Research Proposal
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An Interactive Multimedia Learning Tool for Skeletal Physiology Instruction for Undergraduate Students

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1.0 - Keywords

Skeletal physiology, skeletal biology, osteology, skeletal pathology, soft tissue pathology, interactive visualization, interactive learning, e-learning, multimedia instruction, 3D visualization, undergraduate education

2.0 - Abstract

Skeletal physiology is an important field of study – it is the foundation of many adjacent fields and musculoskeletal research has contributed to a better understanding of injury prevention, treatments, and rehabilitation. Despite being an integral component of various fourth year undergraduate physiology courses, skeletal physiology is a neglected topic in the curriculum and few resources are available to students enrolled in Human Physiology (PHYS3120) at the University of Western Ontario outside of the lecture material. To improve the comprehensive understanding of the topic and to facilitate the students' transition to upper year physiology courses, an interactive learning tool will be designed for PHYS3120 students, utilizing embedded 3D models, 2D graphics and short animations alongside the existing course material to consolidate knowledge and review the inf at the learner's own pace. The current project objectives include creating a multitude of static and dynamic visual resources that can be implemented in the learning tool and be used to engage students through a guided approach and scaffolding of information to direct the inquiry process. The tool will not only address the current learning gap for current physiology students, but also demonstrate the efficacy of integrating novel teaching tools into the curriculum to augment student learning and facilitate their knowledge consolidation process.

3.0 - Introduction

Skeletal physiology, the study of how the skeletal system functions and interacts with other body systems, is an essential topic to the broader scientific field or human anatomy and physiology. It is integral to fostering interdisciplinary collaborations with clinicians (surgeons, rheumatologists, physical therapists) and imaging scientists (Feder, 2005). Trauma- and disease-induced musculoskeletal conditions – such as injuries or osteoarthritis, respectively – affect the quality of life of over 1.7 billion people worldwide, and have the highest direct total costs to the Canadian healthcare system and substantial indirect costs for patients and their families, and society (Feder, 2005). At an undergraduate level, it is crucial to have a firm grasp of the subject area, particularly the process of bone formation, remodeling, and pathologies, before moving on to more advanced courses. It is well-known and documented that both undergraduate and graduate-level students within the fields such as general science, medicine, physiology, pharmacology, and kinesiology do not get enough exposure to the subject area before moving on to advanced courses in comparison to other physiology subtopics due to time constraints and the extent of the material that is covered in general physiology courses (Vioreanu et al., 2013).

At University of Western Ontario, students enrolled in undergraduate physiology courses receive little to no skeletal physiology instruction in their second and third years. Specifically, students enrolled in Physiology 3120 (PHYS3120), a core full-year course in the program, only receive one lecture of skeletal physiology instruction out of the entire year, and lower level undergraduate courses (PHYS2130) phased it out of the curriculum entirely. This MRP focuses on a sub-topic of physiology that is integral to understanding the complex interactions between development, aging, and disease and provides context for translating scientific findings to applications in human patients. The goal of this project is to create a multimedia interactive tool or platform to be used by undergraduate students alongside the PHYS 3120/2130 curriculum to augment, expand upon, and reinforce material learned in lecture. A formative assessment is to be conducted prior to production to pinpoint learning difficulties and student needs alongside those identified by the course instructor, and inform the design of the learning tool.

4.0 - Background

4.1 – Subject Area: Importance of Skeletal Physiology

Physiology plays an essential role in both science and liberal arts education because it provides a context for diverse multidisciplinary integration of information and concepts (Feder, 2005). One of the most important ideas that an undergraduate physiology education aims to communicate is the fact that physiology is intrinsically linked to a number of other disciplines, also known as disciplinary coupling (Feder, 2005). The fundamental understanding of the processes of mass and energy exchange, and transformation necessitate the crossover of physiology, physics, biology and chemistry (Feder, 2005). Evidence suggests that undergraduate skeletal physiology education is under-resourced with inadequate curriculum time allocated to the teaching of musculoskeletal conditions, with the issue persisting well into professional programs with only 12% of medical schools implementing mandatory musculoskeletal medicine teaching (Vioreanu et al., 2013). There is growing evidence that musculoskeletal education has been “squeezed out” of undergraduate and postgraduate education, which has led to medical students reporting feeling less confidence attending musculoskeletal patients and poorer diagnostic skills compared to non-musculoskeletal patients (Vioreanu et al., 2013).

4.2 – Challenges of Skeletal Physiology Instruction

What do students mean when they say physiology is "difficult"? What is the source of this difficulty and what can be done to address the concern? Michael & Kutchai conducted an extensive survey about the possible sources of difficulty in learning physiology by asking physiology instructors at all post-secondary levels. In agreement with previously conducted research, they identified three primary categories of possible contributing factors (Michael & Kutchai, 2007a).

