Training Nurses Using Physiological Simulation

WIHIR Research Seminar

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Abstract

- A shortage of health care providers is on the horizon. As a result, nurses are taking an increasing role in the delivery of complex care. The rise in the number of advanced practice nurses, such as nurse practitioners, speaks to this. Nurse practitioners are trained to perform tasks, such as prescribing drugs, that were previously the responsibly of physicians. Moreover, the role of all nurses is changing and growing in scope. These new responsibilities require new types of training; one such type is physiological simulation. A physiological simulation involves the use of life-like physical representations of humans, human organs or other entities, on which the trainee can learn to perform complex procedures in a risk free environment. This talk will provide a survey of what is currently being done with physiological simulation in the training of nursing personnel. It will provide some conclusions as to simulation's effectiveness as a learning tool.

Outline

1. Background
   - What is physiological simulation?
2. Tour of the State-of-the-Art
3. A Systematic review
   - Research Objectives
   - Search Protocol and Criteria
   - Initial Results & Next Steps

Background:

What is Physiological Simulation?

What is Simulation?

Simulation: representation of the operation or features of one process or system through the use of another

Computer Simulation: the technique of representing the real world by a computer program

Ideally: it imitates the internal processes (not just the results) of the thing being simulated

What is Simulation Used For?

- Most research involving simulation has been done in the fields of:
  - Aviation
  - Military
  - Business
    - Simulated workflows
  - Medicine
    - Concentration on Anesthesia **and** Graduate Nursing (nursing anesthesia).

What is Physiological Simulation?

- A physiological simulation involves the use of life-like physical representations of humans, human organs or other entities.
  - An example:
    - Simulated morphine injection → physiological responses observable in a mannequin (pupil change, respiratory, heart & blood rate decrease).

Examples of Physiological Simulation

- Humans - HHPCS (Full body simulation)
- Human Organs - Heart, Kidney
- Other Entities - Bacteria, Enzyme, Virus

Advantages & Disadvantages

- Main advantages:
  - Risk free environment = ‘cheap’ experimentation
    - If you are simulating surgery and make a mistake, no one is adversely affected
    - Low / zero cost of life
    - Easy to repeat
  - Controlled setting

- Main disadvantages:
  - Cost - monetary and computationally

- Are the benefits worth the cost?

What is Physiological Simulation Used For?

- Testing / Developing Drugs
- Experimentation / Prediction
- Training / Education
  - Simulation is an increasingly useful tool in medical curriculum

Tour of the State-of-the-Art:

How is this technology currently being used?

Satellite Tobacco Mosaic:

