Using virtual reality & ontologies to teach system structure & function. The case of introduction to anatomy

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Outline

1 Introduction

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Anatomy education:

Beyond rote learning of body parts
to an integrated understanding of body structure and function**s.**

Same for other complex systems

Like airplanes or buildings or the environment

1 Introduction

Virtual reality:
visual-spatial processing
and object manipulation

Ontologies:
conceptual processing

Enables learners
to form a comprehensive, integrated mental image
of the structure and functions of highly complex systems

Labeling 3D images with ontology concepts and showing the ontology structure
makes virtual reality an even more powerful tool.

1 Introduction

Virtual reality in education[i]

offers opportunities to teach hands-on material in resource-limited environments and to support diverse learning styles.

Examples: Cadaver dissection, flight simulator for training pilots

2 Virtual Reality and Ontologies in Anatomy Education

2.1 Virtual Reality

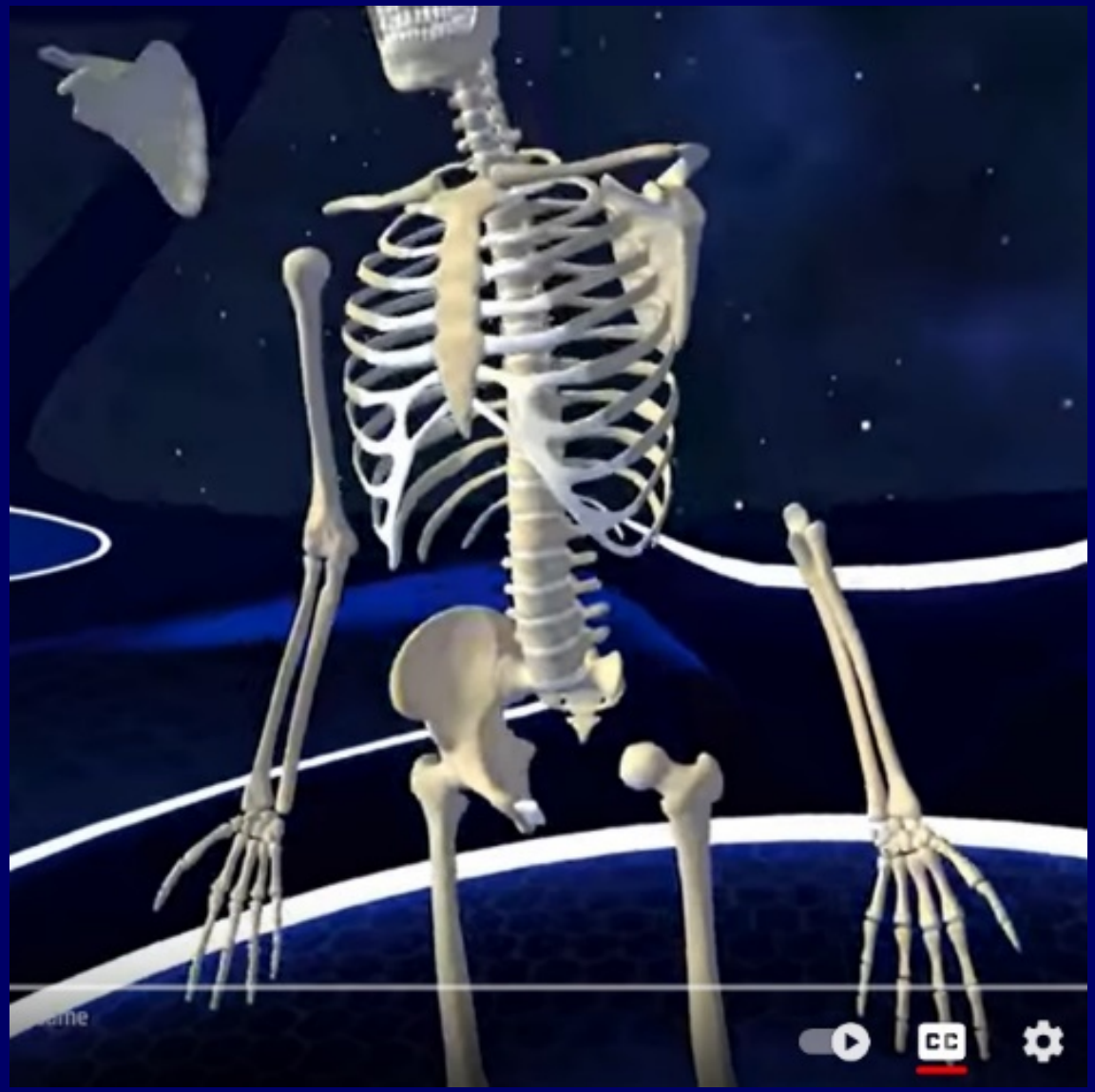


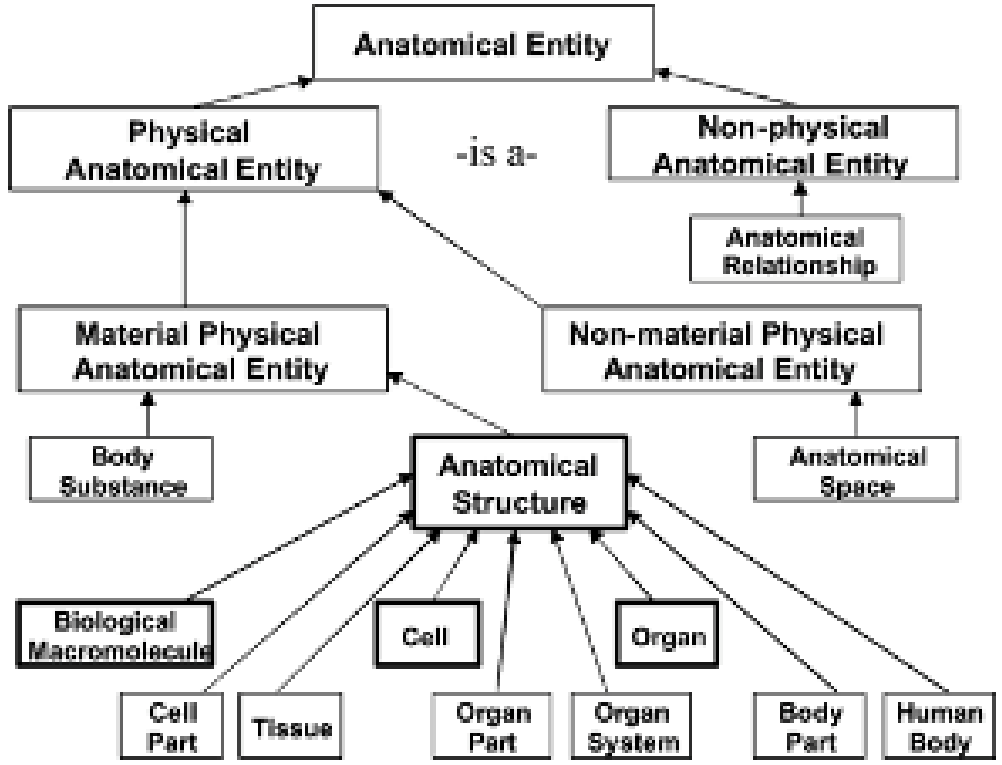
Fig. 1a VR Skeleton youtube.com/watch?v=zAtnKZ-i4LY

Fig. 1b VR Skeleton, part removed for inspection. www.medicinevirtual.com/img/vm-dicom-movie.mp4

2.2 Ontologies. The Foundational Model of Anatomy

Fig. 2 Overall structure

Entity types



Schematic representation of the principal classes of the FMA taxonomy.

[8], left: Fig. 4, p. 486), right: ([8] Fig. 8, p. 491)

Relationship types

- Anatomical relationship
  - Class subsumption relationship
  - Structural relationship
    - Anatomical part relationship
    - Boundary relationship
    - Spatial association relationship
      - Anatomical location
        - Anatomical containment
        - Anatomical adjacency
        - Anatomical coordinate
      - Anatomical orientation
      - Anatomical connectivity
        - Anatomical continuity
        - Anatomical attachment
        - Synaptic connectivity
        - Vascular connectivity
  - Anatomical transformation relationship

"describe the transformation of anatomical entities during the ontogeny of an organism".(p. 481)