First, the interdisciplinary nature of the subject makes it difficult for students to study at the expected level. Undergraduate teachers identified the nature of the discipline, along with the students' contribution, as the most significant determinants of physiology being difficult to study (Michael & Kutchai, 2007a). It is well-known that students often lack the expected level of prerequisite knowledge prior to taking undergraduate physiology courses (Dr. Woods, personal communication, May 18, 2022; Rovick et al., 1999). Studies suggest that instructors have a tendency to both underestimate the students' factual knowledge and overestimate their ability to apply this knowledge by a large margin, thus indicating that their decision-making with regards to delivering their teaching material and evaluating students' knowledge is open to question (Rovick et al., 1999). In addition, the ability to transfer knowledge learned in one context to another is also known to be difficult and contributes to students' inability to make use of their preexisting knowledge (chemistry and physics) in the context of physiology (Michael & Kutchai, 2007a). It has been found that transferring capabilities could be significantly improved through a repeated analogies approach, knowledge quizzing, and working through complex interdisciplinary questions presented as case studies (Goodman et al., 2018).

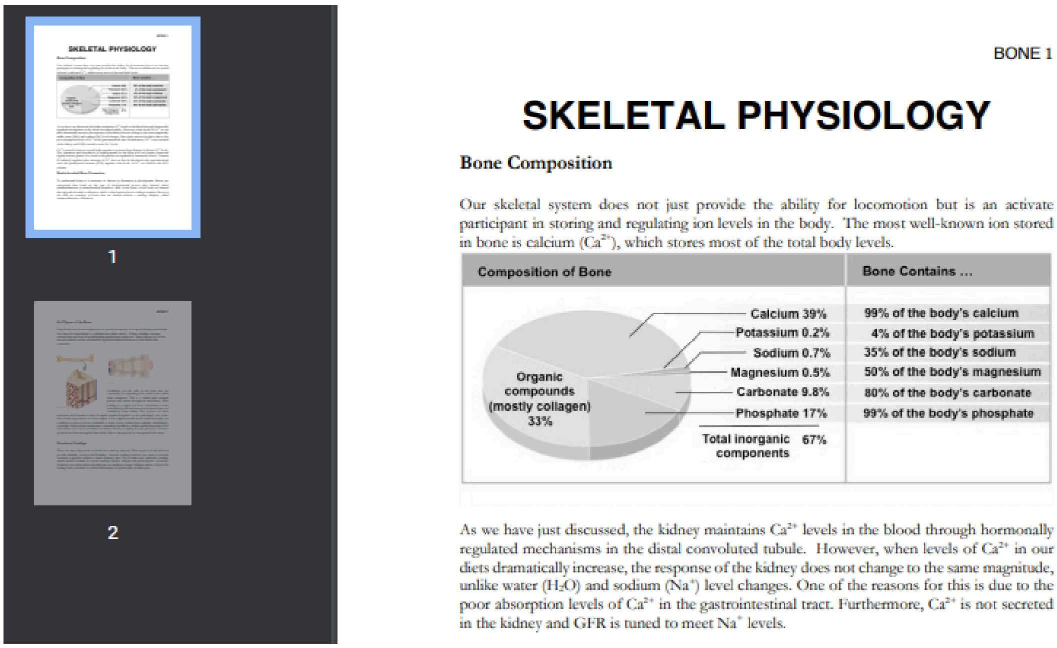
Second, the way physiology is being taught is inadequate or ineffective. It has been reported that students are not reaching the expected goals set for them in the sciences and there have already been numerous calls for change with regards to how material is being taught (*BIO2010 Transforming Undergraduate Education for Future Research Biologists*, n.d.). Though there is abundant evidence for implementing specific strategies, such as active learning (see **4.5.1 Active learning**), to improve physiology education, it has been met with considerable apprehension from many instructors (Goodman et al., 2018). Finally, what students bring to the table when studying physiology, and their expertise and experience are also important to consider (Michael & Kutchai, 2007a). In other words, students' beliefs about learning, and the skills and learning strategies they have accumulated throughout their education play a role in how challenging they find the material presented to them.

4.3 – Current learning resources and teaching methods

Traditionally, physiology is taught through a combined lecture-laboratory approach due to its unique position as an interdisciplinary field in bioscience education. At the University of Western Ontario, Physiology 3120 (PHYS3120) is a core course for students enrolled in Human Physiology and Physiology & Pharmacology instruction (*Physiology 3120 Course Outline* 2021). It follows the traditional lecture-laboratory approach and covers in great detail material pertaining to physiological processes of the central nervous system, nerve, muscle, renal, cardiovascular, respiratory, endocrine, reproductive and gastrointestinal systems (*Physiology 3120 Course Outline* 2021). The accompanying lab component (combined Physiology & Pharmacology PHYS3000E lab course) does not cover every topic covered during the lecture component and instead focuses on students designing or assisting in designing experimental protocols to study various aspects of select topics on a rotational basis, oftentimes excluding skeletal physiology altogether (*Course Outline - Physiology and Pharmacology 3000E: The Physiology and Pharmacology Laboratory* 2020).

Typically, PHYS3120 is taught through an in-person (pre-COVID), instructor-led lecture throughout both fall and winter semesters (Dr. Woods, personal communication, May 18, 2022). The skeletal physiology component consists of the following:

- **Pre-lecture reading (Skeletal Resource)**: a 2-page document outlining some of the things to be discussed during lecture; features text with 2 static visualizations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BONE 1

SKELETAL PHYSIOLOGY

Bone Composition

Our skeletal system does not just provide the ability for locomotion but is an activate participant in storing and regulating ion levels in the body. The most well-known ion stored in bone is calcium (Ca^{2+}), which stores most of the total body levels.

