

Modeling in the Physiology classroom



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Abstract

Physiology and Disease is a Biology elective at IMSA that has been developed to be mostly student-centered. Some examples of student projects include modeling heart structure to reflect function and creating LED arduino monitors to measure heart rate. Students also measure their lung capacity and blood pressure to demonstrate correlation of these values with heart rate, and trace the correlation back to neuronal controls. Projects such as these integrate other disciplines such as engineering and conform to NGSS Science and Engineering standards and NGSS Cross cutting Concepts standards. Students take responsibility for their own learning and articulate better on tests.

Physiology and Disease

- Biology Elective for Juniors and Seniors
- 100 min class twice a week
- Hands-on inquiry based activities
- Student centered learning

Physiology and Disease Topics

- Major Organ Systems
- Alterations in Homeostasis
- Effects upon the body
- Treatment/Palliative measures

Cardiovascular System Structure and Dynamics

- Mapping the human heart structure
- Understanding fluid dynamics
- Mechanical and electrical systems of the heart
- Cardiac circulation

Cardiovascular Function: Blood Pressure

- Depends upon cardiac output and total peripheral resistance
- Measured using sphygmomanometer
- Activity to increase BP



Cardiovascular Function: Lung Capacity

- Activities to increase lung capacity
- Focused on vital capacity and tidal volume
- Measured resting lung capacity and post exercise lung capacity



Cardiovascular Function: Heart Rate

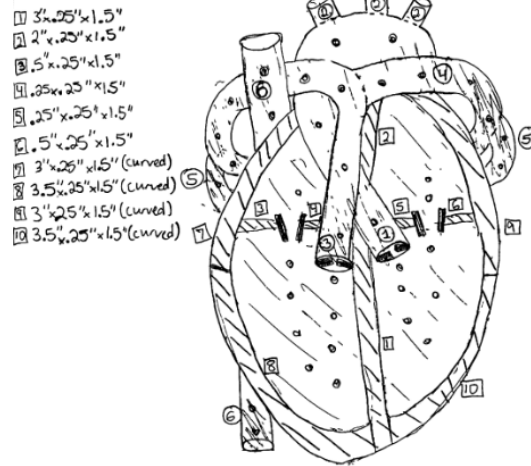
- Students performed activities to increase heart rate
- Measurements were taken before, during and after the activity was performed
- Measurements were taken using radial pulse



Modeling: Blueprint for Heart Model Construction

- ① 1.25" diameter, 6" long, 1 piece
 - ② 1.25" diameter, .5" long, 3 pieces
 - ③ .75" diameter, 7" long, 1 piece
 - ④ .75" diameter, 4" long, 1 piece
 - ⑤ .8" diameter, 1" long, 2 pieces
 - ⑥ 1" diameter, 3" long, 2 pieces
- heart base
5" x 4" x .25" at widest points
- rubber pieces x 8
.5" x .25" x .25"

Top/Front View



- ① 3/4" x .25" x 1.5"
- ② 2" x .25" x 1.5"
- ③ 5" x .25" x 1.5"
- ④ 1.25" x .25" x 1.5"
- ⑤ .25" x .25" x 1.5"
- ⑥ .5" x .25" x 1.5"
- ⑦ 3" x .25" x 1.5" (curved)
- ⑧ 3.5" x .25" x 1.5" (curved)
- ⑨ 3" x .25" x 1.5" (curved)
- ⑩ 3.5" x .25" x 1.5" (curved)

- indicates two clear plastic tubes glued together
- ▨ clear plastic tubing
- ▩ balsa wood
- lights (like Christmas lights) (about 30)
- ▬ rubber pieces indicating valves

