DEVELOPING A SERIOUS VIDEO GAME FOR MEDICAL EDUCATION

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ABSTRACT

Games have long served as effective tools for both play and education. After the rise of video games, the concept of "serious games" emerged, combining entertainment and educational content. In various industries, including medicine, serious games have been leveraged for training purposes. Yet the medical education sector still faces a gap, particularly with respect to basic anatomy and physiology. Using research on the benefits of video game learning, the effectiveness of serious game use in other professions, and attitudes towards serious gaming in medical education, along with analyzing existing serious games in various industries, this paper reinforces the potential of serious games being complementary to traditional teaching methods. This paper also explores the serious medical gaming landscape, highlights existing tools for medical students, and identifies the need for a serious video game for medical students. The author proposes a concept aimed at post-secondary students, specifically targeting undergraduate pre-med students, post baccalaureate medical preparation students, and pre-clinical graduate medical students. By addressing the current gap in medical education and offering a contemporary solution, this paper contributes to the ongoing discussion of using technology for effective medical training.

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INTRODUCTION

Games have long been used as a form of teaching in addition to play. The appearance of video games did not end that tradition, instead creating the use of the term ”serious games”. Like training simulators, serious games are meant to teach their players, but in the context of a game instead of true to life. Some professions have leveraged this newer option in training their personnel for years. Research on the effectiveness of using such games has since occurred. The cycle of use prompting research and research promoting use has fueled the development of serious games in more and more industries, including the medical fields. Then the COVID-19 pandemic forced many industries, including higher education, to look for alternative and digital teaching methods. This improved acceptance of serious games as a viable training option. However, the various medical fields that are currently represented in serious video game education are unbalanced. There are numerous games for patient training and a number of games for training medical professionals in specialties, but basic medical education, in the form of anatomy and physiology, seems to be the least supported. While there are many digital tools, websites, and learning materials available for medical students, there is a lack of serious video games. To even the playing field, the author has proposed a serious video game concept for post-secondary students.

WHAT A SERIOUS GAME IS AND IS NOT

Definition of Serious Game

According to the Oxford dictionary, a game is “a form of play or sport”. According to the Merriam-Webster dictionary, a game is “an activity engaged in for diversion or amusement”. Typically a game is governed by set rules by which all players involved abide. Sometimes games are used as educational tools. Classic examples involving the youngest of humans are “peek-a-boo” (in which infants are delightfully surprised until they are old enough to demonstrate object permanence), “patty-cake” (in which infants learn gross motor skills), and “the drop game” (in which infants learn about gravity and how long they can entice or coerce an older human to pick up dropped objects). Many physical games for older children, such as “Red Rover” or “Freeze Tag”, teach cooperation, coordination[1], and tactics. Older children, and even through to the adult ages, also learn from other game forms: card games such as “Memory” or “Match 2”; board games such as “Chutes and Ladders” or “Tic-Tac-Toe”; chess to teach strategies related to war; dice games that teach Math; word games; guessing games; and puzzles. In the 1960s, video games started to be a form of gaming available to humans.[2] It did not take long before video gaming was applied to teaching. According to various internet websites, “The Sumerian Game” was the first educational video game.[3,4,5] Written and tested 1964-1966, “The Sumerian Game” was a text-based resource management game designed for elementary school students that ran on a mainframe computer.[6] “Oregon Trail” was developed in 1971, became wildly popular among students for being entertaining, became sought after by history teachers for solving the problem of how to embody the past to students, and thus the educational video gaming industry began.[7]

Sometime in the early 2000’s, a group of video games gained the term “serious” instead of “educational”. There is no dictionary definition of the term “serious game”, and various sources describe it differently. The common theme is that “serious games” are a subgenre of video gaming that combines education of the player and entertainment for the player. This

contrasts with simulators (which have no gamification component to their training and are true to life)[8], and pure games (which are just for entertainment and do not care about the nature of reality)[8].

In their 2014 review of professional training and patient training serious games related to health, Ricciardi and De Paolis proposed a schematic representation of a game spectrum classification that includes a fourth type of game on the realistic simulation vs entertainment spectrum[8] (Figure 1). In this, there is an additional separation of serious games from simulations games (different from simulators). Serious games are those created to be realistic and develop skills, but they entertain while doing so to hold the player's interest. Simulation games are created to be fun, entertaining, imaginative, or fictitious, but teach something that could be applied in real life. By these definitions, "The Oregon Trail", "Where in the World is Carmen San Diego?", and the like are simulation games, not serious games.

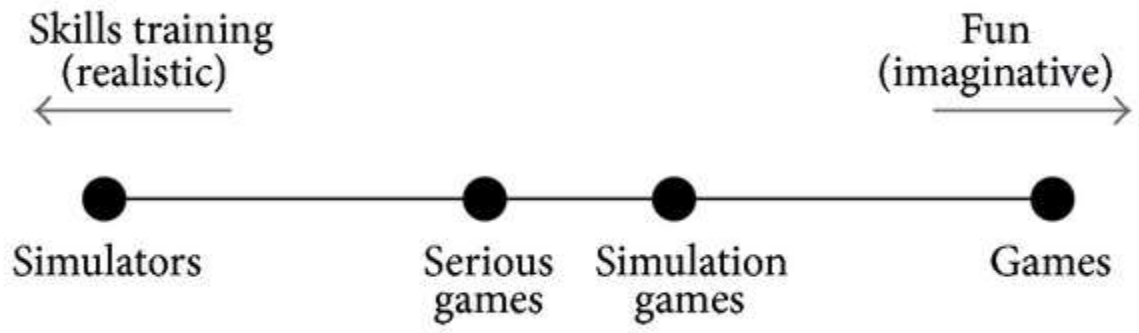

Figure 1: Game Spectrum Classification (Ricciardi and De Paolis 2014)

Examples That Are Not Video Games

There are innumerable software programs that have been called video games but actually are not. With respect to teaching anatomy and other medical topics to students, there are multiple online lists of the best teaching video games. These lists are overwhelmingly

dominated by websites or software programs and apps well known to medical students, that can be categorized as:

- Interactive Learning Platforms. These are Boards and Beyond, Kenhub, and Osmosis, which are videos and study notes plus quizzes or flashcards. They may include gamification pieces like earning points for visiting each day or getting questions right, but there are no actual video games involved.
- Reference programs / atlases and 3D visualization tools. These are A&P Revealed, The Visible Body, Real Bodywork, BioDigital Human, Inner Body, Human Anatomy Atlas, Zygote Body, Complete Anatomy, Essential Anatomy, and others. All of these are indeed video software, but they are in no way games. They are not even simulators as they do not provide learning scenarios. They are for self-teaching or reference by instruction programs or professors. They are for seeing anatomical relationships, or looking up where a piece of anatomy lies.
- Human Anatomy VR (on PlayStation). This is separate from the above item set because it renders the 3D visualization of anatomy in a fully interactive way. However, even though VR is next level technology, this is still only a reference / visualization tool and not a game.
- Quiz programs and Digital Flashcards. These are Purpose Games Anatomy, Quizlet, Anki, and many more. They are games in the sense that they keep score. They are interactive in that they provide a prompt and the user provides a response. Despite being programmed into a computer instead of a human reading the prompts and keeping score, these are trivia games. It could be conceded to classify these as simulation games under the video game spectrum defined previously, but it is a stretch.
- Digital puzzles, crosswords, and word searches. Similar to the above category, they are considered games, and they are computer programs instead of pen and paper, but that

does not make them video games. If Candy Crush involved lining up letters to make words instead of same colored candy, that could be a serious video game that teaches spelling. Trivia games, tools, apps, or programs are all more appropriate labels for computer renditions of static paper games.

SERIOUS GAMES WORK FOR TRAINING IN MANY PROFESSIONS

Benefits of Video Game Learning

Whether or not video games provide benefits beyond entertainment has been long debated. Common phrases the author heard growing up were “good for hand eye coordination” and “interactive is better than passive” but also “rots your brain” and “teaches aggression”. A multitude of studies have been done on the benefits of video games, or lack thereof. By 2014, most of the research done by psychologists on the effects of playing video games focused on negative impacts.[9] However, in the years leading up to then, and in the years since, what video games are made for has changed, as indicated previously by the proposed game classification spectrum. How video games are made have also changed, now offering wireless connections so the human body can move fully and freely in space, and VR connections for a more complete sensory immersion. Accordingly, research on video games has also changed and now includes determining if benefits exist.[10]

A 2023 meta-analysis of the cognitive outcomes of video game training showed improved overall cognition, improved higher-order cognition, and improved attention/perception outcomes, but no significant effects on memory outcomes.[11] Also relevant to the author’s video game project, this meta-analysis found that training using the first-person perspective demonstrated greater transfer to overall cognition than using third-person, and having the player navigate using outside references (ie: cephalad/caudad or medial/lateral) instead of using the player’s perspective (ie: left/right) demonstrated greater transfer to overall cognition.[11]

The American Academy of Pediatrics published an article in January 2023 that included the unique benefits and risks of children and adolescents playing video games, to ensure the doctors in their membership were educated on what the known benefits are and not simply screen time guidelines.[12] Such benefits of video games include practicing acquired knowledge[13], and as shown in numerous articles and studies: being rewarded for successes improves both motivation to learn, and interest in, the material.[13,14,15]