As we have just discussed, the kidney maintains Ca^{2+} levels in the blood through hormonally regulated mechanisms in the distal convoluted tubule. However, when levels of Ca^{2+} in our diets dramatically increase, the response of the kidney does not change to the same magnitude, unlike water (H_2O) and sodium (Na^+) level changes. One of the reasons for this is due to the poor absorption levels of Ca^{2+} in the gastrointestinal tract. Furthermore, Ca^{2+} is not secreted in the kidney and GFR is tuned to meet Na^+ levels.

Figure 1. Skeletal physiology - Skeletal Resource (Dr. Woods, personal communication, May 18, 2022).

- **In-class component (lecture)**: slideshow with text and limited visual media (static images), guides the students through the following topics:
    - Composition and Organization of Bone
    - Endochondral ossification
        - Cartilage template formation, primary ossification, secondary ossification, the growth plate
    - Intramembranous ossification
    - Bone remodeling
    - Pathologies (brief): osteoporosis, osteoarthritis

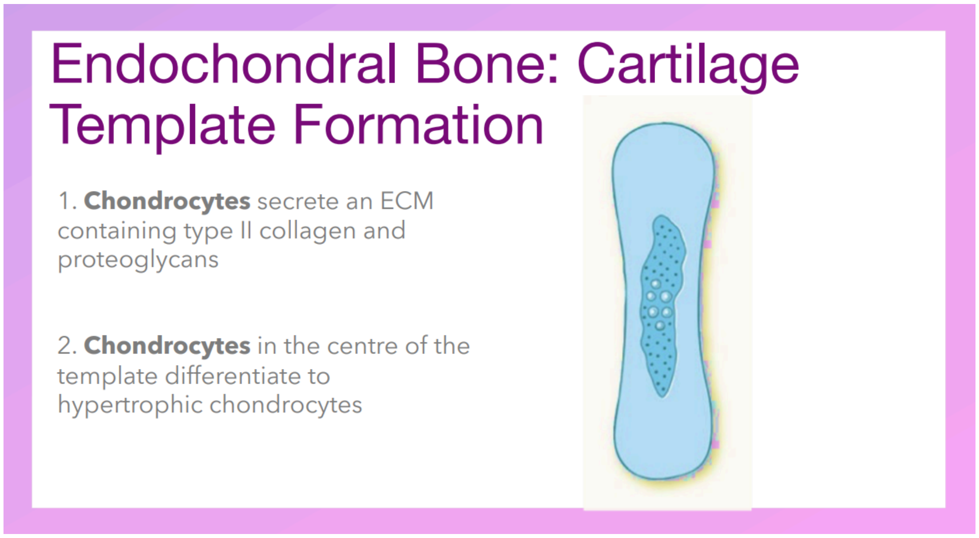
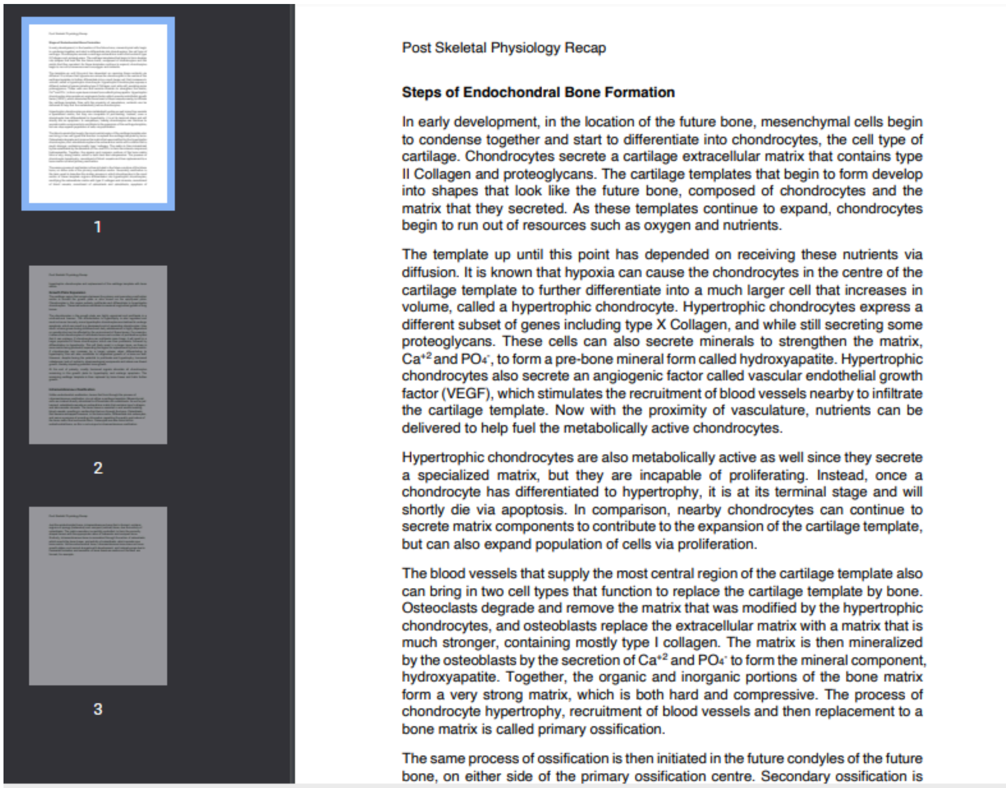


Figure 2. Example of an in-class skeletal physiology lecture slide (Dr. Woods, personal communication, May 18, 2022).