Fig. 2 The overall structure of FMA

2.3 Anatomy Course Learning Objectives & Topics mapped to FMA

FMA concept (examples)	Course objective or topic [11-12]
organ system	List the organ systems of the human body and their major components.
Organ systems are arranged in order of increasing complexity and integrative function	
. musculoskeletal system	. Identify the individual bones and their location within the body. . Identify skeletal, cardiac and smooth muscle. . Describe the structure, location in the body and function of skeletal, cardiac and smooth muscle.
. integumentary system	. Describe the general functions of the skin.
. cardiovascular system	Describe the interaction of the cardiovascular system with other body systems
. respiratory system	List the major functions of the respiratory system
. alimentary system	List and describe the functional anatomy of the organs and accessory organs of the digestive system
. urinary system	Characterize the roles of each of the parts of the urinary system
. genital system	Describe the anatomy of the male and female reproductive systems, including their accessory structures
. immune system	
. lymphatic system	Identify the components and anatomy of the lymphatic system
. endocrine system	Identify the major organs and tissues of the endocrine system
. nervous system (NS)	. Describe the major functions of the nervous system . List the parts of the peripheral NS (PNS) and the central NS (CNS).
. . brain	Describe the orientation of the brain relative to bones of the skull.
Cell	Identify the three main parts of a cell, and list the functions of each.
Anatomical cavity	Describe the location of the body cavities and the organs found in each
Anatomical plane	Identify the various planes in which a body might be dissected.

Figure 3. Anatomy Course Learning Objectives and Topics mapped to the FMA. Examples

2.4 Synergistic Conceptual and Visual-Spatial Processing

There are many ways to say the same thing as found in the literature

Conceptual processing is incorporated into the learning process
by showing conceptual structures alongside the VR images that embody these structures:

This approach to learning and instruction engages different parts of learner's mind
– visual-spatial processing and conceptual processing –
for a total learning experience leading to a **comprehensive understanding of the system**
– the spatial arrangement of its components and the nature and function of each component.

The combination of virtual reality (VR) and ontologies
uniquely affords learners a synergistic application of conceptual and visual-spatial processing
to achieve learning outcomes beyond what each can accomplish on its own.

2.4 Synergistic Conceptual and Visual-Spatial Processing

The immersive nature of VR enables learners' cognition to move from representational to conceptual learning, characterized by a process of structural modifications to the learner's conceptual framework as a result of new experiences and information [13].

The immersive, interactive environment provided by VR promotes the construction of deep conceptual knowledge.

2.4 Synergistic Conceptual and Visual-Spatial Processing

i

A learning environment that offers learners control of virtual objects maximizes learning potential through the autonomy granted to learners by means of physical interactivity, a unique benefit when compared to a non-immersive, decontextualized learning activity.

When learners using VR interact with objects in virtual space,
deeper learning through visual-spatial processing can occur:
motion-produced information caused by interacting with objects in VR provides valuable insights regarding objects' spatial orientation and relation to one another in the virtual environment [14].

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Interactive VR learning environments incorporate conceptual and visual-spatial processing synergistically to support deep learning through grounding knowledge
through learners' physical participation and interaction with their environment [15].