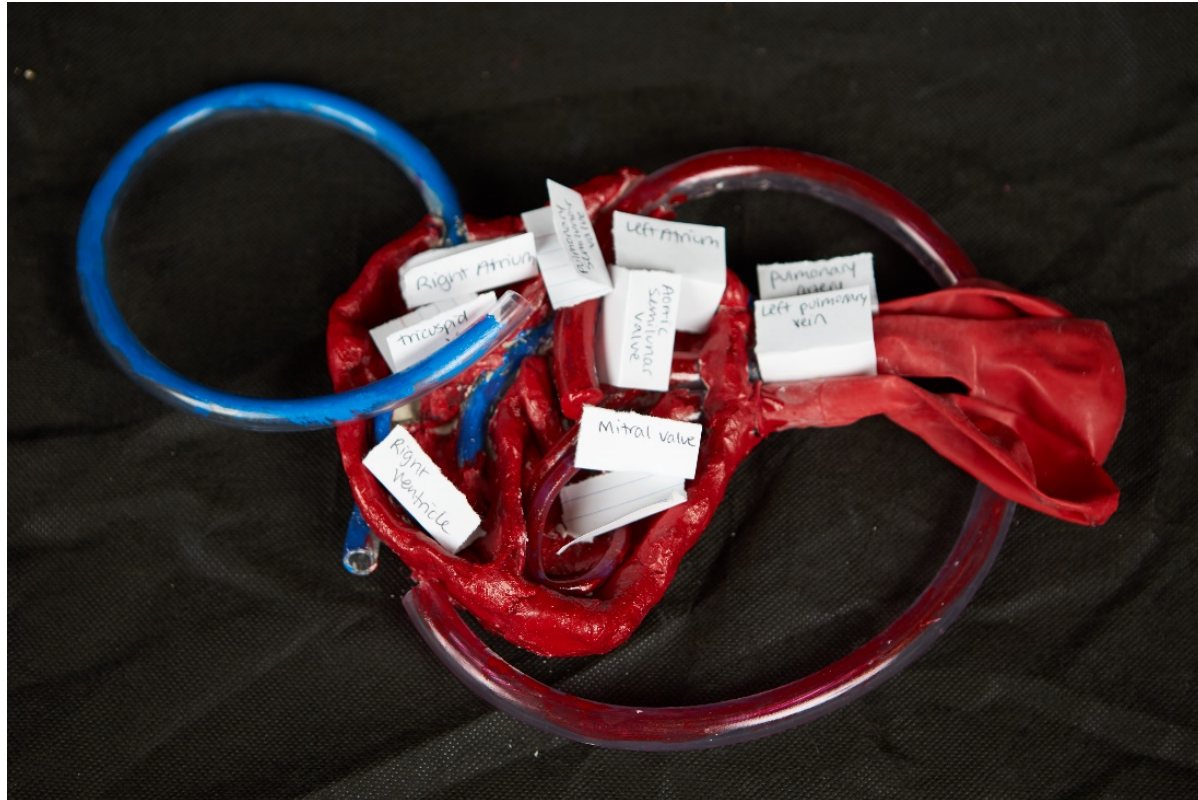
Modeling: Blueprint Report

- Student excerpt from a heart model blueprint submitted for instructor approval:
- “We will use 3” of $\frac{3}{4}$ ” diameter clear plastic tubing for both the superior vena cava and inferior vena cava, to indicate where they flow into the heart. We will use 7” of $1\frac{1}{4}$ ” diameter clear plastic tubing for the aorta because it will cover 4” of the front of the model where it connects to the left ventricle, and we will allow 3” for it to wrap behind the top of the heart.”

Modeling: Heart Model Construction

- Student heart models made of clay
- Hearts were required to have parts marked in the final prototype
- Hearts were also required to be working models circulating “blood”

Modeling: Heart Model Construction



Modeling: Heart Model Construction



Modeling: Heart Model Reflection

- Students reflected on the construction of their heart model
- Students also reflected on what they learned through this modeling procedure and integrated interdisciplinary principles into their articulation.

Modeling: Excerpt From Heart Model Reflection Report

“To replicate the human heart, my partner and I decided to “think out of the box” and create a working heart model out of wood. We decided to make a cross section of the heart that would work by flashing lights, indicating the blood circulation in the heart. When trying to make a heart model that small, carving out intricate details such as the mitral and tricuspid valve was very difficult and it actually cracked the wood. Also, we changed the fact that our pulmonary artery and aorta were made out of wood in the final model. If I was to change anything for the next time, I would definitely try to make the entire piece out of wood without the use of plastic tubing.”

Modeling: NGSS Standards

- **NGSS Science and Engineering Practices standards met by project:**
- **HS-LS1-1** (Systems of specialized cells within organisms help them perform the essential functions of life),
- **HS-LS1-2** (Develop and use a model based on evidence to illustrate the relationships between systems or between components of a system)
- **HS-LS1-3** (Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly).

Modeling: NGSS Standards

- **NGSS Crosscutting Concepts standard met by project:**
- **HS-LS1-1** (Investigating or designing new systems or structures requires a detailed examination of the properties of different materials, the structures of different components, and connections of components to reveal its function and/or solve a problem)

Application to Biophysical Quantitation

- Application to Poiseuille's equation
- Integration of resistance, flow and thickness in biological systems
- Relevance to blood pressure and heart rate controls

Extrapolating to Disease Conditions

- Using the heart model to explain various disease conditions of the heart
 - Valve stenosis
 - Heart attack
 - Cardiac arrest
 - Cardiomegaly

Case Studies

- Based on concepts studied
- Reiterate understanding and force articulation
- For example, A man, en route to the hospital emergency room by ambulance, is in fibrillation. What is his cardiac output likely to be? He arrives at the emergency entrance DOA (dead on arrival). His autopsy reveals a blockage of the posterior interventricular artery. What is the cause of death?