- **Post-lecture component**: a 3-page text-only document, reiterating some of the information covered during the lecture:
  - Steps of endochondral bone formation
  - Growth plate expansion
  - Intramembranous ossification



Post Skeletal Physiology Recap

Steps of Endochondral Bone Formation

In early development, in the location of the future bone, mesenchymal cells begin to condense together and start to differentiate into chondrocytes, the cell type of cartilage. Chondrocytes secrete a cartilage extracellular matrix that contains type II Collagen and proteoglycans. The cartilage templates that begin to form develop into shapes that look like the future bone, composed of chondrocytes and the matrix that they secreted. As these templates continue to expand, chondrocytes begin to run out of resources such as oxygen and nutrients.

The template up until this point has depended on receiving these nutrients via diffusion. It is known that hypoxia can cause the chondrocytes in the centre of the cartilage template to further differentiate into a much larger cell that increases in volume, called a hypertrophic chondrocyte. Hypertrophic chondrocytes express a different subset of genes including type X Collagen, and while still secreting some proteoglycans. These cells can also secrete minerals to strengthen the matrix, Ca^{+2} and PO_4^-, to form a pre-bone mineral form called hydroxyapatite. Hypertrophic chondrocytes also secrete an angiogenic factor called vascular endothelial growth factor (VEGF), which stimulates the recruitment of blood vessels nearby to infiltrate the cartilage template. Now with the proximity of vasculature, nutrients can be delivered to help fuel the metabolically active chondrocytes.

Hypertrophic chondrocytes are also metabolically active as well since they secrete a specialized matrix, but they are incapable of proliferating. Instead, once a chondrocyte has differentiated to hypertrophy, it is at its terminal stage and will shortly die via apoptosis. In comparison, nearby chondrocytes can continue to secrete matrix components to contribute to the expansion of the cartilage template, but can also expand population of cells via proliferation.

The blood vessels that supply the most central region of the cartilage template also can bring in two cell types that function to replace the cartilage template by bone. Osteoclasts degrade and remove the matrix that was modified by the hypertrophic chondrocytes, and osteoblasts replace the extracellular matrix with a matrix that is much stronger, containing mostly type I collagen. The matrix is then mineralized by the osteoblasts by the secretion of Ca^{+2} and PO_4^- to form the mineral component, hydroxyapatite. Together, the organic and inorganic portions of the bone matrix form a very strong matrix, which is both hard and compressive. The process of chondrocyte hypertrophy, recruitment of blood vessels and then replacement to a bone matrix is called primary ossification.

The same process of ossification is then initiated in the future condyles of the future bone, on either side of the primary ossification centre. Secondary ossification is

Figure 3. PHYS3120 Skeletal physiology post-lecture reading (Dr. Woods, personal communication, May 18, 2022).

4.4 – Multimedia in education

Visual learning and interactive tools have seen increasingly greater use in science education, including physiology, as they allow students to achieve deeper learning by being actively engaged and receiving immediate feedback (Domagk et al., 2010). Studies examining the potential benefits of combining traditional textual materials with accompanying visuals and active learning strategies found that image-based questions are more beneficial than text-based question for the purposes of content review and test preparation, while integrating both may be especially beneficial for learning anatomy (Gross et al., 2017). In the active learning setting, students found image-based exercises to be less demanding and requiring less effort compared to text-based activities, potentially suggesting that cognitive load may have been lower and led to greater learning outcomes at a lower cost (Gross et al., 2017). Overall, students found active learning exercises to be useful tools for test preparation, especially for clarifying key concepts and seeing images of key ideas (Gross et al., 2017).

The advantages of visualizations combined with active learning strategies in science education are not limited to simply including more and better images in lecture presentations (Gross et al., 2017). The benefits of immersive multimedia educational tools were demonstrated in a study done among medical students in the United Kingdom (Backhouse et al., 2017). Students demonstrated an improvement in test scores after completing an interactive tutorial that emphasized visualizing anatomical structures by guiding students through an observe-reflect-draw-edit-repeat (ORDER) cycle of learning, compared to a control interactive tutorial in which students were presented with text and image descriptions of the same anatomy (Backhouse et al., 2017). Its main advantages are being cost- and resource-effective, high utility, self-directed learning. In addition, medical students using a mobile augmented reality tool to augment their learning reported lower cognitive load compared to learning using only traditional textbooks and had significantly higher academic success (Küçük et al., 2016). This suggests that including interactive elements in combination with traditional learning materials (in this case mAR application was integrated into printed textbooks) is useful for reducing cognitive load, which yields higher retention of information and therefore increasing academic success (Küçük et al., 2016).