Select Industries and Why Each Uses Serious Games

The following is a non-exhaustive list of industries that use serious video games:

- **Laparoscopic Surgeons**

  For over 10 years simulators have been used for training doctors to use the small instrumentation and cameras necessary for this type of surgery. It has also been shown that story-based, non-simulation games improve the spatial perception and hand-eye coordination of these doctors.[16,17]

- **Other Medical Specialties**

  Level Ex is a company started in 2015 to "advance the practice of medicine through play." Its portfolio of mobile device games is designed for specialists such as cardiologists, pulmonologists, and gastroenterologists. The company has since begun developing medical simulations also.[18]

- **Dental Schools**

  Due to a shortage of volunteers to be a dental student's practice human, both simulators and games have been developed for training on how to do procedures such as implantations and administering anesthetics. One serious game even penalizes the player with vocalizations of unhappiness or pain.[19]

- **Astronauts**

  In 2017, NASA partnered with well-known video game company Epic Games to create an immersive on-Earth teaching version of the International Space Station.[20] The main difference between using the video game and full-scale simulators of the International Space Station was the ability to incorporate low gravity in an interactive way – without needing to put the trainees on an airplane that would nosedive to simulate weightlessness[21]. Would-be astronauts could practice keeping track of tools that float away and maneuvering themselves in an environment without an up or down. NASA has also looked into video game training for astronauts that would land on Mars.[19]

- **Firefighters**

  While traditional training of firefighters includes something called a “burn building”[22], video game training, especially with VR, turns out to be more practical than setting things on fire.[23] Safer too.

- **U.S. Army and Intelligence Officers**

  The Cubic Corporation provides virtual combat training and scenarios through the use of games to military personnel.[24] No specific information on these games is provided by the company or the military.

Attitudes Towards Serious Games

In a 2010 study of learning about orthopedic surgery through gameplay, the students involved indicated the game had increased their interest in the subject.[25] A 2015 study focusing on high reliability and validity found students had positive attitudes, positive cognitive perceptions, and positive affective perceptions along with low negative affective perceptions toward serious video game learning.[26] As mentioned previously, educators have been interested in video games for teaching since the 1970s. With respect to the health care field, however, a recent study in 2023 demonstrated that a majority of psychiatry and internal medicine workers (physicians, nursing staff, and other professional clinical workers) did not know about serious games or gamification as a teaching method. Once informed of the concept, the study found increasing age correlated to preferring traditional or conventional learning methods over teaching with games involving play.[27] It also pointed out that the COVID-19 pandemic forced adoption of new technology in all aspects of our lives, opening the acceptance door for including serious games in blended forms of teaching.[27]

Serious gaming is a complement to traditional teaching, not a replacement

During the COVID-19 pandemic, serious games found a foothold in education alongside synchronous online classes. At least one university studied the use of a serious game in their nursing curriculum while using it, and found when used as a complement to their physiology course it was a valid strategy for supporting face-to-face teaching.[28] Such games allow students and think and work through trial and error in a safe space[29], yet are limited by their programming. Drimify states that games do not replace the need for a teacher, they have found through studies that a teacher is key to student success even with efficient use of serious games.[30]

Conversely, educators should not add a serious game to their curriculum simply to integrate modern technology into their teaching.[30] A game included in a course should be relevant and complementary to the course material, chosen for its usefulness in curriculum integration[31], otherwise problems encountered by the educator and their students results in negative outcomes[32].

CURRENT MEDICAL VIDEO GAMES AND GAP TO BE FILLED

Current Games

In the interest of space, a streamlined table of serious games found using the methods stated below is presented in Table 1. See the Appendix for full information, images, and non-serious medical video games.

Table 1. Serious medical video games available for public use

Audience	Subject	Game Name	Created By	Research
PROFESSIONALS				
All	ECG training	Virtual ECG	University of South Wales	
Anesthesiologists, CRNAs, and Airway specialists	Maintaining airways	Airway Ex	Level Ex	
Cardiologists	Cardiology	Cardio Ex	Level Ex	
Dentists	Patient interview, implant procedure	Virtual Dental Implant Trainer	BreakAway Games	
Dermatologists	Dermatology	Top Derm	Level Ex	
Gastroenterologists	Gastroenterology	Gastro Ex	Level Ex	
Nurses	Hospital protocol	World of Salus		
PCPs	Insulin use	InsuOnline	oniria	yes
Pulmonologists	Pulmonology	Pulm Ex	Level Ex	
STUDENTS				
Medical	Skeletal anatomy	Whack a Bone	Anatomy Arcade*	
Medical	Muscular anatomy	Poke a Muscle	Anatomy Arcade*	
PATIENTS				
All	Pain management	Multiple games	Multiple creators	yes
Autistic	Social interaction skills	iSpectrum	Imaginary Srl	
Cancer	Treatment compliance	Re-Mission	HopeLab	yes
Children	Fight obesity / unhealthy habits	The Incredible Adventures of the Amazing Food Detective	Kaiser Permanente	
Children	Proper eating	Yummy Tricks	Cure4Kids and Saint Jude Children's Research Hospital	

Table 1 (cont'd)

Audience	Subject	Game Name	Created By	Research
Concussions	Recovery	Superbetter	Jane McGonigal	
Diabetic Children	Physical activity and injection routines	Affaire Birman	Les Diablotines	
Diabetic Teens / Adults	Physical activity and insulin pump routines	Timeout	Les Diablotines	
Veterans	Combat related PTSD	VR PTSD project	Multiple creators	yes
CHILDREN				
Ages 5 to 10	Human body anatomy	BodyQuest: Anatomy for kids / Science Adventure	Didactoons	
Ages 4 to 12	Human body anatomy	How Does The Human Body Work?	Learny Land	

*** For Medical Students**

As this section addresses the author's target audience, it is included here instead of in the Appendix. Video games for current medical students could only be found in one location:

- **Anatomy Arcade** (Website on internet)

  This website hosts a collection of independent mini games. While most of them are jigsaw puzzles and trivia games – crosswords, word searches, and match twos - the authors of the website also created two serious video games to teach anatomy. They are named "Whack a Bone" and "Poke a Muscle".[33] Both are flash games, but as Adobe flash is no longer supported it is unknown how much longer access will be maintained. Nothing on this site integrates even 2 systems together, much less the whole body.

Methods

While the investigation was not exhaustive, Google Play, the Nintendo E-store, the PlayStation E-store, and the internet via Google Search for "video game" were included. The

following multiple variations of terminology as the descriptor for video game were used: “human body”, “anatomy”, “medical”, “physiology”, “doctors”, “nurses”, “medical students”. In addition, “similar to your search” and “you might also like” links were followed in applicable results of all 4 of the searchable sources to uncover other games mentioned in this paper. Internet searching was complicated by the dominance in results of a horror video game named simply “Anatomy” which is about the player exploring a house that progressively changes. “-anatomy” was added to the Google Search to help circumvent that issue, but that may have removed valid results that should have been included in this paper.

University of Michigan Library’s “Video Game Studies” research guide was also reviewed. PubMed was searched for applicable publications whenever a website or video game claimed it had been part of a study, which lead to finding other medical field video games. Finally, the personal experience of the author as a medical student of 3 years was drawn upon to include the learning and study tools provided by Michigan State University College of Osteopathic Medicine and recommended by other medical students.

Serious video games that are no longer accessible are not included in this paper. Many of the published studies reviewed used games developed explicitly for the study, some of which were only prototypes and some of which were not even given a name. Games not released for mass use are not included in this paper. Simulators are not included in this paper.

Gap to Be Filled

As presented in the sections above, there is a dearth of serious video games for medical school concepts and medical students. Surgical and other medical specialty professions use serious video games for training. Dentistry education uses serious video games. Many serious video games are used to teach patients. Children have more anatomy and physiology teaching video games than medical students do. It is time doctoral medical education joins the rest of the industry.

MY CONCEPT

What

This is to be a video game that teaches human body anatomy with integrated systems physiology and some biochemistry. This is not to be a reference tool such as A&P or Netter's or Noted Anatomist, and is not to be a study guide. As a method of active learning, and not passive listening or reading, this game will help students apply and retain basic medical knowledge necessary for future success in medical school. This game is not intended to replace medical school education but is meant to be used to supplement classroom instruction.

Who (Target Audience)

The simple description of this serious video game's target audience is College level students. More specifically, this game is being built for undergraduate pre-med students, post baccalaureate medical prep (Postbac MEDPREP) students, and pre-clinical graduate medical students (year 1 of physician assistant medical school and years 1 and 2 of medical school).

Why

The author specifically remembers 3 instances over 3 years of medical school while playing open world video games during which the following thoughts surfaced: "If this [game] was about medicine, I would already know everything inside and out."; "I have all these useless maps memorized taking up space in my brain...."; and "Ugh, another map I am going to incidentally memorize that I do not even care about just because I am going to be running around it over and over." The third time it clicked in the author's brain that the repetition of video gaming could, and should, be leveraged to help teach medical students. Since the author had an 18-year career as a software engineer before beginning the journey to medical school, it seemed obvious the author was just the person to make such a game.

