

ITERATIVE DEVELOPMENT OF AN INCLUSIVE LEARNING ENVIRONMENT FOR HUMAN ANATOMY STUDIES: FROM ONLINE ENGAGEMENT WITH 3D MODELS TO VIRTUAL REALITY

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ABSTRACT

In the fields of medicine and health, there is a growing interest in resorting to the affordances offered by game-based learning and 3D interactive platforms. In human anatomy education, interactive learning environments can indeed foster higher levels of learner engagement and more effective learning of abstract and complex anatomy concepts. Though evolving quickly in the last decade, the design of learning environments has been accelerated by the pandemic and the associated need for online and hybrid learning. This paper presents the process of designing and developing a prototype for an interactive learning environment for human anatomy education anchored in educational theories of learning, especially the Universal Design for Learning framework. In this context and with the purpose of helping students understand the content of human anatomy courses in a more intuitive and interactive manner, we developed a multimedia teaching tool called Anatomy 3D. Our learning environment leads students through anatomical topics using an interactive scenario-based quiz with a 3D model. Our quizzes follow “pathways” throughout the body, where each question builds on the previous one. After each question, the student gets feedback tailored to their response. Anatomy 3D is unique among the wide range of tools already existing, as it highlights the functional relationships between anatomical elements, the understanding of which is important to building an accurate mental representation of human body systems. Anatomy 3D is also bilingual, with all content available in both French and English. The development of our learning environment involved an iterative process with regular inputs from students and designers. Our more recent development has been to adapt Anatomy 3D to a virtual reality system, allowing an even more immersive experience for learners.

KEYWORDS

3D, Bilingual, Human Anatomy, Interactive, Learning Environment, Virtual Reality

1. INTRODUCTION

Immersive learning environments foster learner engagement and facilitate learning abstract and complex concepts [Kuhail et al., 2022; Lui et al., 2020; Alharbi et al., 2020]. The affordances offered by game-based learning and 3D interactive platforms are of particular interest in the fields of medicine and health education [Ali et al., 2015; Singh et al., 2019; Estai & Bunt, 2016].

The paper presents the process we used to design and develop a prototype for an interactive learning environment dedicated to human anatomy education anchored in educational theories of learning, especially the Universal Design for Learning framework [CAST, 2018]. With the purpose of helping learners understand the content of human anatomy courses in a more intuitive and interactive manner, we used an iterative process involving input from students and designers at each step to develop a multimedia teaching tool called Anatomy 3D.

2. ANATOMY 3D PLATFORM

2.1 Description of Anatomy 3D

Anatomy 3D is an interactive, multimedia teaching tool. Its purpose is to help students understand the content of anatomy classes in a more intuitive and interactive manner. It leads students through anatomical topics using an interactive quiz with a 3D model (Figure 1).

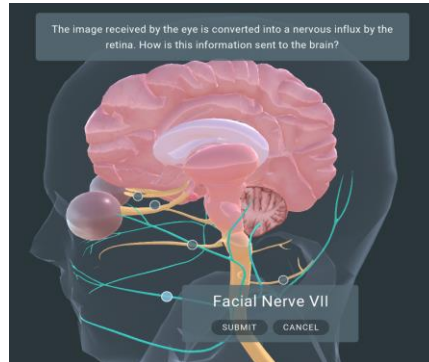


Figure 1. 3D image and question illustrating the visual appearance of Anatomy 3D

The quizzes follow “pathways” throughout the body, meaning each question builds on the previous one. After each question, students are provided with context-aware feedback based on their answers (Figure 2).