It is important to consider students' visual-spatial abilities when implementing tools such as 3D models into interactive learning models – it is useful for some learners, but not others (Bogomolova et al., 2020). High-spatial ability students perform equally well with 3D and 2D variants of the same interactive tool, but low-spatial ability students struggle with 3D learning (Bogomolova et al., 2020). This is important to consider when choosing the media treatment for the project.

(Bogomolova et al., 2020). Specifically, for my MRP I plan on using 3D models and potentially 3D animations, but I do not plan on integrating interactivity to the 3D models themselves (i.e. no 3D model viewer). Dynamic visualizations bring a lot of value to inquiry instruction – they promote complex science learning and enhance science instruction. Learners benefit from opportunities to process and reflect on the complexity of dynamic representations relative to static visuals (McElhaney et al., 2015). Based on these findings, a better option is to introduce interactivity by allowing the user to pause, play, and rewind the animation at their own pace without worrying about interacting with the model. If animation is deemed necessary to illustrate a particular concept (for example, joint movement), it will be from a fixed angle and contain labels to help low-spatial ability students orient themselves and allow them to gain the same learning benefits as high-spatial ability students.

4.5 – Relevant frameworks

4.5.1 Active learning and flipped teaching

In order to truly understand gross anatomy and physiology, students are required to master both structure and function. Tools traditionally used in the classroom (illustrations, cadavers, diagrams etc.) are typically the preferred method of teaching both anatomy and physiology (Wilhelmsson et al., 2010). To study physiology effectively, one needs to apply the knowledge gained by studying static illustrations and dissection by understanding the function of the structures in question and how they interact and work with one another to contribute to the overall bodily functions (Jittivadhna et al., 2010). Static media (illustrations, diagrams, computer-generated models) are useful for identification purposes, but lack effectiveness when it comes to demonstrating dynamic function (anatomy vs physiology) (Malone et al., 2019). This is the primary basis of integrating 2D/3D animation and sliders where applicable throughout the skeletal physiology interactive module. Active learning principle in constructivism is one of the educational concepts that suggests that students lack the opportunity for interactive hands-on learning and the current teaching tools are ineffective (Malone et al., 2019). There are different strategies employed by active learning, all ranging in scale but all focusing on the instructor's role becoming that of a facilitator of learning/feedback provider instead of a funnel for information (Goodman et al., 2018). For example, peer discussion time during lecture hours, asking a question in the beginning of class rather than at the end to help the instructor give feedback during class time and allow students to think through the problem, and having students write down answers for the question posed in class.

In addition, flipped classroom learning is a form of active learning that involves having students read or watch videos prior to coming to class, or doing quizzes based on the reading material. Flipped teaching is based on the premise of shifting lecture content outside of the classroom as assigned homework, and classroom time is instead spent integrating and processing the information learned prior to class time (Gopalan, 2019). It has been found that flipped teaching significantly improves student performance compared to traditional lecture (particularly for difficult concepts), though there is a period of adjustment when implemented (Gopalan, 2019). Though it seems counterintuitive, it has been proven that students gained significant learning benefits from predicting answers to questions concerning material they lack expertise in and had better knowledge retention once the material was taught to them afterwards (Goodman et al., 2018). Timely feedback is integral for this to be of value (i.e. students must be told the correct answer shortly after answering the question) (Goodman et al., 2018). Flipped teaching is already implemented in PHYS3120 curriculum to an extent, consisting of pre-lecture readings, in-class lecture, and post-lecture readings. Expanding upon and improving this approach to teaching through the implementation of an interactive tool can help students engage in learning and improve their academic performance further. The current intended use of the tool is to be integrated into the pre- and post-lecture components of the course to balance more effective information delivery with improving the students' review and assessment resources. However, based on the student survey results (to be conducted at the end of July), the focus of resource allocation may change depending on student needs.

4.5.2 Cognitive load theories and guided activity principle in multimedia learning

The premise of *cognitive load theory (CLT)* is that learners have a limited working memory, both in terms of capacity and duration – almost all information is thought to be lost after ~20 seconds unless it is reinforced by repetition (van Merriënboer & Sweller, 2005). Cognitive load refers to the amount of information the working memory is capable of holding at a time. Minimizing cognitive load allows learners to reduce the strain on the working memory and improve overall learning (de Jong, 2010). Classic CLT recommendations and guidelines are made based on the differences outlined between 3 types of cognitive load(de Jong, 2010) :

1. **Intrinsic** – present material that aligns with the prior knowledge of the learner; should be optimized
2. **Extraneous** – avoid non-essential or confusing information; should be minimized
3. **Germane** – stimulate processes that lead to conceptually profound knowledge

Furthermore, *Meyer's cognitive theory of multimedia learning* indicates that the learner (student) possesses two information processing systems – visual (animation) and verbal (auditory) (Mayer & Moreno, n.d.). The revolves around the learner engaging in three cognitive processes:

1. **Selecting** – processing incoming visual and verbal information to yield an image or text base, respectively

2. **Organizing** – processing these image and test bases to create a visual and verbal model of the system
3. **Integrating** – forming connections between the visual and verbal models