3 Computer imaging to Support Learning

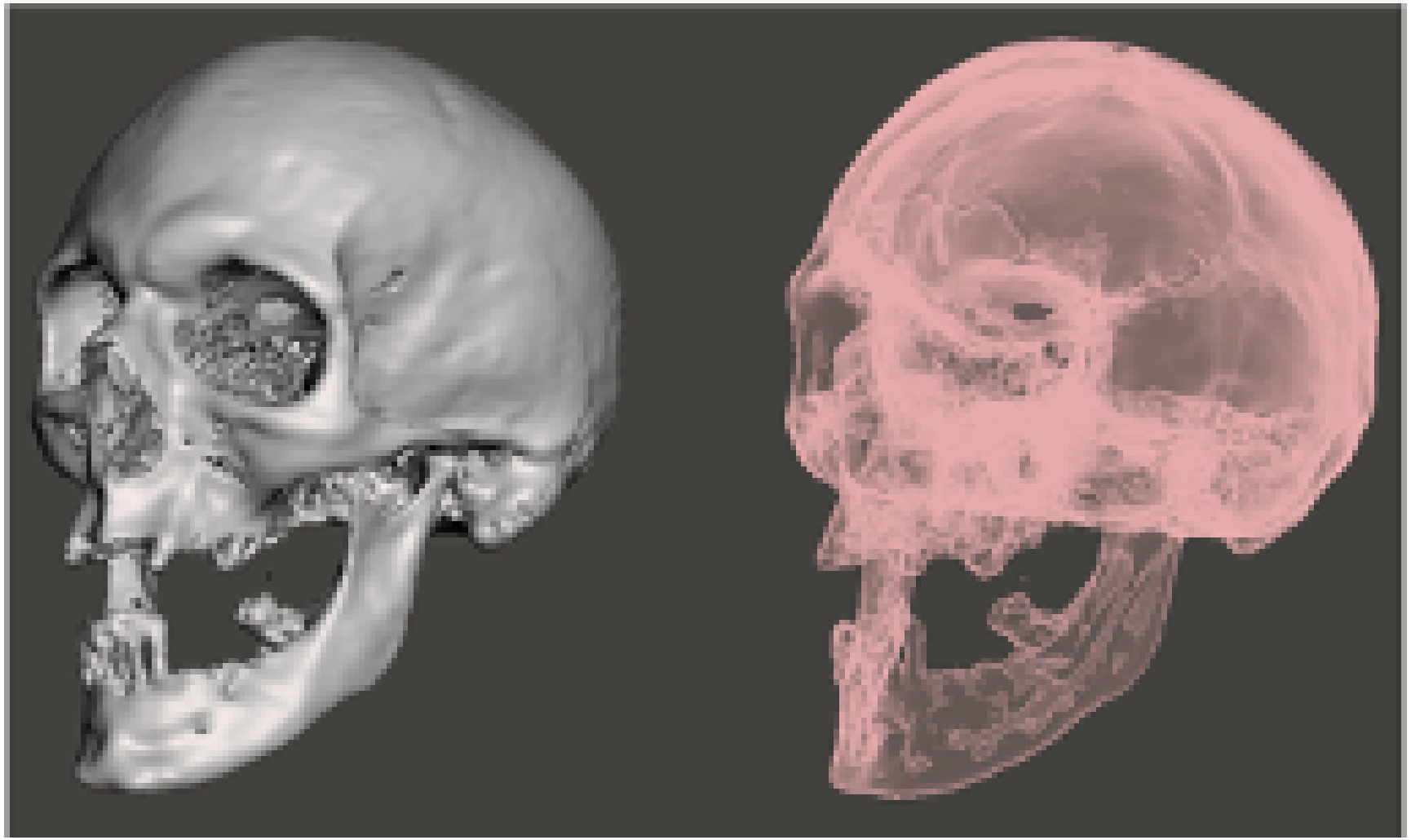

Fig. 4 Skull and transparent skull displaying internal structures (e.g., mandibular canal)