Simulation of a Virus

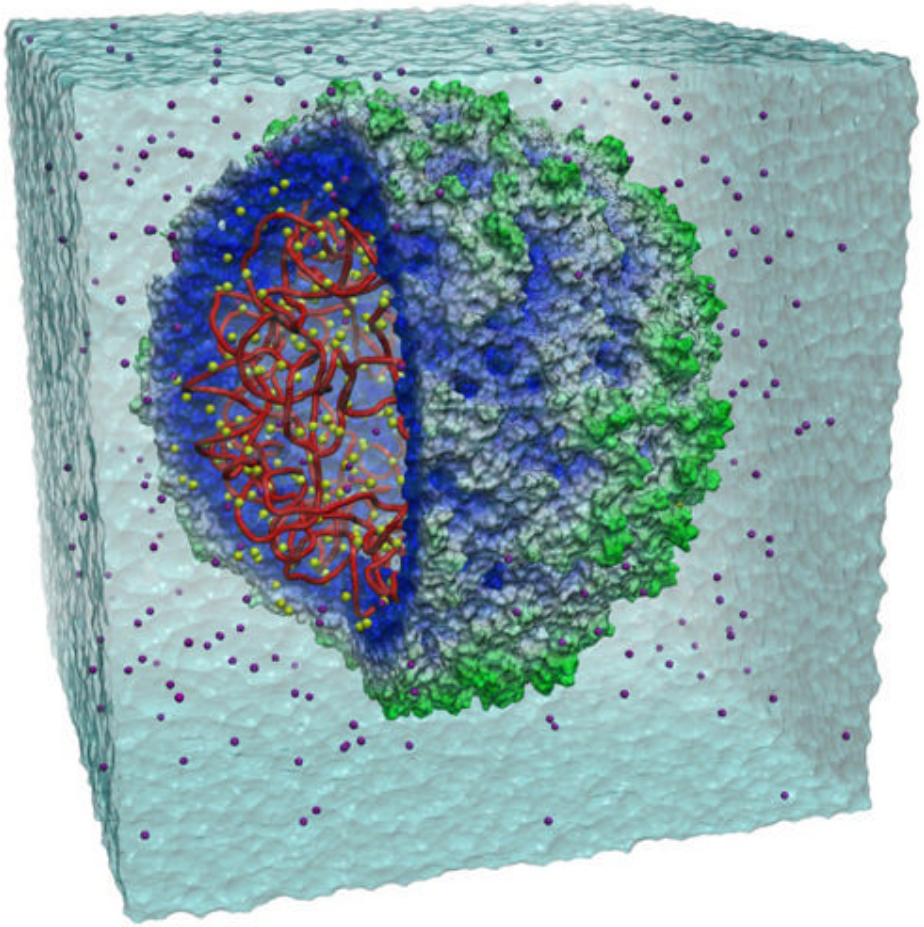
Simulation of a Virus

- Simulations of enzymes are common
- Viruses are more complicated than single molecules because they are composed of not only a shell but also of genetic material (DNA or RNA) located inside the shell
- Simulating a virus requires reverse engineering the dynamics of all atoms of the virus*

Simulation of a Virus

- The Satellite Tobacco Mosaic Virus
  - One of the simplest viruses
  - Still had ~1 million components
- “First atomic-level simulation of a functioning organism”
- Performed at University of Illinois at Urbana-Champaign by:
  - Dr. Klaus Schulten
  - Peter Freddolino (grad student)
  - Anton Arkhipov (grad student)
- Required a super-computer (SGI ALTIX)
- Took over 1 year to complete
- Published in March 2006 issue of the journal “Structure”

The Satellite Tobacco Mosaic Virus



Simulating a Virus - Why?

- *"It allows us to see how the virus assembles and disassembles,"* notes team member Peter Freddolino. *"Because assembly and disassembly are two of the key steps in the viral life cycle, understanding these events could lead to the development of drugs designed to attack them at these vulnerable points."*

(http://www.sgi.com/features/2006/june/ncsa)