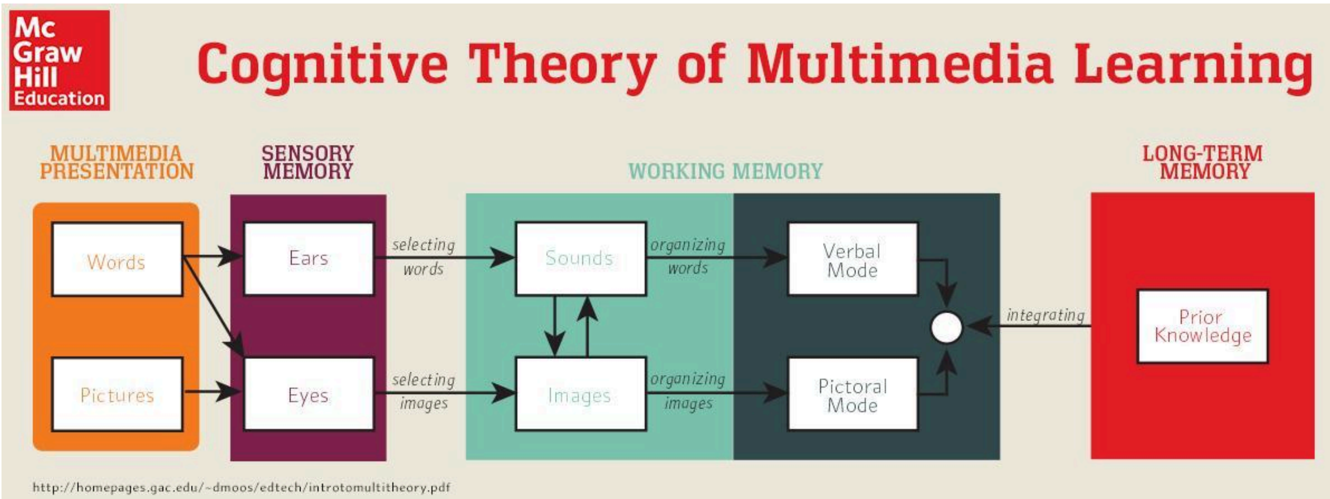


Figure 4. Cognitive Theory of Multimedia Learning

This model led to a series of experiments that yielded five important principles of multimedia design:

1. **Multiple Representation Principle**: two modes of representation are better than one (words and pictures are better than words alone)
2. **Contiguity Principle**: students learn better when corresponding words and images are shown to them together rather than separately or one after another
3. **Split-attention Principle:** in a multimedia approach, presenting words as auditory narration is better for learning than on-screen text
4. **Individual Differences Principle:** principles 1-3 described above all depend on the learners' individual differences (for example, the level of prior knowledge)
5. **Coherence Principle:** students learn more effectively from a concise summary of concepts rather than an extensive one in a multimedia approach (Mayer & Moreno, n.d.)

This concept is particularly useful to my MRP because it takes a learner-centered approach to describe how to implement successful multimedia teaching strategies without compromising the educational benefits of technology-centered learning environments. The challenge is to find load-reducing approaches for intensive knowledge producing mechanisms (ex. learning from multiple representations) (de Jong, 2010). Combining approaches with enough structure to avoid cognitive overload is a leading research theme(de Jong, 2010).

While interactive tools are extremely useful and may facilitate and reinforce information retention in students, it is important to consider their design to avoid overloading students with excessive extraneous cognitive load (Moreno & Mayer, 2007). Cognitive overload may occur when the information processing demands exceed the processing capacity of the cognitive system of the learner (Moreno & Mayer, 2007). Designing for both low- and high-ability learners may require a more structured experience, with students being led through the learning module to guide their cognitive processes and prevent cognitive overload that may result from students being left to explore content on their own (Liang & Sedig, 2009). This is referred to as the Guided Activity Principle – students learn better when their cognitive processing (selection, organization, and integration of information) is guided by an agent when they receive instruction compared to when they do not receive guidance and are left to engage in pure discovery (Moreno & Meyer 2007). In addition, students learn better when they are not only guided through the experience, but are also allowed to set the pace of the presentation of the educational materials (Moreno & Meyer 2007). Pace control allows students to process smaller chunks of information in their working memory and thus prevent cognitive overload and facilitate learning, as well as allow students with more prior knowledge avoid frustration (Moreno & Meyer 2007). Lastly, feedback and knowledge assessment are very important to consider when designing the tool. The type of feedback given to students matters – explanatory rather than corrective feedback reduces extraneous processing to help students correct their misconceptions and create their own explanations to questions while reducing the likelihood of attempted guesswork. These design principles and strategies are aimed at maximizing the effectiveness of the planned interactive learning tool and creating a smooth navigational experience for the students while reducing extraneous cognitive load (Liang & Sedig, 2009; Moreno & Mayer, 2007).