Student Survey Comments

- Student comments on a class survey were positive regarding heart model construction and reflection
- “Hands- on activities help us understand the material better”
- “Its so much better than listening to lectures”
- “I like working in small groups, I can speak my piece better”
- “I learn by doing, so I am doing much better in this course thanks to the heart model”

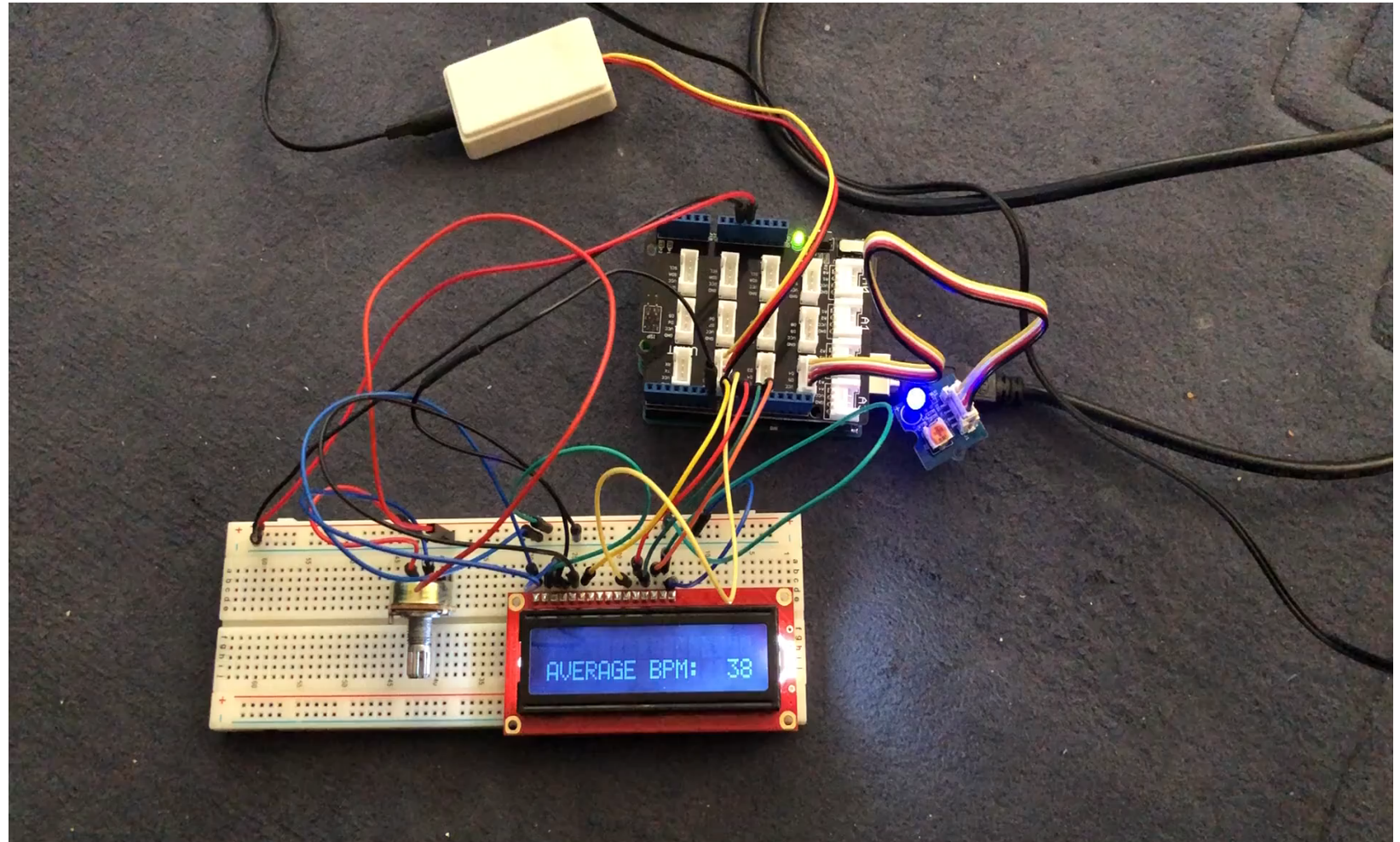
Correlation to Assessment Scores

- Initial studies show a strong correlation between student heart model building scores and unit assessment scores
- Further analysis is under way to follow up on this observation over a period of five to ten years.

STEM: Arduino heart rate monitors

- Arduino LED heart rate monitors is the newest project in the course, designed to replace measurement by radial pulse, and to help students integrate computer programming into physiology class.
- Students program breadboards to blink LEDs with each heartbeat, measured through an earclip device.

Arduino Heart Rate Monitors at Work



Next Steps

- Implement structure-function relationships in other science classrooms
- Take the heart models one step further by building bigger models that demonstrate biophysical quantitation better
- Build Arduino blood pressure monitors

Application to Other Disciplines

- Biophysics
- Mathematics
- Computational Biology
- Psychology

New Course Proposals

- Pathophysiology and Biological Systems Modeling
- Stress Management in daily life (with Wellness faculty)
- Psychology: Theory and Research (with school counselor)
- Sudden Cardiac Death Awareness Curriculum (with S.C.A.R.F.)