# The Simplest iTextbook for Cardiovascular Anatomy: A CRAM Minigame

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Abstract. This paper describes a cell phone minigame for teaching students the fundamentals of the relationship between the heart, the lungs, and the oxygenation of body tissues. It is one of the first of a series of minigames intended to teach cardiovascular physiology to undergraduate and graduate biology students. The game covers the most basic things students need to learn about the anatomy of the heart in a way that we believe will be more engaging and more effective than the use of conventional textbooks.

Keywords: intelligent textbooks anatomy education gamification.

## 1 Introduction

Human anatomy is a required course for both undergraduate and graduate students in health related disciplines, including everyone from medical technologists to premed and biology majors. Many students experience it as a difficult "gatekeeper" course that they need to pass to complete their program.<sup>1</sup>

Students face three main challenges in learning anatomy. First, the subject requires mastering a large amount of detail in order to understand each organ system. Second, many of the functional activities taking place in the body occur simultaneously. Finally, students need to build a hierarchy of ideas to cope with the increasing level of complexity.

Standard textbooks for these courses, e.g., Tortora and Nielsen [5] for lowerlevel courses or Moore et al. [4] for upper-level courses, do not help students overcome these challenges. Even publisher-produced computer-based supplementary materials, such as those found on thePoint or WileyPLUS, while interactive and multimodal, provide little additional insight because they do not help students draw connections. Proper scaffolding has the potential to help students learn anatomy faster and more successfully.

As part of the Cardiovascular and Respiratory Anatomy (CRAM) project, we are building a prototype of an intelligent textbook based on a set of minigames

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and designed for mobile platforms. The purpose of the project is to provide a new model for the teaching of anatomy that ameliorates the problems listed above. It is intended to cover the content at the level that students need, promote active learning, yet contain text that is much shorter and simpler than conventional textbooks.

The total text written for the game shown here and the next one in the series, which adds the chambers of the heart to the diagram shown below, consists of about two pages of text. Based on a survey of six textbooks, conventional textbooks spend 4–8 pages on this topic. The sentences in our text are similar in length and complexity to the slides an instructor might use, but the minigame encourages active learning rather than memorization.

## 2 Background

Gamification has the potential to increase not only time-on-task but quality of engagement. Mobile platforms are popular with students and make it easy to provide multimodal content and tactile input.

Minigames are smaller or simpler games incorporated within a larger framework. By chunking and sequencing the material, the use of minigames reduces the level of complexity for the student without reducing the amount of content to be taught. It also simplifies game authoring by limiting the amount and complexity of material in each game, much as object oriented programming does in large system design.

The system uses a logic-based approach with underlying hierarchical causal concept maps [2] that make explicit the causal, hierarchical and simultaneous relationships between biological processes. In addition, concept maps also provide an outline for the material to be covered, a benefit for authors and students.

# 3 Playing the Game



The figure to the left contains a sketch of the first minigame for teaching cardiovascular anatomy. The top section contains typical gamification features: number of points the student has earned, time remaining, number of lives remaining and a difficulty bar. The difficulty level is currently set to green, which gives the student the most time to play the game.

The main part of the screen shows the simplest possible schematic of the cardiovascular system, showing just three objects: the lungs, the heart and the body. It also shows four connecting vessels, two between the heart and the lungs and two between the heart and the body. At the bottom of the screen is a flag allowing the student to see the vessel names if interested.

The student's job is to state two features about each of these vessels, namely which direction the blood is flowing and whether the blood in that vessel is oxygenated (red) or deoxygenated (blue). In order to accomplish this, each vessel is decorated with two widgets, one for direction and one for color.

The student chooses one of the vessels and sets its color and direction. After the student sets one of these items, the remaining one is highlighted and other widgets on the screen are locked out so that the student has to finish each vessel before moving to the next. Students can choose the order of vessels that makes the most sense for them. Highlighting is used because it is more effective to guide the student non-verbally through the task where possible. We don't want to drown the student in words about the task; we want to save the words for the textbook content.

If the student gets either the color or direction wrong, the game pops up a contextualized sentence from the textbook. The second author, who has taught different types and levels of anatomy throughout her career, wrote all of the sentences and chose the ones to be used in this game. The sentences for the four vessels, clockwise from the upper left, are as follows:

- 1. Pulmonary arteries (upper left): Deoxygenated blood returns from the heart to be oxygenated in the lungs.
- 2. Pulmonary veins (upper right): Pulmonary veins carry blood, oxygenated in the lungs, back to the heart.
- 3. Systemic arteries: (lower right) Systemic arteries carry oxygenated blood from the heart to the body.
- 4. Systemic veins (lower left): Systemic veins carry deoxygenated blood from the body back to the heart.

The systemic vessels are named in line with a concept we expect the student to have learned earlier, namely that arteries usually carry oxygenated blood and veins carry deoxygenated blood. The pulmonary vessels are the exception to this rule, causing the student to have to work harder to understand the upper loop in the diagram.

The simplest version of the game defaults to being played without the names of the vessels. The goal is to get the student to learn the idea behind the double loop system before trying to memorize the terminology. Similarly, although most anatomical diagrams show the relationship of the vessels to the chambers of the heart, we are leaving that to the next game in the series.

## 4 Minigame Ecology

Once students have mastered this game, they can move to another minigame. That minigame might cover a new topic, cover the same topic using a different type of question, or level up to a more complex game on the same topic. 4 Freedman et al.

With regard to the game shown here, the next level contains a view of the heart at a deeper level of the hierarchy. It teaches students a more traditional view of the heart, showing the four chambers and ensuring that they can connect each of the vessels to the correct chamber.

Just as some games have interstitial ads, we are considering showing an interstitial piece of content from the online textbook before the next game appears.

The game is implemented in C# using the Unity game engine [6]. We are looking forward to testing this game and its successor with students in anatomy and physiology classes. In addition to learning whether the games are successful and enjoyable, we are interested in testing different game mechanics.

#### 5 Conclusion

Ken Koedinger's observation that "the student is not like me" [3] remains relevant today. Learners of human gross anatomy face many challenges. The CRAM project attempts to address these challenges. We have developed a new ITS platform which aims to improve student learning and reduce cognitive load through the use of minigames. We have implemented two prototype games, one to teach the student about atrial fibrillation and the one described here.

Implementing individual minigames has several advantages. In addition to being easier to conceptualize and implement, this approach is consistent with contemporary trends in game design. Some of the additional cost of designing multiple games for related topics can be amortized by reusing art, widgets and other design elements.

The use of minigames cannot fix the fact that anatomy is a voluminous and complex topic, but it does help organize it consistent with ways that instructors organize material such as slides, class demos and lab assignments, moving from simpler to more complex and from recognition to recall items. Although there are other games for teaching aspects of anatomy (see, e.g., [1]), we do not know of any that depend on a logic-based approach to the underlying content.

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