4.5.3 Scaffolding of information

There is significant interest in optimizing software tools to guide learners through complex tasks and provide enough support to enable them to digest more complex content, reduce cognitive load and solve more difficult problems that they could handle otherwise (Reiser, 2004). Scaffolding traditionally refers to a number of instructional techniques in which the instructor assists and supports the students as they move towards deeper understanding of the material and accomplish tasks previously out of their reach (Reiser, 2004). There are two main scaffolding mechanisms: 1) Structuring a learning task, guiding learners through key elements, and supporting their performance; and 2) Making some aspects of students' work more difficult ("problematizing") in a way that requires attention and intense problem-solving, resulting in short-term difficult but long-term productive learning (Reiser, 2004). Scaffolding information and varying levels of complexity can guide students from basic to advanced comprehension level of the subject matter (Reiser, 2004).

A study by Way & Rowe (n.d.) describes four types of scaffolding and their hierarchy:

1. **Procedural** (low level)– shows how to use the resource (navigation and specific functions)
2. **Conceptual** (mid level) – helps to focus thinking, prioritize information and make connections
3. **Strategic** (mid level)– directly or indirectly suggests strategies or approaches to help

learning

4. **Meta-cognitive** (high level) – helps with reflection and self-assessment of what the students learned

Because of the complexity of the material to be presented in the interactive learning module, all four of these types of scaffolding are important to consider when designing the tool, particularly meta-cognitive scaffolding due to its reflective and evaluative nature (Way & Rowe, n.d.). Procedural scaffolding can take the form of instructions and blinking/fading indicators to direct attention to the interaction needed (clicking on something etc.). Conceptual scaffolding can consist of providing additional representations of the same concept to focus attention on making connections and simplifying complex concepts into digestible diagrams. Strategic scaffolding could be implemented in the form of direct suggestions (pop ups or tooltips) prompting the learner to compare representations or suggest approaches on how to connect them. Lastly, meta-cognitive scaffolding could consist of prompting the user to reflect on the newly learned information in the form of questions or even simple but focused prompts to think about key concepts to organize and integrate them better. What is also important to note is that studies show that students recognize the learning design principles embedded into interactive tools, such as interactivity, prompts that support cognitive processes, pacing, navigation, and feedback (Clarke & Gronn, 2004). It is integral to consider the audience when deciding how much of each type of scaffolding to integrate and whether it will be mandatory or available on demand. Understanding the audience, the material, and the types of scaffolding will lead to creating a balanced navigational experience, result in greater learner autonomy and yield better results when dealing with learning tasks of greater complexity.

4.6 – Media Audit

Most existing educational media focus on teaching basic anatomy, but lack information on function, motion of limbs (ex. Joint types), or bone remodeling past the childhood development stage. No applications addressing the content covered in PHYS 3120 were found. Among the most successful multimedia applications found, Bone Anatomy Viewer was good for understanding basic structural relationships between different levels of bone, but had very limited interactivity and poor knowledge consolidation design.

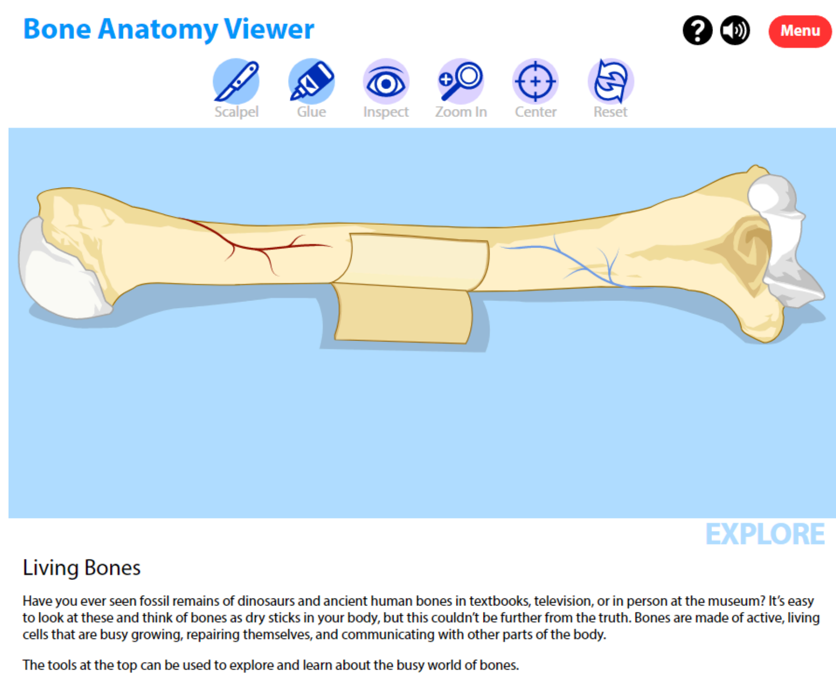


Figure 5. Bone Anatomy Viewer user interface.

In fact, most physiology training modules found had very limited visualizations (static and visibly dated), difficult to understand language for someone at an undergraduate level of education, and poorly designed user interface. Overall, the media audit shows a lack of clear, comprehensive visuals that focus on depicting physiological processes and function rather than strictly focusing on anatomy. The most successful applications feature both linear and non-linear navigation, mixing 2D and 3D dynamic visuals, and providing a way for students to quiz themselves at the end of the module rather than providing a summary of the content.

4.7 – Gaps in literature

Skeletal physiology is an important, but severely underrepresented area of pedagogical research, with many unanswered questions.