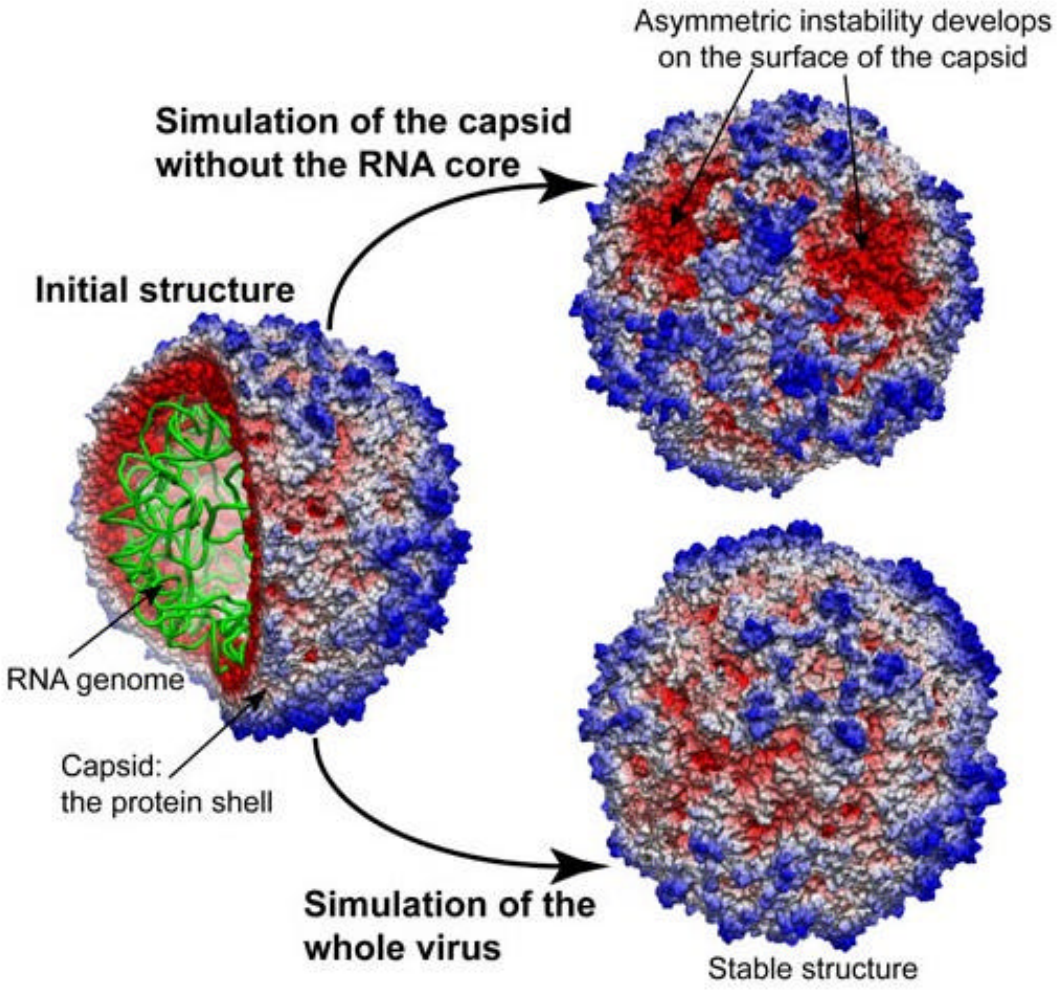
Virus Simulation - Costly…

- It took a super computer:
  - They used the National Center for Supercomputing Applications (NCSA) 1024-processor Altix cluster
  - Their simulation used ‘only’:
    - 256 processors (Intel Itanium 2)
    - 128GB of total memory
  - Took 50 days to complete (for only a 50 nanosecond simulation)

Virus Simulation - Outcomes

- Found that:
  - Virus is not symmetrical (pulsates in-and-out asymmetrically)
  - This matched findings observed in the lab
  - BUT they were able to speculate as to why:
    - Had to do with the importance of nucleic acid

Virus Simulation - Structure



TCD Simulator:

Simulation of a Part of the Body

TCD Simulator

- Transcranial Doppler (ultrasonography)

- The TDC Simulator is:

  “a comprehensive virtual reality model of the cerebral circulation”.

- A hemodynamic simulator includes:
  - All common forms of cerebrovascular disease
  - Diagnostic and Therapeutic interventions

http://www.hemodynamic.com

TCD Simulator - Demo

- The system will now be demonstrated live in the main viewing window.
- You can download this demo at: http://www.transcranial.com/tcdsim/download.html

HHPCS:

Simulation of the Entire Body

HHPCS - What are they?

- HHPCS = High-fidelity Human Patient Computer Simulators
- Realistic, whole-body patient simulators
- Introduced to the health care industry in the early 1990s for use in anesthesiology
- **Purpose:** study human performance and improve education

(Lupien & George-Gay, 2001).

HHPCS - Characteristics

- As realistic as possible:
  - Functioning cardiovascular system:
    - palpable pulses
    - measurable blood pressure
    - heart sounds
    - hemodynamic monitoring capabilities
  - Airway and functioning respiratory system:
    - self-regulating spontaneous ventilation
    - breath sounds
    - measurable exhaled gases
  - Reactive pupils
  - Production of output drainage (urine, chest tube)
  - A pharmacologic system*

(Dunn, Egan, Kozlowski, Loyd, 2004; Ravert, 2002; Euliano, Lupien, 2001;, Lampotang, 1998;)

What does an HHPCS provide?

- A controlled/risk-free environment
- Real-time feedback for the learner
  - Based on both their skills and decision making
    - For interventions on the cardiovascular and/or respiratory system
  - Learning occurs ‘in the situation’
  - Consequences are ‘real’ (physiological feedback)

What does an HHPCS look like?

Canadian Medical Simulation Special Interest Group
(http://www.anesthesia.org/canmedsim/Images/HOME_OR.JPG)

An example of an HHPCS

The Georgetown University Simulator (GUS)

GUS - an Example HHPCS

- The Georgetown University Simulator (GUS)
- GUS is a life-sized mannequin with computer-integrated physiological features
  - A good example of an HHPCS:
    - Chest raises when breathing
    - Realistic heart and lung sounds
    - Measures intake oxygen and expires carbon dioxide
    - Can be intubated, given a tracheotomy, administered drugs
    - Realistic reactions to interventions

