introduction for Nurses and Allied Health Professionals. Exeter: Reflect Pets Ltd; c2008.
19. Drake RL, McBride JM, Lachman N, Pawlina W. Medical education in the anatomical sciences: the winds of change continue to blow. Anat Sci Educ. 2009 Dec;2(6):253-9.
20. Estai M, Bunt S. Best teaching practices in anatomy education: a critical review. Ann Anat. 2016;208:151-157. Available from: https://www.sciencedirect.com/science/article/pii/S0940960216300322?casa_token=_EVgI3PMhesAAAAA:Z7OrW4tXppM6xx_2505MnakFvrdM5BRznn5DzAp6YowOTCmKV20Vui8Wgq-QvsIlbwX0sHRG-sg
21. Fruhstorfer BH, Palmer J, Brydges S, Abrahams PH. The use of plastinated prosections for teaching anatomy: the view of medical students on the value of this learning resource. Clin Anat. 2011 Mar;24(2):246-52.
22. Henik RA. Manual of Canine and Feline Cardiology. 2nd ed. Philadelphia: W.B. Saunders Company; c1995. p. 75-107.
23. Hift RJ. Should essays and other "open-ended"-type questions retain a place in written summative assessment in clinical medicine? BMC Med Educ. 2014;14:249. Available from: https://link.springer.com/content/pdf/10.1186/s12909-014-0249-2.pdf
24. Hollway A, McConnell F. BSAVA Manual of Canine and Feline Radiography and Radiology: A Foundation Manual. 1st ed. United Kingdom: BSAVA; c2013.
25. Hu J, Niu H, Carrasco J, Lennox B, Arvin F. Voronoi-based multi-robot autonomous exploration in unknown environments via deep reinforcement learning. IEEE Trans Veh Technol. 2020;69:14413-23.
26. Huang KT, Ball C, Francis J, Ratan R, Boumis J, Fordham J. Augmented vs Virtual Reality in education: an exploratory study examining science knowledge retention when using AR/VR mobile applications. Cyberpsychol Behav Soc Netw. 2019 Feb;22(2):105-10.
27. Interact Elsevier. Netter's 3D Interactive Anatomy. 2022. Available from: https://netter3danatomy.com/ (accessed on 25 August 2022).
28. Jaksa L, Pahr D, Kronreif G, Lorenz A. Development of a multi-material 3D printer for functional anatomic models. Int J Bioprint. 2021;7:420. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8600298/
29. Klenowski V. Assessment for learning revisited: an Asia-Pacific perspective. Assess Educ Princ Pol Pract. 2009;16:263-268. Available from: https://eprints.qut.edu.au/28741/1/28741.pdf
30. Koong B. The basic principles of radiological interpretation. Aust Dent J. 2012;57(1):33-39.
31. Kulkarni P, Mahadevappa M, Chilakamarri S. The emergence of artificial intelligence in cardiology: current and future applications. Curr Cardiol Rev. 2021;10.2174/1573403X17666211119102220.
32. Lannek N. A clinical and experimental study of the electrocardiogram in dogs [thesis]. Stockholm; c1949.
33. Li YS, Lam CSN, See C. Using a machine learning architecture to create an AI-powered chatbot for anatomy education. Med Sci Educ. 2021;31:1729-1730. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8651944/
34. Liebrenz M, Schleifer R, Buadze A, Bhugra D, Smith A. Generating scholarly content with ChatGPT: ethical challenges for medical publishing. Lancet Digit Health. 2023;5(3)
35. Martín JG, Mora CD, Henche SA. Possibilities for the use of anatomage (the anatomical real body-size table) for teaching and learning anatomy with the students. Biomed J Sci Tech Res. 2018;4:4080-4083. Available from: https://www.researchgate.net/profile/Jesus-Garcia-Martin-2/publication/350775565_Possibilities_for_the_use_of_Anatomage_the_Anatomical_Real_Body-Size_Table_for_Teaching_and_Learning_Anatomy_with_the_Students_Mini_Review_Open_Access/links/6070fc774585150fe9980eca/Possibilities-for-the-use-of-Anatomage-the-Anatomical-Real-Body-Size-Table-for-Teaching-and-Learning-Anatomy-with-the-Students-Mini-Review-Open-Access.pdf
36. McBride JM, Drake RL. National survey on anatomical sciences in medical education. Anat Sci Educ. 2018;11:7-14. Available from: https://anatomypubs.onlinelibrary.wiley.com/doi/abs/10.1002/ase.1760
37. McCarthy J, Minsky ML, Rochester N, Shannon CE. A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence, August 31, 1955. AI Magazine. 31 December 2016. Available from: http://ojs.aaai.org/aimagazine/index.php/aimagazine/article/view/1904 (accessed on 25 August 2022)

38. McMenamin PG, Quayle MR, McHenry CR, Adams JW. The production of anatomical teaching resources using three-dimensional (3D) printing technology. Anat Sci Educ. 2014;7:479-486. Available from: https://anatomypubs.onlinelibrary.wiley.com/doi/abs/10.1002/ase.1475
39. Moxham BJ, Plaisant O. Perception of medical students towards the clinical relevance of anatomy. Clin Anat. 2007;20:560-564. Available from: https://onlinelibrary.wiley.com/doi/abs/10.1002/ca.20453
40. Nara Institute of Science and Technology. Artificial Intelligence Learns Muscle Anatomy in CT Images. Science Daily. 31 October 2019. Available from: www.sciencedaily.com/releases/2019/10/191031100526.htm (accessed on 25 August 2022).
41. Norr J. Uber Herzstromkurvebaufnahmen an Haustieren. Zur Einführung der Elektrokardiographie in die Veterinarmedizin. Arch Tierheilk. 1922;48:85-111.