- What do the students find difficult about skeletal physiology specifically? (see **6.3 – Assessments**)
- What content is applicable to PHYS3120 that will be relevant in upper-year physiology courses? (to be answered throughout the summer/fall 2023 as the course is being restructured)

5.0 - Project Objectives

The primary goal of this project is to develop a supplemental interactive multimedia learning tool to improve undergraduate Physiology & Pharmacology students' understanding of skeletal physiology and address the continuous phasing out of the subject out of the undergraduate curriculum in a way that is engaging to students and helps increase their interest in higher-level courses.

Objectives:

- Employ proven UI/UX design methods to develop a solution that exhibits a pleasing user experience while limiting extraneous cognitive load
- Engage students through guided interactions with the created media and encourage independent learning

- Design and create an accessible and aesthetically pleasing tool/platform that is easy to navigate and effectively communicates the information

6.0 - Methodology

6.1 - Audience

Key Questions:

- Who are you designing this project for?
- In what context will it be used?

The primary audience of this research project is undergraduate Physiology & Pharmacology students enrolled in PHYS3120 Human Physiology at the University of Western Ontario. The secondary audience of this project includes students enrolled in related physiology/pharmacology courses, that fall within the following criteria:

A. Course curriculum includes the topic of skeletal/bone physiology and has PHYS3120 as a prerequisite course (i.e. **PHYS4530B Skeletal Health and Disease**)
B. Course curriculum is paired with PHYS3120 and the tool may be integrated seamlessly (i.e. **PHYS3000E Physiology & Pharmacology Laboratory**)
C. Course curriculum no longer includes the topic of skeletal/bone physiology (i.e. **PHYS 2130 Human Physiology**) and the tool may be integrated as an extra-credit component of the course

6.2 - Design Scope

The tool will be primarily focused on covering the topic of bone physiology taught at the level of PHYS3120, using the content provided by Dr. Woods in the lecture and post-lecture material.

6.3 - Assessments

To inform the design of the interactive project, I plan to conduct a formative assessment throughout the months of June-July 2022. The assessment (see breakdown below) will consist of 3 separate components: **1) focus groups**, **2) instructor feedback**, and **3) analysis of course syllabi**. Additionally, I have completed the course myself during the 2018-2019 academic term and am very familiar with content that is delivered to students and the manner in which it is delivered, as well as the pacing and the level of student-instructor interactions during lecture. This experience will also help with the design and focus of the project.

1. **Student focus groups**. In July 2022, I will attend the student focus group interviews held by Dr. Woods (starting third week of July) to observe and understand the students' opinions and attitudes about specific sections of the course. I will also be conducting an informal questionnaire
2. **Instructor interview & content review.**
3. **Analysis of course syllabi.**

6.4 - Visual Treatment

Key questions:

- How will it be designed and presented?
- Linear or interactive narrative?

The proposed design is a multimedia educational platform or e-module with embedded static (2D/3D) graphics and animations. Some interactivity may be introduced in the form of sliders and user-controlled videos (with the ability to pause/slow down/speed up/rewind content at one's own pace).

6.5 - Development Plan

- After the content outline is written and approved by Dr. Woods, a user journey chart will be created to outline the user's path through the tool
- Afterwards, low and high-fidelity wireframes will be created using Figma (prototyping software)
- A high-fidelity prototype will be completed after several rounds of iteration and feedback, tentatively by December 2022 (2nd full committee meeting)
- After approval of the high-fidelity prototype, development of the visual 2D/3D assets will begin
    - **List of tools:** Figma, Adobe Photoshop, Adobe Illustrator, ZBrush, Maya, Adobe After Effects, Unity

6.5 - Implementation

The tool/module will be available to all students enrolled in future PHYS3120 courses offered, as well as potentially other courses within the Physiology and Pharmacology Department at Western University (particularly the 2nd year Physiology course PHYS2130 and several 4th year courses which require PHYS3120 as a prerequisite). The tool is intended to be used outside of class to facilitate, consolidate and solidify information learned during lecture and the post-lecture reading. It is intended to be a resource for self-directed deeper understanding of the topic and an opportunity to review the material at one’s own pace. The tool may also be implemented as an extra-credit component of PHYS2130 due to the course no longer having a skeletal physiology component in the syllabus.

6.6 - Limitations

The formative assessment will be distributed to focus groups of students who have completed PHYS3120 in the past academic year (2021-2022). However, student responses may be limited or students that volunteer to participate may not be representative of the entire student population due to having very strong positive or negative opinions, thus electing to participate.

7.0 - Anticipated Significance

This project will be the first multimedia interactive tool focusing on teaching skeletal physiology to an undergraduate audience, improving upon existing available media in the field and ultimately deepening students’ understanding of this interdisciplinary and complex subtopic. The project will use and build upon existing design principles to demonstrate the efficacy of integrating novel teaching tools into the curriculum to augment student learning and facilitate their knowledge consolidation process. Designing, prototyping, and developing this tool will not only provide deeper insight on the potential of implementing interactive learning tools to teach complex, highly interdisciplinary concepts within a classroom environment, but also provide future BMC students and other scientists with the documentation needed to build upon this project and consider working on similar tools to help fill the need to better educational resources in the field.

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