How

Based on initial research into the current state of video game development, the author decided to try both Unity and Unreal Engine video game development platforms. Both use the C++/C# programming language, which the author has extensive experience in using. The intention is for the game to be available for Windows and iOS systems at minimum, ideally Mac and Android also, and both Unreal Engine and Unity support this list. After going through tutorials provided by both Unity and Unreal Engine, in that order, the author researched why other developers chose one development platform over the other and found their experiences agreed with the author's tutorial experiences. Based on both the experiences and the information, the author chose to use Unity for the development of this game.

High Level Concept and Design Specification

The Goal of the Base Game is to get a human body functioning via the circulatory system. Future versions of the game would include the nervous system and have other goals involving illnesses / diseased states that need solving.

Each goal is defined by various Projects. For the Base Game, there are 8 projects the player must complete to reach the goal (2, 3, and 4 can be done in any order. 6, 7, and 8 can be done in any order):

1. Get Thorax functioning
2. Get Abdomen functioning
3. Get Pelvis functioning
4. Get Back functioning
5. Get inter-organ communication functioning (this is the endocrine system)
6. Get Upper Extremities functioning
7. Get Lower Extremities functioning
8. Get Head functioning (does not include brain / nerves as Player is serving as the brain!)

Each project has multiple Tasks the player must undertake to complete the project.

This is a First-Person perspective game. The player will not see themself in the game.

The player starts in the Heart inside the Thorax; thus the thorax is unlocked. There are 6 more areas to be unlocked: Abdomen, Pelvis, Back, Upper Extremities, Lower Extremities, and Head.

Each organ that the player interacts with has a personified characterization. The character names are mnemonics for respective organ's medical terms. The author has established 24 such names thus far, with some examples being:

- Heart person is Cara (Cardiac)
- Lungs people are twins Paula and Broncho (Pulmonary and Bronchial)
- Stomach person is Ol' Gassy (Gastric)
- Large intestines person is Colin (Colic)
- Liver person is Heppy (Hepatic)
- Gallbladder person is Chloe (Cholecystic)
- Kidneys people are Rena and her Nephew (Renal / Nephric)

Cara will be the first character encountered by the player, and will also be the player's go to for hints and help with the game.

The major currency in the game is ATP. The player cannot perform any tasks without ATP.

In addition to ATP, 5 or 6 molecules are also tracked by the game: O_2, CO_2, Glucose, Fatty Acids, Ketone Bodies, and maybe Lactic acid. GTP is tracked as ATP. For simplicity's sake, the game assumes any Ketone Body is β-hydroxybutyrate as that is the most common one in the human body, and the game assumes any Fatty Acid is Palmitic acid as that is the most common one in the human body. NOTE: H_2O is not tracked by the game, and so will be left out of chemical equations.

The tracked molecules can be found:

- O_2 by exchanging CO_2 at alveoli
  (Respiratory Exchange Ratio is 0.7-1.0 O_2 / CO_2 in a healthy body)
- O_2 in a red blood cell (RBC), up to 4 per RBC
- CO_2 resulting from any form of cellular/aerobic respiration (see ATP below)
- Glucose inside the liver (where it is made), inside the small intestines (where it is absorbed), and visible in skeletal muscle (but not available to anything outside of that skeletal muscle!)
  NOTE: this game leaves out the tiny amount made by kidneys
- Fatty acids inside adipose tissue (where they are stored) and inside the liver
  NOTE: if a future version of the game includes offspring, it must add finding fatty acids inside mammary glands during lactation
- Ketone bodies only inside the liver
  (made there by breaking down fatty acid stores via beta-oxidation)
- Lactic acid resulting from anerobic respiration (see ATP below)
- ATP by exchanging Glucose at any cell via anerobic respiration:

  1 Glucose → 2 ATP + 2 Lactic acid

  by exchanging Glucose at mitochondria containing cell via aerobic respir.:

  1 Glucose + 6 O_2 → 30 ATP + 2 GTP + 6 CO_2 (thus 32 ATP)

  by exchanging Ketone Bodies at a non-liver mitochondria containing cell:

  1 Ketone Body + 4 O_2 → 20 ATP + 2 GTP + 4 CO_2 (thus 22 ATP)

  by exchanging Fatty Acids at a liver mitochondria containing cell:

  1 Fatty Acid + 22 O_2 → 98 ATP + 8 GTP + 16 CO_2 (thus 106 ATP)

The player starts with a store of Glucose, as all bodies have 1 days' worth of glucose stored in the liver. This game gets around the fact that the player does not have access to the

Liver at the start by having Cara give the player this store of Glucose on behalf of Heppy. The player starts with no ATP, no CO_2, no O_2, no Fatty Acids, and no Ketone bodies.

The player also starts with an empty doctor bag. When the player finishes all tasks in a project, the player is rewarded with a tool for their doctor bag. Therefore by the time the player achieves the goal of the base game, the player will have earned all the tools to put in the bag. The rewards for the projects in the base game are:

1. Get Thorax functioning = Stethoscope (can customize tube color)
2. Get Abdomen functioning = Surgical Mask and Gloves (can customize color)
3. Get Pelvis functioning = Tympanic Thermometer (can customize shell color)

   "Actually, we don't take temperature at this end anymore. Here, have this."
4. Get Back functioning = Osteopathic Hands (can customize skin color)
5. Get inter-organ communication functioning = Prescription pad (uses player title + name)
6. Get Upper Extremities functioning = Sphygmomanometer (can customize tube color)
7. Get Lower Extremities functioning = Reflex Hammer (can customize handle color)
8. Get Head functioning = Otoscope (can customize handle color)

The organs and vessels of the human body are to look anatomically accurate. The cells will not be represented to scale so that the player may interact with them as needed to exchange molecules.

Future updates to the Base Game would include:

1. Addressing the player by a provided name
2. Make doctor’s bag customizable
3. Make doctor’s tool colors customizable
4. Allowing the player to choose which reproductive organs the human body has
5. Giving voices to the characters so the player learns how to pronounce medical terms properly

6. Background sounds in appropriate locations (heart pumping, lungs breathing, stomach and intestines digesting, other), and / or background music
7. 2D map of the human body that requires the player to use anatomical terms to change depth or views (sagittal, coronal, transverse)
8. Earning a tool unlocks new mini-games using that tool. For example: gaining the Stethoscope opens the 4 Cardiac listening posts and the 8 (6 posterior, 2 anterior) Pulmonary listening locations
9. Camera view that shows the body in selectable modes of x-ray, MRI, CT, or standard anatomical
10. Changing content based on the player's ability to access a cadaver lab

Prototype

For the purposes of the author's capstone project, a demonstrable prototype is a much smaller and targeted aspect of the base game. Given time constraints and that the start of the game is in the Thorax, the prototype's goal is to implement only the cardio-pulmonary portion of the thorax and the related thoracic project tasks. This includes:

- The heart and lungs
- Tracking game molecules on screen, shown in Figure 2
- Cara, Broncho, and Paula, as shown in Figures 3, 4, 8 and 9
- The great vessels, which can been seen in Figure 2 and from the inside in Figure 5
- Some accessory vessels, which are visible on the sides of Figure 5
- Red blood cells, as shown in Figure 6
- Mitochondria containing cells, as shown in Figure 7
- A rudimentary dialog system, shown in Figures 3, 4, 8 and 9
- Player ability to move through the circulatory system, part of which is seen in Figure 5

- Player ability to interact with characters, as shown in Figure 4
- And player ability to interact cells, as shown in Figures 6 and 7

There will be 2 tasks for the player in the prototype:

1. Getting the lungs working: The player will have to deliver glucose and oxygen to either lung, which will allow the lungs to exchange carbon dioxide and oxygen. However, the lungs will not start inflating and deflating. The player will have to get the diaphragm working by delivering glucose and oxygen to it. Once all 3 can perform aerobic respiration, the lungs will function on their own and the task is complete.
2. Get the heart working. The player will have to deliver glucose and oxygen to the heart via the coronary circulation, which will allow the heart to contract erratically. The player will have to get the heart's electrical system working by providing glucose to the SA and AV nodes and each bundle branch. Once pace-making and conduction are working, the heart will function on its own and the task is complete.

Completion of the task to get the heart working means glucose is now transported via the bloodstream to all tissues in the body, and so the player will no longer need to deliver glucose individually to complete tasks.

Since the author has no graphic design or digital artistic experience, wireframed basic shapes will be used to represent organs, vessels, cells, and characters. Colors may not be accurate. There will be no sound. Functionality overall will be basic. The author is focusing on delivering a solid framework with scientific accuracy.