GUS - as a Learning Tool

- Can load different patient profiles:
  - Examples:
    - a 42-year-old man with coronary artery disease
    - a 90-year-old woman with heart failure and atrial fibrillation
- Can load different events for different training scenarios
- Instructors can pause the simulation to review
- GUS is used to teach and evaluate:
  - assessment skills
  - pharmacological, physiological, and pathophysiological concepts
  - basic and advanced cardiac life support techniques

GUS - the Cost

- GUS is an HPS V6 from METI (Medical Education Technologies)
- The HPS was the only HHPCS on the market when purchased
- Cost approximately $200,000 USD
- Learn more about GUS at:
  http://snhs.georgetown.edu/facilities/gus.html

Canadian Universities:

Simulation-based Training

University of Ottawa - Patient Care Simulation Centre

- Since 1999
- Use ‘high-realism simulation’
- Typical applications:
  - Physiology and Clinical Medicine
    - In-class/lecture aide
  - Acute Care Medicine & Invasive Monitoring
    - Simulate the ICU, insertion of pulmonary artery catheters, etc
  - Airway Management

University of Ottawa - Patient Care Simulation Centre

- Typical applications (con't)):
  - Clinical Anesthesia Skills
    - Can program 'unusual scenarios' which don't arise during residency (lost of electrical power, fire)
  - Team Skills
    - Crisis Resource Management
  - Service to Industry
    - Equipment and Drug providers can observe how anesthetists interact with equipment - test modifications, etc.

- Learn more at: http://www.anesthesia.org/patsim

University of Toronto - Health Sciences Building

- Faculty of Nursing:
  - Clinical Simulation Learning Centre (SIMS Lab)
  - 18 adult, pediatric and infant simulation mannequins
  - Also has an isolation room for infectious disease training

Systematic Review:

Research Objectives / Goals

Objectives - Rationale for Study

- **Goal:** to enable health care educators to increase the effectiveness of the use of simulation to educate nurses
  - Specifically:
    - Identify simulation tools with the potential for greatest impact on the nurses' learning
- **The Ideal:** The complexity of health care is growing, so if we understand how to simulate complex things it may enable a better understanding of those things

Objectives - Research Question

- What common themes exist in the literature regarding the effectiveness of physiological simulation tools in nursing education?
  - Why physiological simulation?
    - High-quality, realistic environment for learning without risk.
  - Why nursing?
    - Shortages of healthcare providers are on the horizon → nursing responsibilities are changing: ex. nurse practitioners.
    - Gap in studies focused on nursing education.

Objectives - Dual Focus

1. Nurses critical thinking abilities and learning outcomes:
   - Critical Thinking
     - underlies independent and interdependent decision making
     - includes questioning, analysis, synthesis, interpretation, inference, inductive and deductive reasoning, intuition, application, and creativity (AACN, 1998)
   - Learning Outcomes
     - Bloom's Taxonomy of Educational Objectives for Cognitive Domain (Bloom et al, 1956)
     - Six different hierarchical cognitive levels of learning outcomes ranging from knowledge, which is the lowest and most basic level, to evaluation, which is the highest and most sophisticated outcome

Objectives - Dual Focus

2. Technical aspects:
   - What is the nature of the simulation (Meller, G. (1997)):
     - Elements of the clinical experience:
       - P1 = the patient and/or their disease process
       - P2 = the procedure, diagnostic test, or equipment being used.
       - P3 = the physician or paraprofessional
       - P4 = the professor or expert practitioner
     - Nature of each element:
       - p = passive element
       - a = active element
       - I = interactive element
   - Underlying models used:
     1. Discrete/declarative or continuous/mathematical?
     2. What is best represented and how?

Systematic Review:

Search Protocol

Framework for Systematic Review

- Alberta Research Centre for Child Health Evidence (ARCHE) based on framework provided by Cochrane Collaboration's Reviewers' Handbook (http://www.ualberta.ca/ARCHE/sysreviewsproc.html)
  1. Formulate the question
  2. Develop protocol
  3. Conduct search for studies
  4. Assess titles and abstracts for possible inclusion in the review
  5. Assess citations and full text reports of studies for inclusion in the review
  6. Assess the quality of included studies
  7. Extract data
  8. Pursue missing data and unpublished studies
  9. Analyze data
  10. Interpret results and prepare report