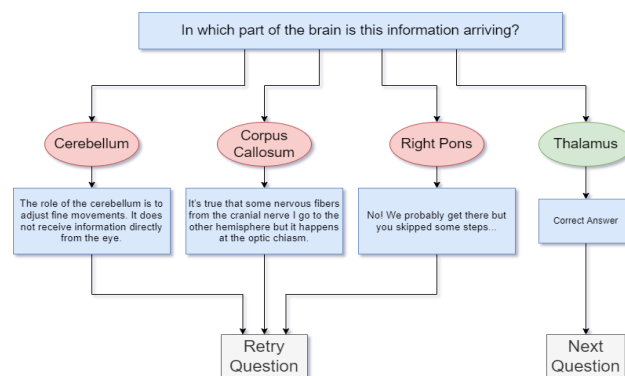


Figure 2. Typical structure of a question associated with response-tailored feedback

2.2 Scenarios

We currently have developed four scenarios using models of the brain, skin, and ear (Figure 3). Each module is five to ten questions and is designed to be completed in one sitting.

Scenario development is supported by a domain-specific language and a corresponding editing tool to enable instructors to efficiently develop multiple high-quality modules using the same 3D anatomical model, if desired. Anatomy 3D is bilingual, with all content available in both French and English.

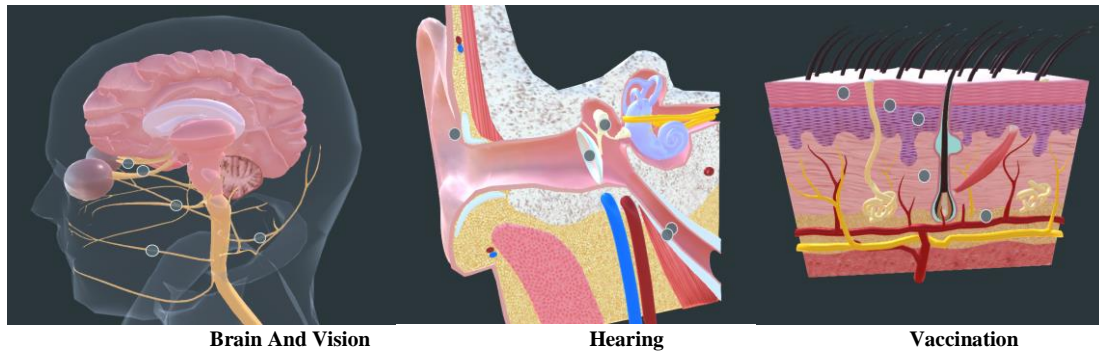


Figure 3. Three scenarios using models of the brain, the ear and the skin

2.3 Iterative Improvement of Anatomy 3D

Iterative design is a process of continuous step-by-step refinement, alternating the testing and updating of a product [Enginess, 2021]. Our initial prototype was presented to students taking a first/second-year human anatomy course in the Fall 2019 semester. This course is typically offered annually in both the Fall and the Spring terms. Using the iterative process illustrated by Figure 4, three additional improved versions of Anatomy 3D were prepared and shared with students over three years until the Fall 2022 semester.

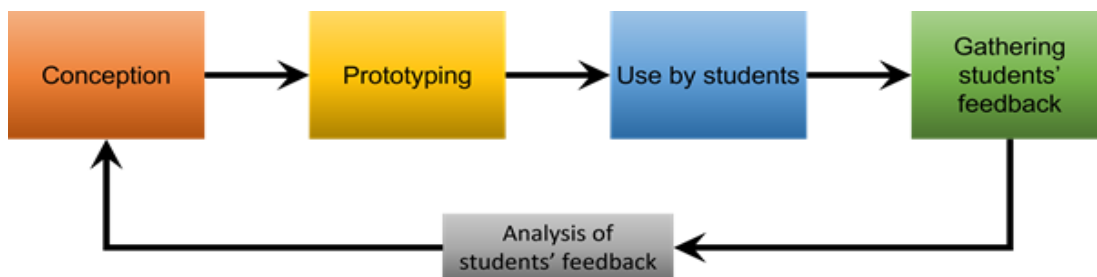


Figure 4. Process used for the iterative improvement of Anatomy 3D

3. METHODOLOGY

3.1 Participants

The prototype was tested by first- and second-year undergraduate students enrolled in the introductory Anatomy course taught by one of the authors, Dr. David Vergote. We used an online questionnaire to gather students' perceptions of and feedback on the prototype. This research was approved by the University of Alberta ethics approval committee.