Screenshots of Prototype

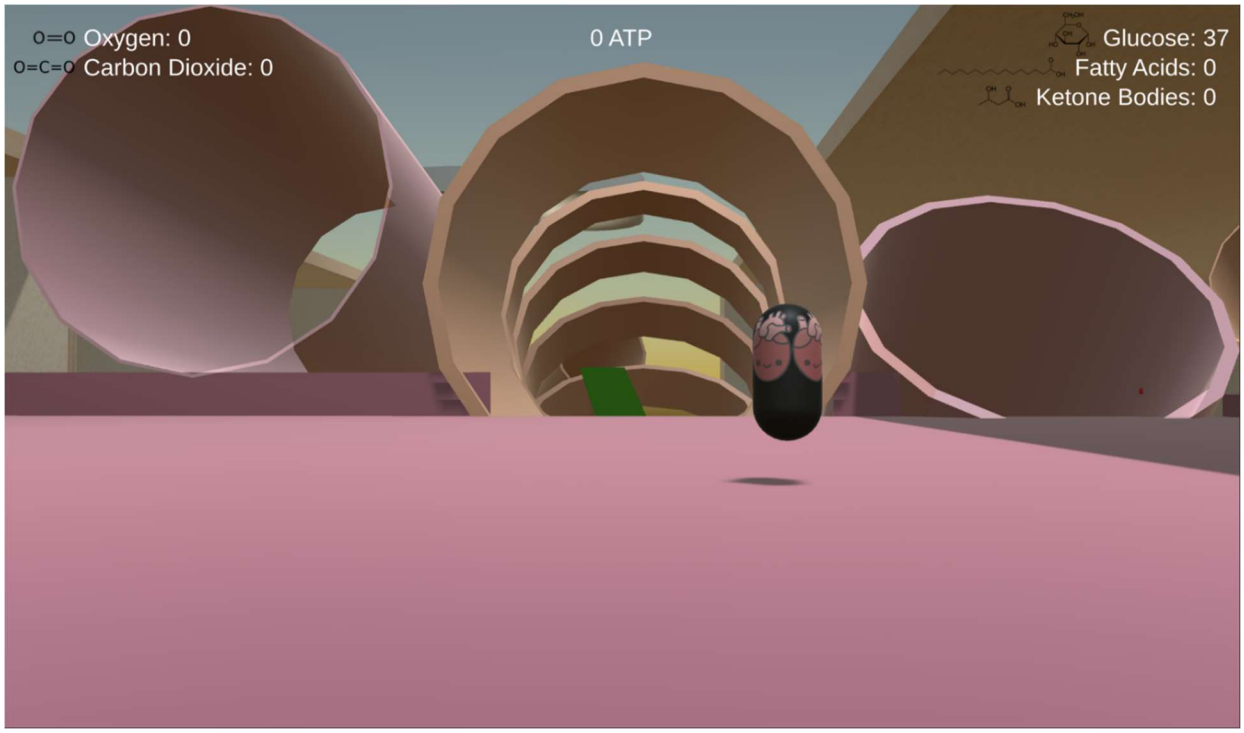

Figure 2: Prototype - Initial Player View showing tracked molecules

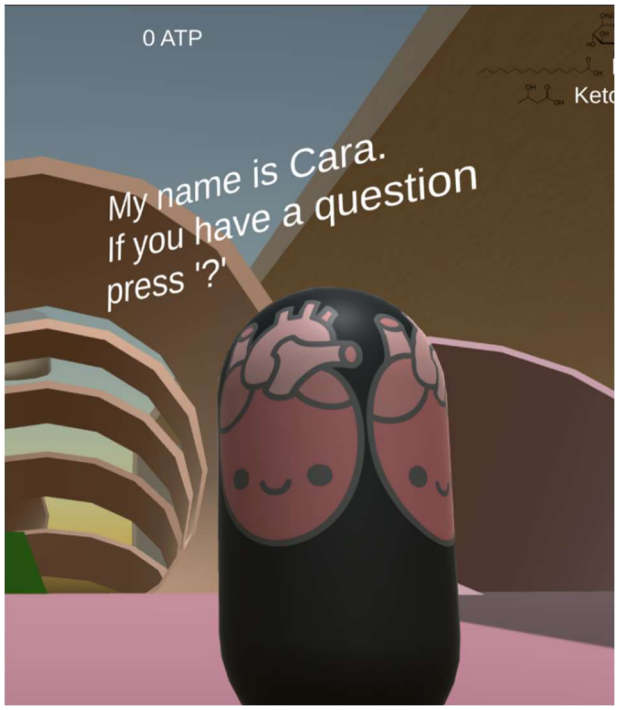

Figure 3: Prototype - Cara in Heart

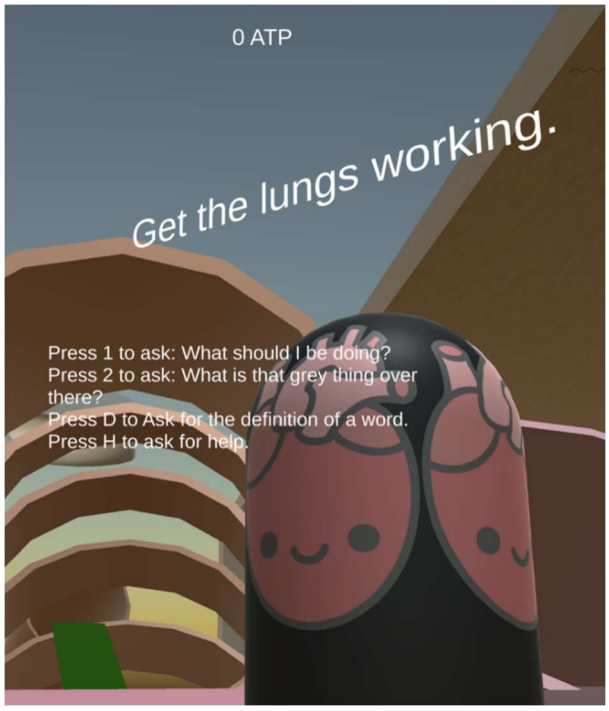

Figure 4: Prototype - Interacting with Cara

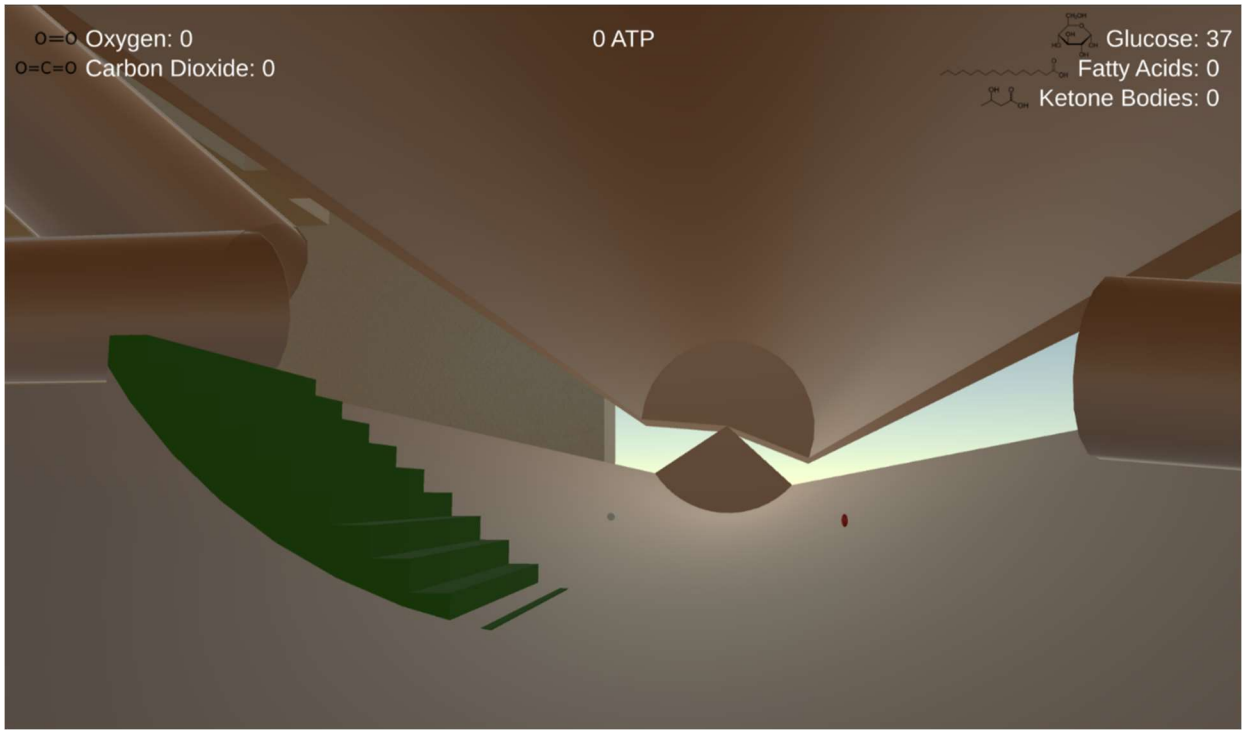

Figure 5: Prototype - Descending Aorta view

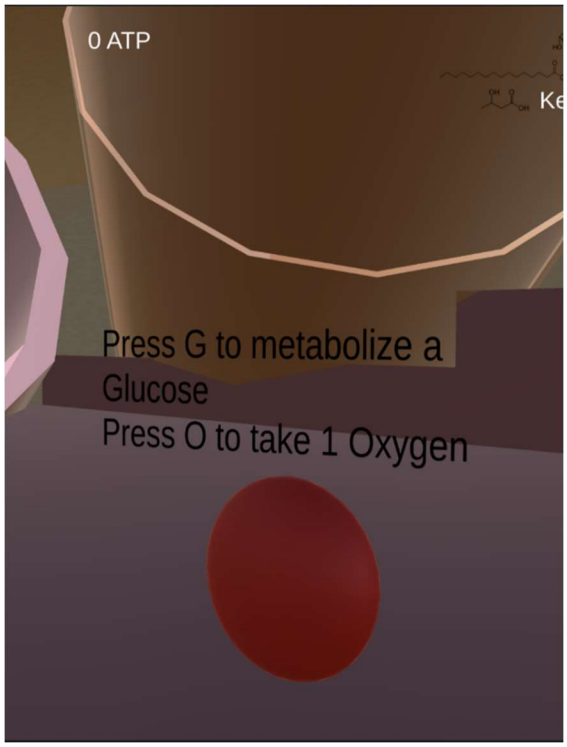

Figure 6: Prototype - Red Blood Cell interaction

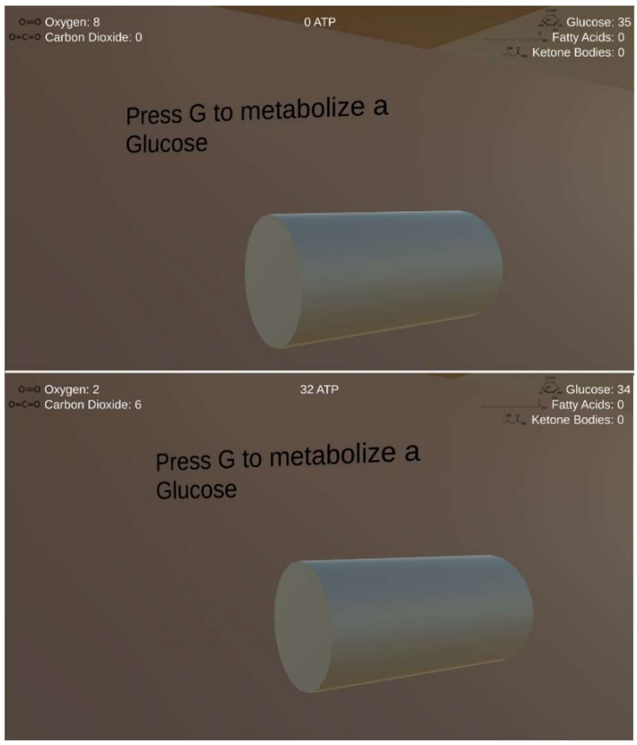

Figure 7: Prototype - Aerobic Respiration interaction

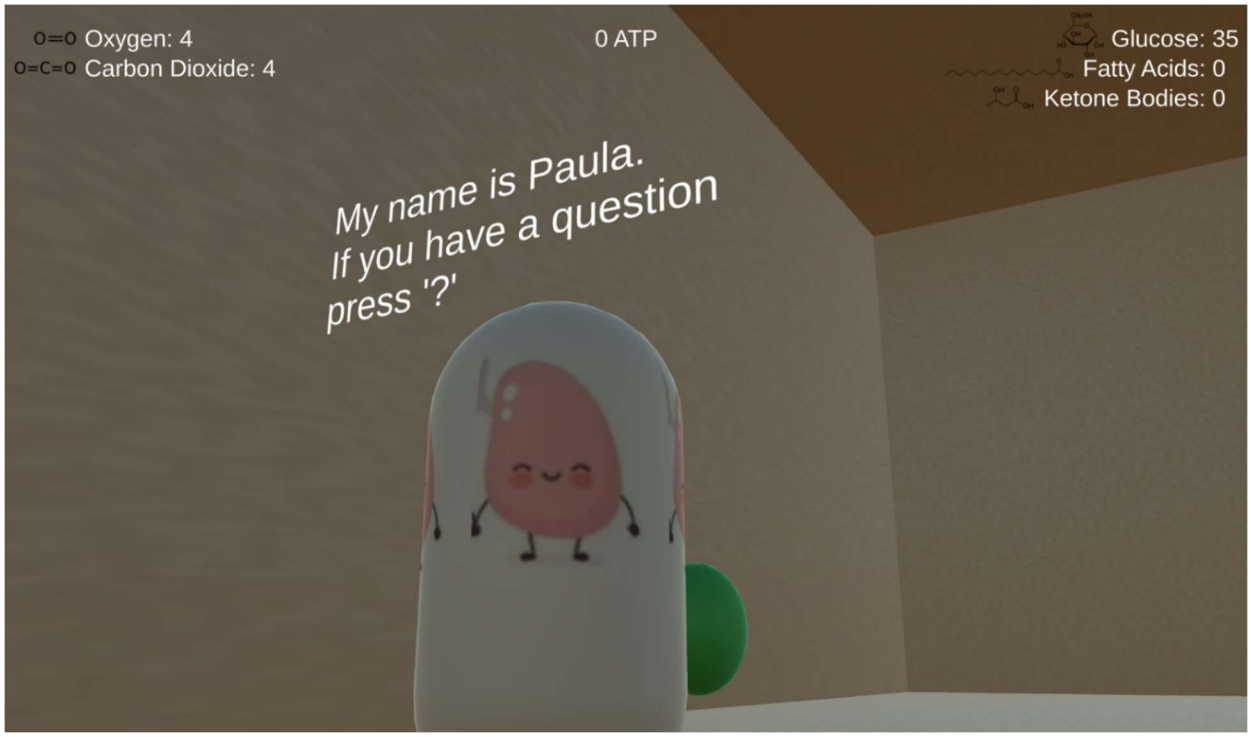

Figure 8: Prototype - Paula in Left Lung

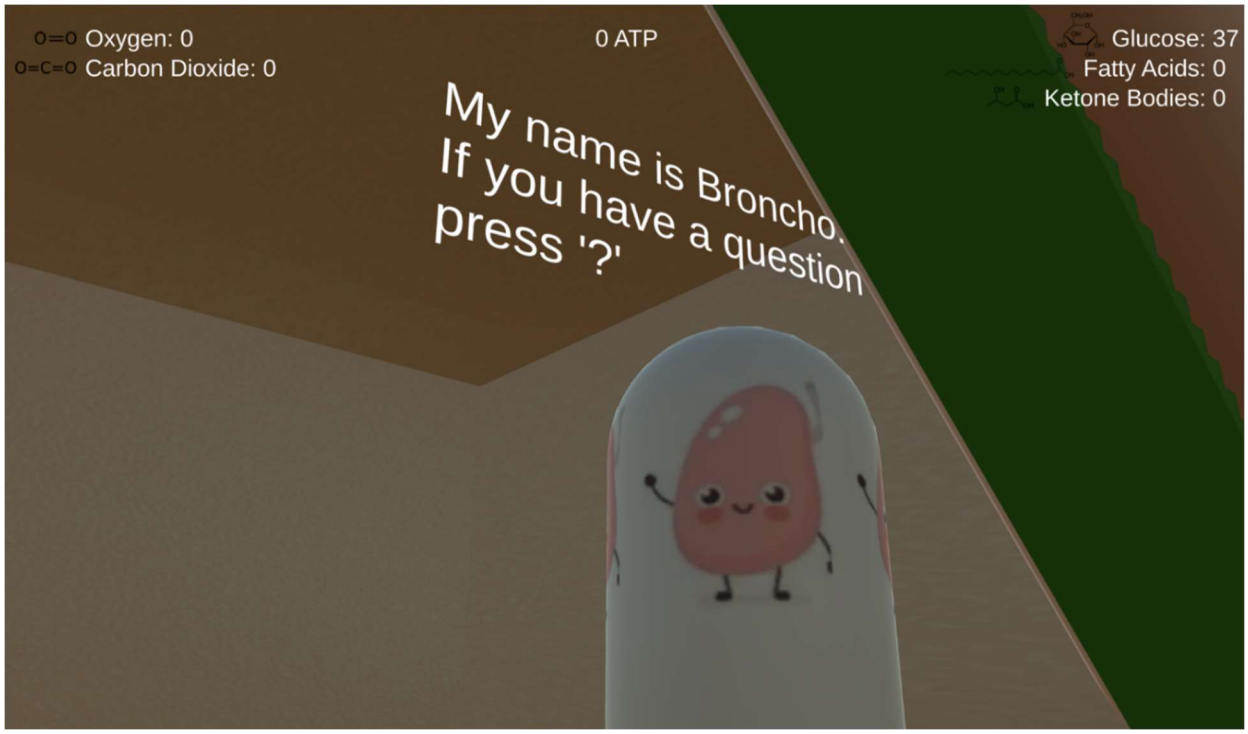

Figure 9: Prototype - Broncho in Right Lung

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APPENDIX

For Professionals

- **InsuOnline** (Google Play)

  This 3D Brazilian app by oniria is for training general practitioners or PCPs on the use of insulin to treat their patients with diabetes. It was built in 2012 using Unity, and was still in use as of 2022.[34] It has been the subject of numerous research papers.[34,35]

- **Virtual ECG**

  Created by the University of South Wales, this was an online simulation game to teach accurate electrode placement, cable attachment, and recording of 12-lead Electrocardiographs (ECGs). Figure 10 shows the game in progress. As it was built with Flash which has been terminated by Adobe, Virtual ECG was retired at the end of 2020.[36]