Search Protocol and Criteria

- Inclusion Criteria:
  - Physiological simulation for nursing education, with sufficient technical detail
- Types of studies:
  - Participants – studies which involve practicing nurses or nursing students
  - Outcome measures – included critical thinking and/or learning outcomes as measures
- Search strategy for identification of studies:
  - We will look at the journals: Medline, Ovid, ABI/Inform, Biological Abstracts, Cancerlit, Cinahl, Compendix, Eric, HealthStar, Inspec

Systematic Review:

Initial Results

Initial Results - Literature Searches

- Ovid Journals:
  - Search term “simulation and nurs$”
  - 300 initial results
  - Trimmed to 60 after review of titles & abstracts
  - Trimmed to **22** after review of the text
- PubMed:
  - Search term “simulation and (nurse or nursing)”
  - 616 initial results
  - Trimmed to 121 after review of titles & abstracts
  - Currently reviewing the full text (**~30** suitable thus far)

Initial Results - Highlights

- Vandrey,C., Whitman,K. “Simulator Training for Novice Critical Care Nurses: Preparing providers to work with critically ill patients”. AJN, American Journal of Nursing, 2001, 101, 9, 24GG-24:
  - “Computer-controlled patient simulators allow educators to present students with more complex case scenarios and allow students to hone their clinical skills as well as their knowledge”
  - Use of anesthesia patient simulators significantly improve the overall response times and performances of anesthesiologists (and residents).
  - They measured student response to training with the patient simulator - students consistently gave the highest ratings to each practice experience.

Initial Results - Highlights con't

- As of 2001: ~150 patient simulator facilities in operation worldwide
  - Many more in development
- Cost ranged from about $30,000 USD for a basic ACLS model to $180,000USD for a state-of-the-art anesthesia patient model.
- "health care professionals are beginning to understand the value of patient simulator training, which promises to be an increasingly important tool for preparing nurses and other health care providers to work with unstable, critically ill patients".

Initial Results - Highlights

- Rauen, 2004. “Simulation as a Teaching Strategy for Nursing Education and Orientation in Cardiac Surgery”:
  - Simulation allows learners to function in an environment that is as close as possible to an actual clinical situation and provides them an opportunity to "think on their feet, not in their seat.”
  - Simulation is an excellent teaching strategy for many skills but especially for critical care nursing.

Initial Results - Summary

- Common themes:
  - Simulation is an effective training tool for nurses:
    - Provides a participative and interactive learning environment
    - Stronger Immersion provides more reinforced critical learning
    - There are no common problems in to be found in the learning which occurs
  - Emergence of ‘Standardized Patients’ for assessment
  - Many articles on the increased patient safety promoted by simulation-based training
  - Problems normally stated:
    - Cost of the simulators
    - Reliability & maintenance
    - Technical support and training

Initial Results - Summary

- These initial results are intuitive.
- We are too early in the systematic review process to reach definitive conclusions but results so far seem optimistic.

Our Goal:

- To enable health care educators to increase the effectiveness of the use of simulation to educate nurses. Specifically, to identify types of simulation tools with the potential for greatest impact on the nurses' learning.

- Self-directed lifelong learning is a fact of life for any care provider, we believe simulation can help in this pursuit.

Systematic Review:

Next Steps

Next Steps

- Complete Literature Searches
- Analyze and Select Studies for Inclusion
- Interpret Results and Compose Systematic Review
  - Target completion: October 2006
- Publish systematic review in peer-reviewed publication
  - Submission of abstract for our student paper to the Information Technology and Communications in Health (ITCH) conference.

Wrap up

Acknowledgments

This is a CHPSTP Project

- CHPSTP = The CIHR Health Informatics PhD/Postdoc Strategic Training Program
- We would like to thank CHPSTP for funding and support, without which this research would not be possible.
- Mini-cohort…

Mini-Cohort

- ***William Malyk***
  - Graduate Student, David R. Cheriton School of Computer Science, University of Waterloo
  - Member of the Computer Systems Group
  - Founding leader of the WIHIR Student Group
  - Research focuses on workflow technology, health informatics and human-computer interaction
- ***Jennifer Jewer***
  - Graduate Student, Department of Management Sciences, University of Waterloo
  - Research and consulting activities have centered on the management of information systems
  - Investigating the socio-technical impacts of instituting governance mechanisms – rules, standards and accountability frameworks - in information systems
- ***H. Dominic Covvey***
  - Professor, University of Waterloo
  - Founder & Director, Waterloo Institute for Health Informatics Research
  - Mentor for this project

Thank you…

Questions?

University of Waterloo

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