3.2 Data Collection

The students' perceptions and feedback regarding the prototype, such as its usefulness, design, and usability, were gathered through the use of an online questionnaire involving students enrolled in an anatomy course. Students were encouraged to fill up the survey by rewarding them with bonus points on their final exam. Although every student who filled up the survey received bonus points, only the answers of those who agreed to be part of this study are considered here.

The platform also collects data (average time to answer, difficulty, common wrong answers) from the system-learner interaction for further learning analytics (Figure 5). To date, we have used this data to evaluate the usability of the platform.

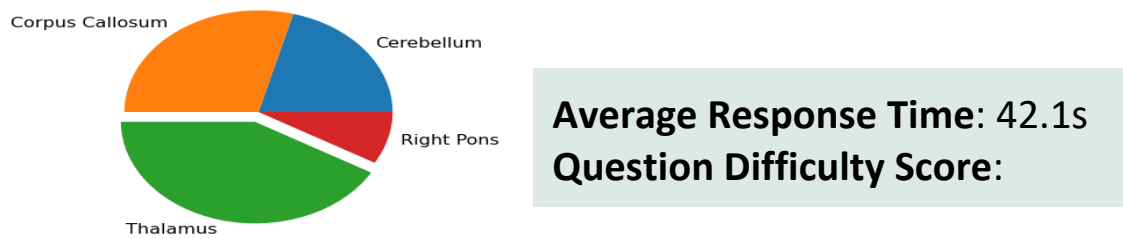


Figure 5. Example of the analysis of answers to a question

3.3 Recent Development

A more recent development has been to adapt Anatomy 3D to a virtual reality system, allowing for an even more immersive experience for learners. However, we have not shared this latest improvement with students yet.

4. CONCLUSION

The novelty of Anatomy 3D among the wide range of tools already existing lies in the fact that it highlights the functional relationships between anatomical elements, the understanding of which is important to build an accurate mental representation of human body systems as complex as the brain, for example. The content or teaching methods can be adjusted to improve student success using the collected data. In the future, there is potential to personalize question content based on users' past performance to optimize the difficulty and topic of the next question displayed.

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REFERENCES

- Alharbi, Y., Al-Mansour, M., Al-Saffar, R., Garman, A., & Alraddadi, A. (2020). Three-dimensional Virtual Reality as an Innovative Teaching and Learning Tool for Human Anatomy Courses in Medical Education: A Mixed Methods Study. *Cureus*, 12(2):e7085.
- Ali, A., Khan, Z. N., Konczalik, C. P., & El Sayed, S. (2015). The perception of anatomy teaching among UK medical students. *The Bulletin of the Royal College of Surgeons of England*, 97(9):397–400.
- CAST. (2018). Universal design for learning guidelines version 2.2. <http://udlguidelines.cast.org>
- Enginess. (2021). What is Iterative Design? (and Why You Should Use It). <https://www.enginess.io/insights/what-is-iterative-design>.
- Estai, M., & Bunt, S. (2016). Best teaching practices in anatomy education: A critical review. *Annals of Anatomy*, 208:151-157.
- Kuhail, M. A., ElSayary, A., Farroq, S., & Alghambi, A. (2022). Exploring immersive learning experiences: A survey. *Informatics*, 99(4):75.
- Lui, M., McEwen, R., & Mullally, M. (2020). Immersive virtual reality for supporting complex scientific knowledge: Augmenting our understanding with physiological monitoring. *British Journal of Educational Technology*, 51(6):2181-2199.
- Singh, K., Bharatha, A., Sa, B., Adams, O. P., & Majumder, M. A. A. (2019). Teaching anatomy using an active and engaging learning strategy. *BMC Medical Education*, 19:249.