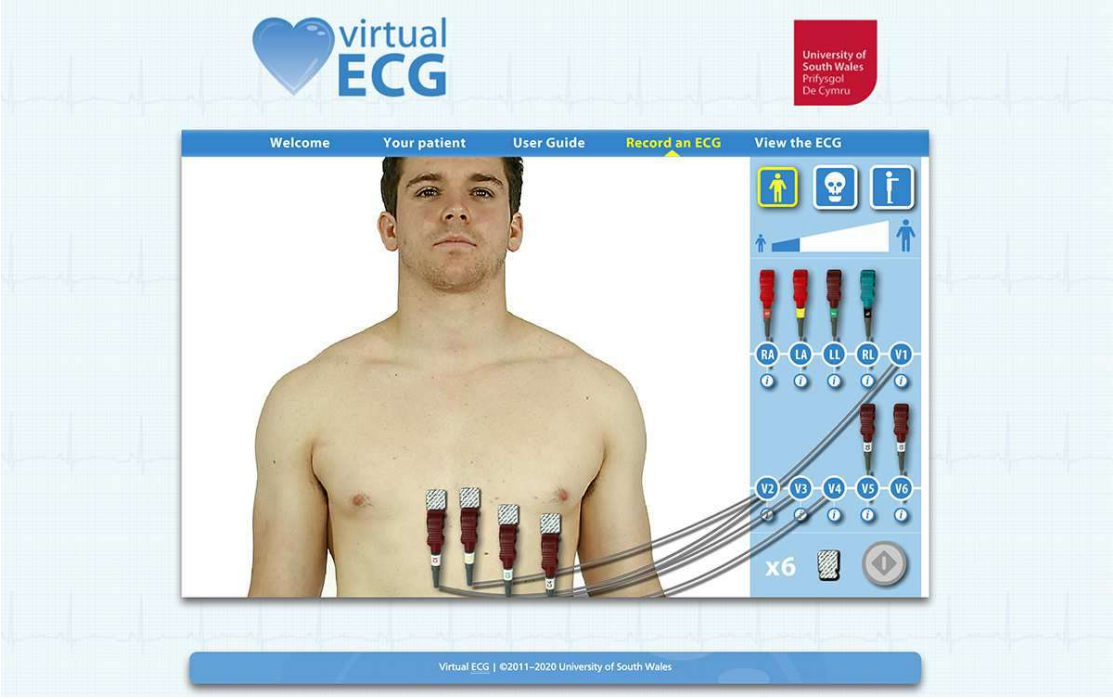

Figure 10: Demonstration Image (University of South Wales, 2020)

- **Top Derm**

  Top Derm is a mobile device game designed for Dermatologists that covers a wide

range of dermatological issues. Computer generated medically accurate imagery of patient presentations are incorporated in quick-burst challenges to enhance learning.[37]

- **Gastro Ex and Pulm Ex**

  Within the last 5 years, Level Ex developed computer driven fluid and tissue simulations that respond to player touch.[38] The company has leveraged their technology and input from specialty specific doctors to create 2 mobile games that support diagnostic skills and procedural skills - including scoping, biopsying, and injecting.[39,40] Figure 11 shows how Gastro Ex alerts the player to mistakes made that would cause tissue damage in a live patient.

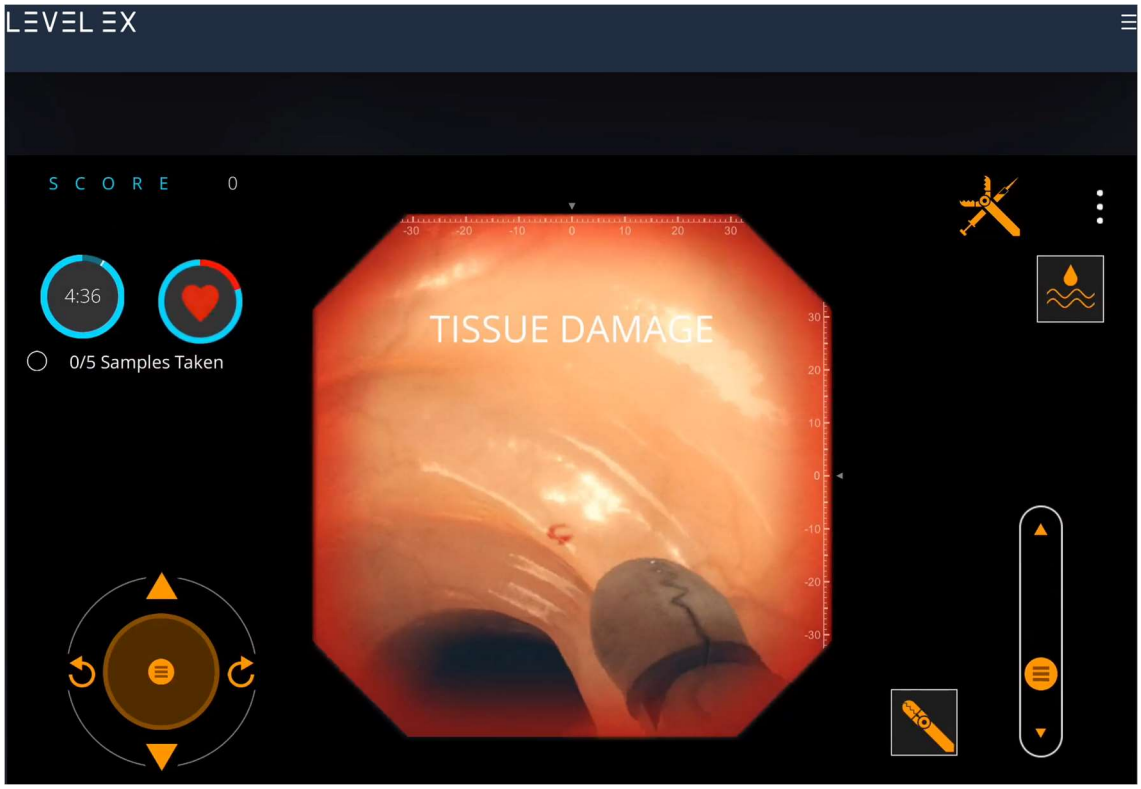

Figure 11: Game Demonstration Video (Level Ex, 2023)

- **Cardio Ex and Airway Ex**

  Both these games provide free CME via playing medical cases informed by medical experts in order to improve the player's decision-making skills and clinical reasoning.[41,42]

The games feature a simple interface with accurate anatomy. Figure 12 is from Airway Ex.

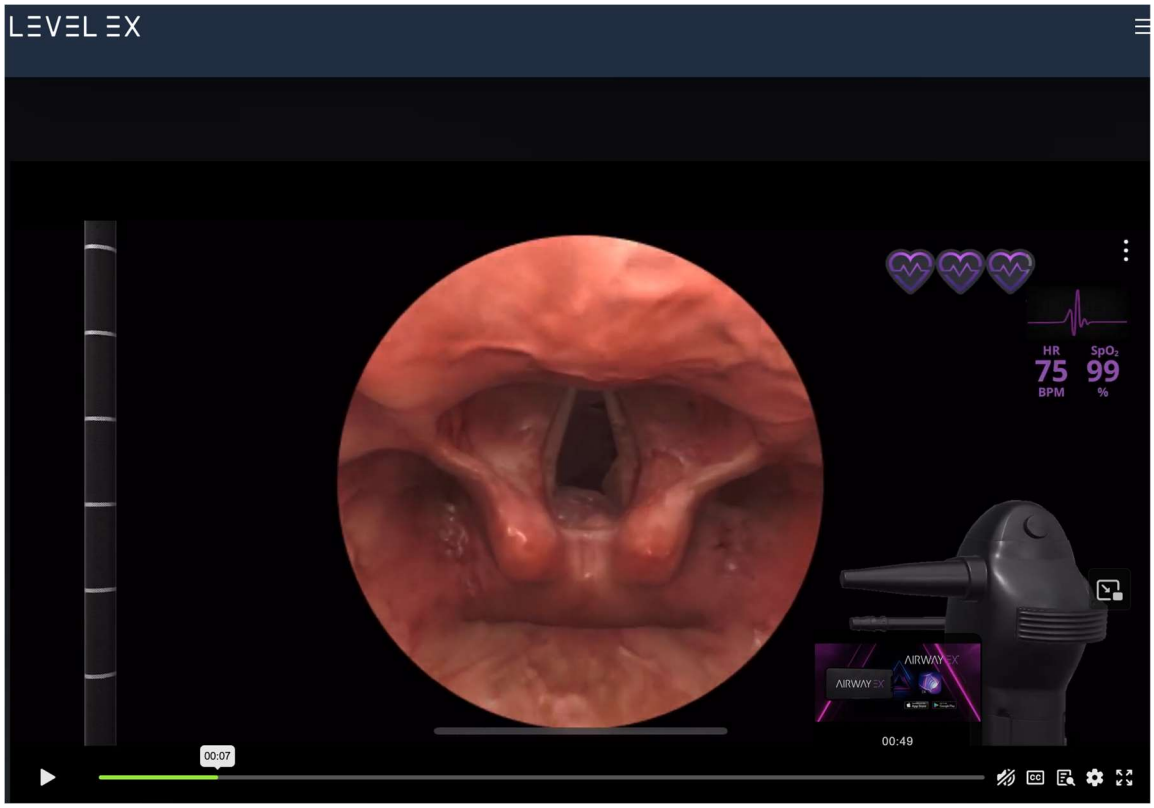

Figure 12: Game Demonstration Video (Level Ex, 2023)

- **Virtual Dental Implant Trainer**

  This computer game download was commissioned by Nobel Biocare, a maker of dental implant tools and hardware, in partnership with the Medical College of Georgia. It was made by BreakAway Games in the mid-2010s and is still in use. In the game, odontologists practice patient interviewing as shown in Figure 13, dental implant decision-making, and performing a dental implant as shown in Figure 14.[43]