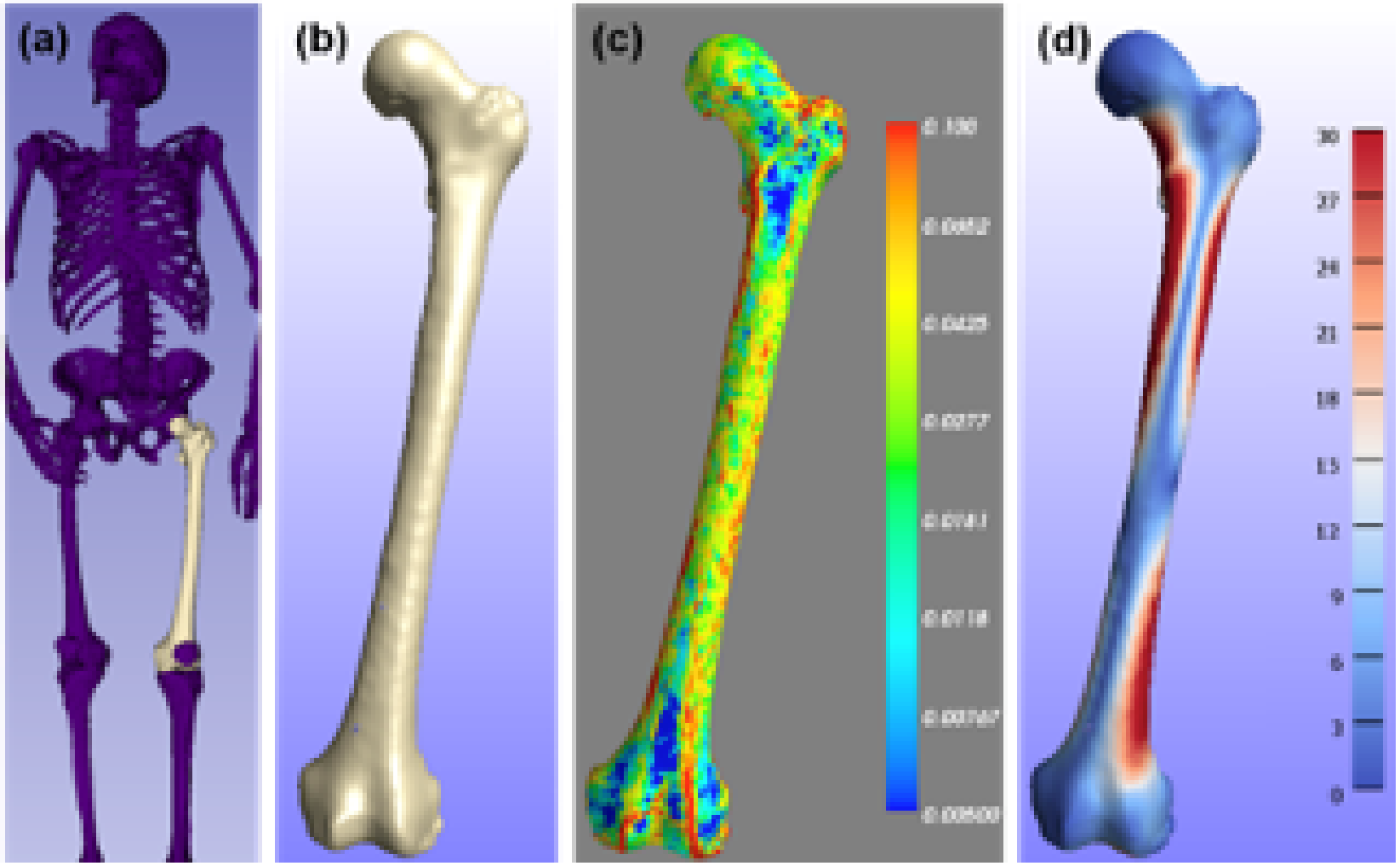

Figure 5: Cadaver-specific 3D models: a) skeleton; b) left femur; c) quantitative morphological data heatmap indicating surface curvature; d) quantitative biomechanical data heatmap showing stress distribution during a walking simulation.

4 Assessment of Learning Outcomes

Some findings from the literature on using virtual reality tools in teaching anatomy and physiology

Difference in test scores was not statistically significant, but tendencies

- quicker time to acquire information
- improved retention
- students found using virtual reality to be fun and engaging
- the models were useful as study aids.
- direct manipulation is better than passive viewing for learning anatomy in a three-dimensional virtual reality environment.

One concern: The initial learning curve when introducing virtual reality into the classroom. Can be addressed by more widespread use of virtual reality tools.

4 Assessment of Learning Outcomes

Results of using ontologies to support learning mostly in the areas of **reading comprehension and writing**,
both supported by better understanding of text structure.

Synergistic use of virtual reality and ontologies to support learning has not been formally assessed in classrooms (to our knowledge).

Future collaborative work for the Dept. of Anatomy and the Dept. of Learning & Instruction to assess the effect on learning outcomes in

- high school anatomy instruction
- university courses in introduction to anatomy and physiology
- advanced university courses, practica, and perhaps even research endeavors

5 Conclusion

Virtual reality:
visual-spatial processing
and object manipulation

Conceptual structure through ontologies:
conceptual processing

promising approach to
improving learning and instruction
in the important subject of **anatomy**
and, by extension, in improving learning of the
structure and function of **any highly complex system**

Questions? Comments?

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