42. Pabst R, Rothkotter HJ. Retrospective evaluation of undergraduate medical education by doctors at the end of their residency time in hospitals: consequences for the anatomical curriculum. Anat Rec. 1997;249:431-434. Available from: https://anatomypubs.onlinelibrary.wiley.com/doi/pdfdirect/10.1002/%28SICI%291097-0185%28199712%29249%3A4%3C431%3A%3AAID-AR1%3E3.0.CO%3B2-U
43. Primal Pictures. The Leading 3D Anatomy Resource. 2022. Available from: https://www.primalpictures.com/ (accessed on 25 August 2022).
44. Pushpa NB, Patra A, Ravi KS. Will artificial intelligence assume a role in anatomy education? Natl J Clin Anat. 2022;11(2):65-67.
45. Qayumi AK, Qayumi T. Computer-assisted learning: Cyberpatient—A step in the future of surgical education. J Investig Surg. 1999;12:307-317. Available from: https://www.can-health.org/wp-content/uploads/2015/05/Computer-ASsisted-Learning-CyberPatient-A-Step-in-the-Future-of-Surgical-Education.pdf
46. Ramesh AN, Kambhampati C, Monson JR, Drew PJ. Artificial intelligence in medicine. Ann R Coll Surg Engl. 2004;86:334-338.
47. Raymond JL, Medina JF. Computational principles of supervised learning in the cerebellum. Annu Rev Neurosci. 2018;41:233-253.
48. Rivero MA, Vázquez JM, Gil F, Ramírez JA, Vilar JM, Miguel AD, Arenbica A. CT-soft tissue window of the cranial abdomen in clinically normal dogs: an anatomical description using macroscopic cross-sections with vascular injection. Anat Histol Embryol. 2009;38:18-22.
49. Russell S, Norvig P. Artificial Intelligence: A Modern Approach. 3rd ed. Harlow, UK: Pearson Education Limited; c2010. Available from: https://zoo.cs.yale.edu/classes/cs470/materials/aima2010.pdf (accessed on 25 August 2022).
50. Samarasekera DD, Gopalakirshnakone P, Gwee MC. Assessing anatomy as a basic medical science. In: Chan LK, Pawlina W, editors. Teaching Anatomy: A Practical Guide. 1st ed. New York, NY: Springer International Publishing; c2015. p. 279-289.
51. Samarasekera DD, Ang ET, Gwee MC. Assessing anatomy as a basic medical science. In: Teaching Anatomy: A Practical Guide. 2nd ed. Chan LK, Pawlina W, editors. Cham, Switzerland: Springer Nature Switzerland AG; c2020. p. 393-404.
52. Sedaghat S. Early applications of ChatGPT in medical practice, education, and research. Clin Med (Lond). 2023;23(3):278-279.
53. Senthil Kumar S. Anatomical, histological and ultrasonographical studies of mammary gland in small ruminants. PG thesis submitted at TANUVAS, India. 2019.
54. Senthil Kumar S. Computed tomographic anatomy of abdomen in indigenous breeds of dogs. PhD thesis submitted at TANUVAS, India. 2023.
55. Singh R, Tubbs RS, Gupta K, Singh M, Jones DG, Kumar R. Is the decline of human anatomy hazardous to medical education/profession?—A review. Surg Radiol Anat. 2015;37:1257-1265. Available from: https://www.researchgate.net/profile/David-Jones-165/publication/278787458
56. Sullivan GM. A primer on the validity of assessment instruments. J Grad Med Educ. 2011;3:119-120.
57. Szencziova I, Strapak P. Ultrasonography of the udder and teat in cattle: perspective measuring technique. Slovak J Anim Sci. 2012;45(3):96-104.
58. Thrall DE. Textbook of Veterinary Diagnostic Radiology. 4th ed. Saunders; c2002. p. 65.
59. Tilley LP. Essentials of Canine and Feline Electrocardiography: Interpretation and Treatment. 3rd ed. Lea & Febiger; Philadelphia; c1992. p. 1-60.
60. Tirri K, Nokelainen P. Measuring multiple intelligences and moral sensitivities in education. In: Moral Development and Citizenship Education. Rotterdam, Netherlands: Sense Publishers; c2011.
61. Vatankhah R, Emadzadeh A, Nekooei ST, Yousefi BT, Rezaiyan MK, Moonaghi HK, *et al*. 3D printed models for teaching orbital anatomy, anomalies, and fractures. J Ophthalmic Vis Res. 2021;16:611-619. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8593539/
62. Villifana T. Physics and instrumentation: CT and MRI. In: Lee SH, Rao KCVG, editors. Cranial Computed Tomography and MRI. 2nd ed. New York: McGraw-Hill; c1987. p. 7. Available from: https://inis.iaea.org/search/search.aspx?orig_q=RN:20034978
63. Wilson AB, Miller CH, Klein BA, Taylor MA, Goodwin M, Boyle EK, Brown K, Hoppe C, Lazarus M. A meta-analysis of anatomy laboratory pedagogies. Clin Anat. 2018;31:122-133. Available from: https://research.monash.edu/files/239998967/53594771_oa.pdf
64. Yuan ZM, Zhang XD, Wu SW, Nian ZZ, Liao J, Lin W, Zhuang LM. A simple and convenient 3D printed temporal bone model for drilling simulating surgery. Acta Otolaryngol. 2021;142:19-22. Available from: https://www.tandfonline.com/doi/abs/10.1080/00016489.2021.2015079.

How to Cite This Article
Abinaya P, Dharani K, Gnanadevi R, Kannan TA. Beyond the dissection table: AI powered virtual anatomy for veterinary students. International Journal of Veterinary Sciences and Animal Husbandry. 2024;9(6):94-102.