Figure 13: Patient Interaction (BreakAway Games, 2015)

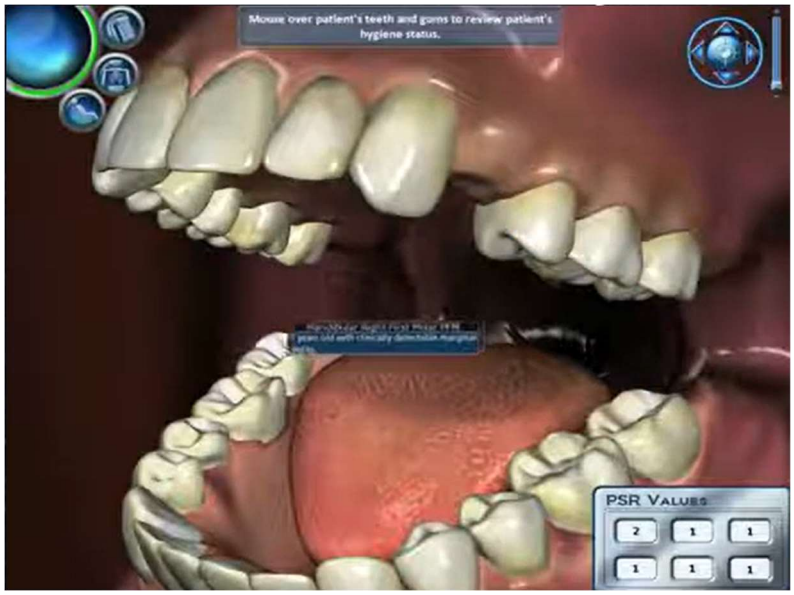

Figure 14: Implant Procedure (BreakAway Games, 2015)

- **World of Salus**

  This browser-based adventure game has important medical information for new hospital nurses embedded within it. Minigames similar to the one shown in Figure 15 maintain the player's interest while teaching, and training rooms as shown in Figure 16 test the

player's knowledge. The first to adopt this game in their training was Mercy Medical Center, Baltimore, MD in 2018.[44]

Figure 15: A minigame in World of Salus (Sam Robinson, 2018)

Figure 16: A training room in World of Salus (Sam Robinson, 2018)

For Patients

- **Re-Mission**

  This is supposedly the first serious game in the medical industry. It is a video game that helps child cancer patients learn treatment compliance. It has since been the subject of 2 randomized controlled trials (RCTs) and 1 fMRI study. The first RCT was conducted by Hopelab – which is the company that created Re-Mission. The results of that trial were published in the August 2008 edition of the journal “Pediatrics”. The fMRI study was published in “PLoS ONE” in 2012. The second RCT trial study was published in Psychol Health Med in December 2023. Results across studies indicated “positively affected levels of fatigue and quality of life of adolescents aged between 13 and 18 diagnosed with cancer”[45] and “significantly improved treatment adherence and indicators of cancer-related self-efficacy and knowledge in adolescents and young adults who were undergoing cancer therapy”[46]. Figure 17 shows the most recent player interface.

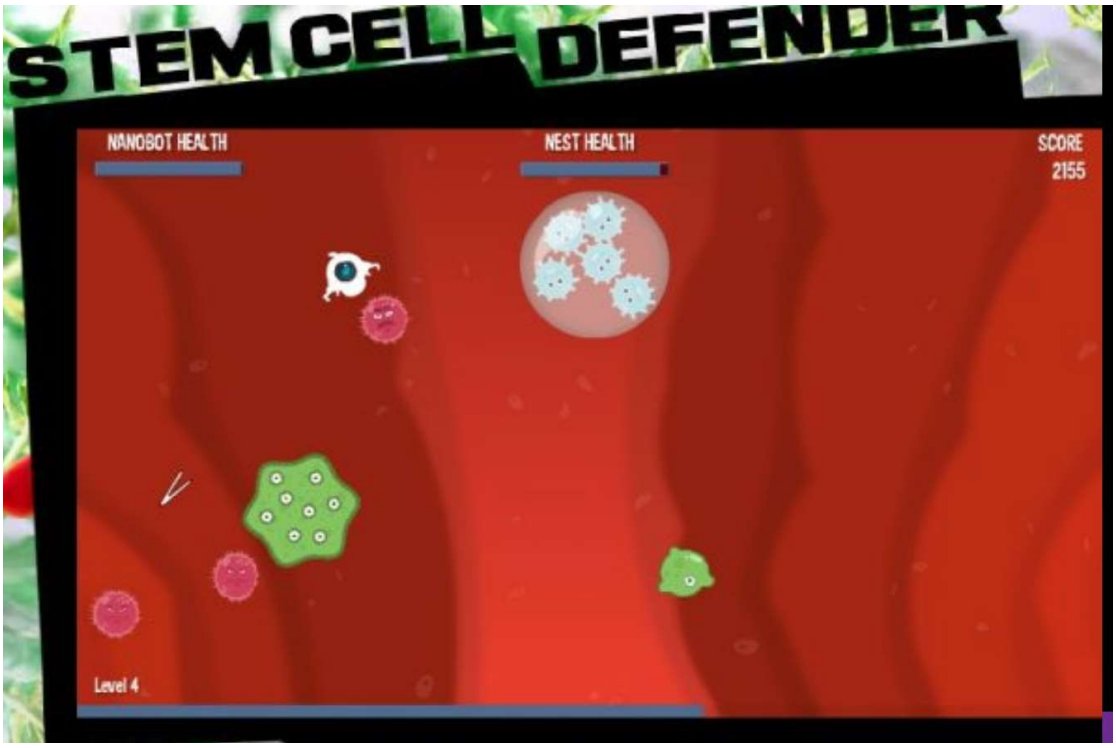

Figure 17: Stem Cell Defender level in the sequel called Re-Mission 2 (HopeLab, 2013)

- **EZ Induction**

  The point of this game is to reduce children's anxiety by turn the scary medical procedure of anesthesia into an entertaining one. It is a breathing-controlled video game run on a hospital tablet that uses an anesthesia mask as its controller. A child is taught the game in preop, and then plays the final level in the operating room which ends with the child falling asleep.[47]

- **Virtual Reality (VR) Assessment and Treatment of Combat-Related Post-Traumatic Stress Disorder (PTSD) project**

  Using VR to treat veterans with combat related PTSD has been the subject of at least three RCTs and a meta-analysis in the last 4 years. Such treatment is based on the 3MDR model (Multi-modal Motion-assisted Memory Desensitization and Reconsolidation) which is an exposure-based, virtual-reality supported intervention developed in the Netherlands that combines a treadmill with a VR experience.[48,49] When the VR scenarios are customizable to match the locale of the patient's initial experience, better results are obtained.[50]

- **Superbetter**

  After a gamification guru suffered a concussion in 2009, she created a game designed to treat her condition (as well as keeping her occupied) while she recovered. Seeing its success both for herself and her initial players, the creator renamed it "Superbetter" and developed a gamified application to help patients.[51] The current home screens for mobile devices and tablets are shown in Figure 18.

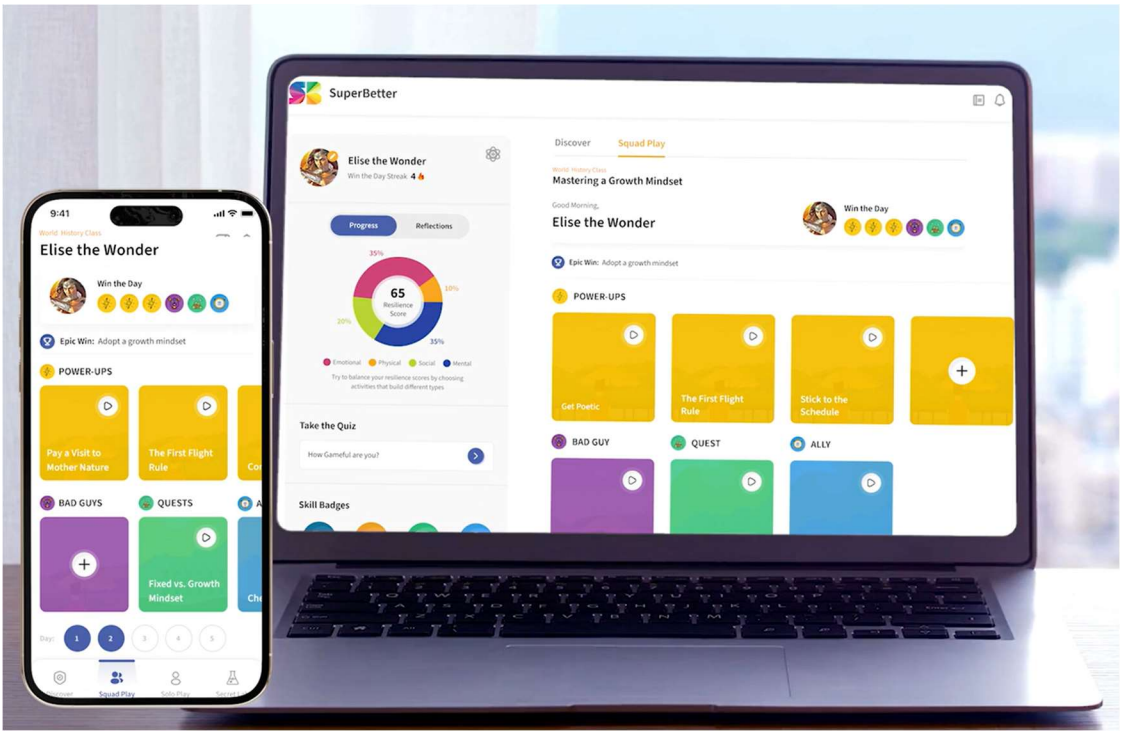

Figure 18: Player home screen (SuperBetter, 2024)

- **Various EEG-based serious games**

  In 2010 Sourina et al developed an EEG-based serious game for pain management. It used wireless EEG sensors, their own algorithm for brain state quantification, and "blobby" visualization tools that were useable by the patient at home for pain management as an alternative to traditional drug treatment.[52] By 2015 EEG-based technology was becoming more common in serious game design for patients due to the rise of affordable wireless headsets[53] and in 2017 an EEG-based serious game for ADHD management was developed[54]. Despite the various designs and research publications, EEG-based games for patients have not become widespread.

