JSIM and CRM Synergistically Help Students to Model Breath-Dependent Drift When Deriving Tidal Volume From Pulmonary Airflow Measures

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<table>
<thead>
<tr>
<th>Time</th>
<th>Presenters</th>
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<tbody>
<tr>
<td>8:00</td>
<td><em>When the working hypothesis is wrong, what next?</em>&lt;br&gt;&amp;<em>James B. Bassingthwaigthe, MD, PhD</em></td>
<td>4616</td>
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<td>8:30</td>
<td><em>Using manipulatives to help students build conceptual frameworks in science</em>&lt;br&gt;&amp;<em>Johanna Krontiris-Litowitz, PhD</em></td>
<td>5265</td>
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<td>8:45</td>
<td><em>JSIM and CRM are synergistic for modeling breath-dependent drift when tidal volume is derived from pulmonary airflow measures</em>&lt;br&gt;&amp;<em>Nancy Pelaez, PhD</em></td>
<td>4528</td>
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<td>9:00</td>
<td><em>Demonstrating the control of ventilation via a 'simulation enhanced' physiology curriculum for undergraduates</em>&lt;br&gt;&amp;<em>Judy Harris, to be presented by Stephen Lisney, PhD</em></td>
<td>6936</td>
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<td>9:15</td>
<td>Using a human patient simulator (HPS) with 1st year medical students to facilitate learning of cardiovascular function curves</td>
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<td><strong>Dave Harris, PhD</strong></td>
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<td>9:30</td>
<td>Teaching the dynamics of cardiac-vascular coupling with a visual computational simulation</td>
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<td><strong>Bill Rose, PhD</strong></td>
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<td>9:45</td>
<td>Teaching physiology with the marble game</td>
<td>6301</td>
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<td><strong>Pete Nelson, PhD</strong></td>
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<td>10:30</td>
<td>Claude Bernard Distinguished Lectureship of the APS Teaching of Physiology Section</td>
<td>2760</td>
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<td><strong>Patangi Rangachari</strong>, McMaster Univ., Canada (T28 481.6)</td>
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The use of a science education model (CRM) to facilitate students’ use of JSIM for solving respiratory measurement problems

Nancy Pelaez                              Trevor Anderson
Purdue University                        University of KwaZulu-Natal

Educational Use of Modeling and Simulation to Foster Learning of Physiology
EB2011
Washington, DC, April 10, 2011
Our Study: The Problem

New Laboratory Course: Multidisciplinary Design of Systems and Devices for Physiology Measurements – 2007

- Design/optimize a device for functional respiratory measures
- Students discovered ‘breath dependent drift’ problems

Physiome Modeling - 2009

- JSIM – correction model from BME grad student
- *Flow is a periodic signal, hence FOURIER SERIES can be used for correction.*

CRM Model of Factors – 2010

- Undergraduate students created original correction models
- JSIM and MS Excel
The Context

Airflow measures with each inspiration and expiration

Bell Spirometer
Spirometer with a device for measuring gas volumes

Lilly-type Pneumotachometer
Spirometer with a device for measuring gas flow
MEASURED VARIABLE: AIR FLOW (L/SEC)

CALCULATED VARIABLE: VOLUME (L)

\[ V = \int F \, dt \]
JSIM model: breath-dependent drift
2007 LABCHART Drift Correction Methods

1. modification to integration of flow reduces the expired volume:

\[ V = \int F \, dt \text{ (inspiring)} \]
\[ V = \int F/k \, dt \text{ (expiring)} \]

where \( k (> 1.0) \) is a volume correction ratio

2. Manually set the value of the volume back to dead space volume in a dialog box by selecting Apply volume correction.
2008 Students explained lung volume drift

- Temperature expands air in lungs
- Expired flow > Inspired flow
- Expired Volume > Inspired Volume

They attempted to correct for ‘breath dependent drift’ of the volume trace.
TO CORRECT DRIFT,
SUBTRACT $\Delta F$ SO THAT:

$$V = \int (F + \Delta F) \, dt = 0 \text{ at each breathing cycle end.}$$

Flow is a periodic signal, hence FOURIER SERIES can be used for correction.
2010 students applied the CRM Model

Cognitive skills: Students retrieve relevant concepts when they transfer, integrate, reason analogically

Prior conceptual knowledge:
1. Science concepts: volume, inspiration, flow
2. Research concepts e.g. variable, sampling

Propositional Knowledge: Meaning of representation and its symbolism

Mode of representation: experimental equipment, graphs, equations, models

Total reasoning skills: for interpreting the ideal case, applying quantitative reasoning, using equations

Visual skills: Students make Students decode, manipulate, translate, construct, and interpret visuals

Ability to visualize and conduct the research process.

One Students’ CRM Model

Poster T41 shows more detail and examples (481.4)
2010 CRM-guided Correction Method 1

My goal is to replace the purpose that K serves in the equation with variables that can be determined in advance by theoretical calculations. Developing a theoretical equation for correction of air flow will allow for statistical analysis of experimental deviations. To begin, the original equation should still apply to inward flow of air to the lungs. The location at which the flow is measured is in equilibrium with the air. Thus,

\[ V_{in} = \int F_{in} dt \]

The air expansion that occurs within the lungs must be accounted for when finding the volume of the flow out of the lungs, which from this point on will be defined as the system. Air expansion can be represented as a percentage of \( V_{in} \). In addition to this, the equation can be made to correct positive or negative drift if that percentage is added or subtracted, respectively from 1. The new equation proposed for exhaled air:

\[ V_{out} = \int F_{out} dt \cdot (1 \pm \frac{\text{air expansion}}{V_{in}}) \]
2010 Correction Method 2

When considering correcting the data, the possible drifting factor should be condensed and subtracted from the original flow. To find the drifting factor, we determine the slope of the drift and subtract the slope from the flow.

\[ V = \int (F - k) \]
Implications

- CRM helped guide students’ independent strategies as they learned that microprocessing is used in detection devices and raw signals undergo signal processing.

- A science education model (CRM) can guide students’ original and creative problem-solving strategies.
  - Need to provide students with both problems and tools.

- CRM helped some students use JSIM
  - Good support for reasoning

- JSIM and CRM are available to test with new problems and other students.

- Future research: more in-depth study
Acknowledgments

JSIM and the NSR Physiome Project, University of Washington Seattle

Purdue’s International Biology Education Research Group (PIBERG-MAKERS)

Grad TAs and Students in BME45600/BIOL44800 Multidisciplinary Design of Systems and Devices for Physiology Measurements
AIR FLOW FOURIER SERIES

\[ F(t) = a_0/2 + \sum a_n \cos(nt) + b_n \sin(nt) \]

\[ \int_T F(t) \, dt = \int_T [a_0/2 + \sum_{n=0,1,..} a_n \cos(nt) + b_n \sin(nt)] \, dt \]

\[ \int_T F(t) \, dt = \int_T a_0/2 \, dt + \int_T \sum_{n=0,1,..} a_n \cos(nt) + b_n \sin(nt) \, dt \]

DRIFT CORRECTED FLOW: REMOVE CONSTANT TERM FROM FOURIER SERIES SO THAT FLOW INTEGRATES TO ZERO i.e. \( \int_T F(t) \, dt = 0 \)
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