- **iSpectrum**

  This Italian built web-based game simulates a real work environment in which Autistic people practice social skills and improve social interaction abilities. It contains 3 phases for practice: working with a recruiter the game calls an employment advisor; a job

interview with the potential boss, as shown in Figure 19; and then job tasks related to the environment the player chose.[55]

Figure 19: Job Interview Screen (Imaginary Srl, 2012)

- **The Incredible Adventures of the Amazing Food Detective**

  Kaiser Permanente released this mystery game in 2007 in which players are called "junior food detectives". It focuses on teaching children how to fight obesity through solving unhealthy habit cases. It was originally released in Flash, but instead of suffering the same fate as other Flash games this game was resurrected by the emulator Ruffle and can still be played.[56]

- **Yummy Tricks**

  This game is a collection of minigames. In each one the player is taught a trick for eating correctly.[57] The game was developed in 2010 for the contest of Global eHealth Challenge held by Cure4Kids and Saint Jude Children's Research Hospital.

- **Affaire Birman** and **Timeout**

  Both of these were a French built video games by the same company. "Affaire Birman" – which means Burmese Affair in English – was for under 18-year-olds with type 1 diabetes and a multiple daily injections regimen. "Timeout" was for teenagers and adults

with type 1 diabetes who used insulin pumps. Players developed an understanding of dietary terms, physical activity routines, and insulin injection skills.[58]

For Kids

Surprisingly, the most educational video games that exist about human anatomy and other basic medical topics currently are built for children.

- **BodyQuest: Anatomy for kids** (Google Play) or **Science Adventure** (Nintendo Switch) This is an actual video game, where the player learns human anatomy while trying to stop a virus invading their best friend's body. It was previously named Human Body Adventure for Kids. Players earn tools as rewards, and as with many video games today there are mini games within the larger game. The game covers the basic processes of 5 systems: Musculoskeletal, Nervous, Digestive, Respiratory, and Circulatory.[59] The game seems fun and involved, but it is cartoon based (see Figure 20) and the 3 levels of play are aimed at children ages 5 to 10. The game does not include all the organs of the body and only includes "major" bones and muscles. Marketing images such as Figure 21 show that the insides of the body are not depicted anywhere near accurately.

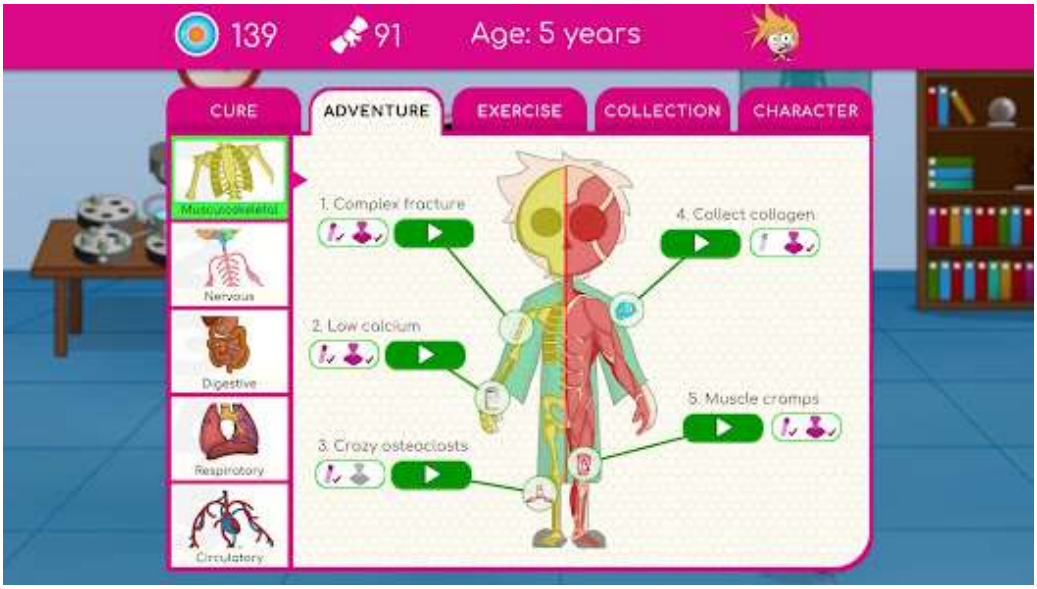

Figure 20: Game Interface (Didactoons 2023)

Figure 21: Gameplay (Didactoons 2023)

- **How does The Human Body Work?** (Google Play and Apple App Store)

  This is an interactive human body app for children to learn how all the major systems of the body work -such as scabs forming and digestion - and that lets the player trigger each - such as by feeding the human. The imagery is fairly accurate but drawn for children, and the systems are not shown integrated together; they each have their own screen (see Figure 22). While the images appear detailed, the information taught is high level concepts without many specifics.

Figure 22: Game Interface (Learny Land 2023)

For Fun (i.e. Not Serious)

- **Two Point Campus: Medical School** (PlayStation)

  This is a simulation video game – not a simulator – and not meant for medical education. It does not teach anatomy or physiology. The player is either a student doctor or student nurse in clerkship, in 1 of 3 clinic locations, and sees patients with varying range of treatment needs in one of 6 areas: Head, Psychiatry, Surgery, Injection Room, Thumping Therapy, and Recovery Ward.[60] The game requires the player, despite being a student doctor / nurse and not a medical employee, to manage large scale public medical emergencies, maintain the clinic itself or risk equipment catching fire, and occasionally deal with the ghost of a patient that did not survive. The educational value lies in potentially applying lessons learned about mass casualty coordination and clinic management.

- **Dr. Panda Hospital** (Google Play)

  This app has the player interact with 8 anthropomorphized animal patients in a hospital setting by seating them in the waiting room, placing them in a hospital room (see Figure 23), and providing cleaning or comfort items that make the patients feel better. There are 10 mini games in which the player treats one of the patients in a non-realistic way (see Figure 24) and earns a sticker when the patient leaves the hospital. A reference is not cited for this app as the author's children used it and thus the author is well versed in it.

Figure 23: One of two hospital rooms located above the waiting room (Dr. Panda, 2021)

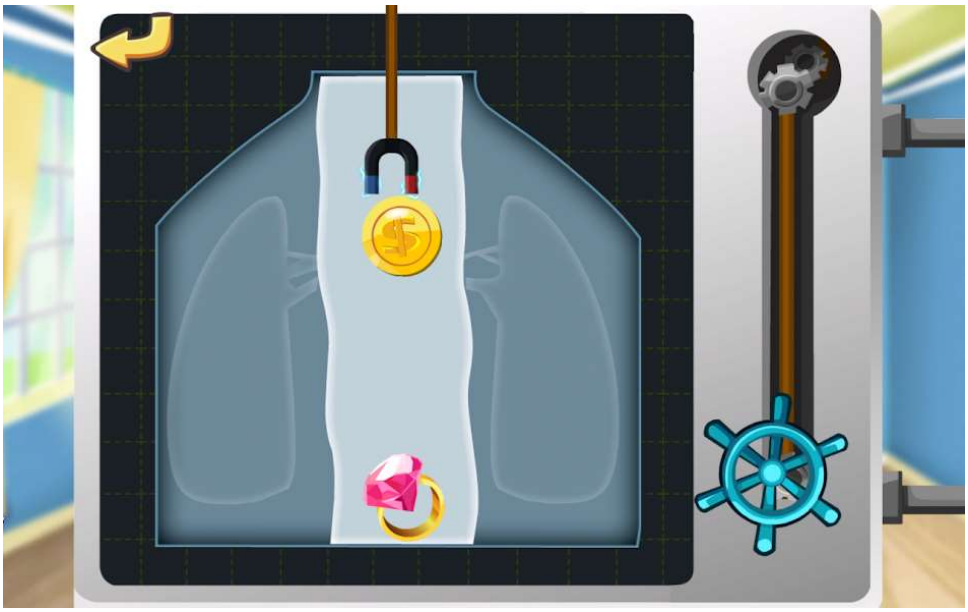

Figure 24: Minigame to retrieve a ring swallowed by the patient (Dr. Panda, 2021)

- **Many Others**

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