Why use simulations?

• Increased comprehension of the curriculum
  • Controlled studies show increased comprehension using “games” vs. lectures or static web-based learning
  • Controlled studies also show improved outcomes measured by behavior

• Better understanding of context and holistic, system-spanning nature of lean changes

• Learning through experience - a practice field for lean change
  • Supported as goals, improved outcomes unproven

• Increase student involvement and excitement
  • Observed!

Teaching lean is hard – simulations help
Simulating Processes

- Lean works on Processes
  - So this is what we need to simulate
- Processes have
  - Material and Information they operate on
  - Times, rates, and/or capacities
  - Variations, branching flow, rework
  - Interactions
Understood Value Streams and associated lessons

- **Manufacturing**
  - Standardize path and eliminate rework and variations
  - Balance line and inventory to achieve Takt, flow and pull

- **Engineering and Product Development**
  - Eliminate *unplanned* rework and *avoidable* variation
  - Plan capacity to achieve "psuedo-Takt", flow and pull

- **Supply chains**
  - Standardization, Communication and Coordination

- **Enterprise**
  - Synchronize many inhomogeneous value streams

*All need to adapt to changing environments*
Manufacturing Sim: Build Lego Airplane

- Lego aircraft starts as a non-lean product
  - Excessive part count
  - Too many part types
  - Weak tail
- Built in a non-lean way
  - Unbalanced production system (bottlenecks, unused capacity)
  - Long supply chain
  - Excessive paperwork
  - Unclear communication
- Apply lean tools
- People issues key!

Legos come together to build aircraft
Simulating PD Organizations: Passing paper “jobs”

- Complex VS must be uncovered; characterized by rework loops, branching paths, imbalances and variations
- Capacity matching, planned iterations, simplified flow illustrated
- Process design, humans-in-loop issues also explored
Simulating Supply Chains

- Long, uncoordinated chain to supply Lego parts
- Standardize, forecast, communicate, develop relations
- Kanban, JIT, Lego inventory management

```

<table>
<thead>
<tr>
<th>Part Description</th>
<th>Deliver to:</th>
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<tbody>
<tr>
<td>Brick</td>
<td>A</td>
</tr>
<tr>
<td>Light Grey</td>
<td>1x2 3</td>
</tr>
<tr>
<td>Brown</td>
<td>1x2 2</td>
</tr>
<tr>
<td>Sand Red</td>
<td>1x2</td>
</tr>
<tr>
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<td>White</td>
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<tr>
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</tr>
<tr>
<td>Black</td>
<td>4x3</td>
</tr>
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Total number of parts shipped: 9

Fulfillment Receipt

Delivered to: A
Invoice amount: 45
Fulfilled by: 1
```
Simulating Enterprises

- Link inhomogeneous parts
- Coordination, communication, relationships key
- Silo solutions don’t work!
Simulation Toolkit

- Build Lego airplanes
- Treat Lego patients
- Process paper orders
- Complete paper “jobs”

- Modular “process boxes” specify inputs, outputs, and transformation rules at each station

- Paper “mats” are an easy and versatile way of specifying processes
Timers Represent Process Times and Capacity

- Process proceeds by the pace of an hourglass (e.g. time depends on Lego part count)
- Prevents racing, dexterity contests
- Focuses attention on the process

<table>
<thead>
<tr>
<th>Part Count</th>
<th>Hourglass</th>
<th>Sec</th>
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<tbody>
<tr>
<td>2-3</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>4-7</td>
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<td>60</td>
</tr>
<tr>
<td>8-13</td>
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<td>120</td>
</tr>
<tr>
<td>14-21</td>
<td></td>
<td>180</td>
</tr>
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</table>
Variability can affect:

- Process Quality (failure at review)
- Process Capacity (amount of work done)
- Process Time (which hourglass to use)
- Process Path (where does the work go next)
Example: Learning About Variation

- The impact of variation on processes is a good subject for simulation
  - Non-intuitive but simple

- Simple dice game for experiential lesson in effects of variation on waiting times
  - Computer simulation to rapidly show impact of process changes

\[
\text{WaitTime} = \frac{u}{1-u} \cdot \left( \frac{CV_i^2 + CV_p^2}{2} \right)
\]
Simple Dice Game

- 5-step clinic value stream
- Dice (provides variation) and a Lego patients (flowing value)
- Everyone, simultaneously,
  - Rolls die
  - Passes that many patients (or all in the waiting room, whichever is smaller) to the next step
  - Record number of patients in the waiting room
- Repeat for 20 “shifts”
Collect Data

- How many patients entered the system?
- How many came out?
- How crowded did the waiting rooms get?

- Computer simulation can be used to do many more “runs,” but credibility is established by physical simulation
Healthcare Value Streams

• New to us!
• Lean Healthcare team members and cooperating medical personnel at University of Indiana and the VA in Bedford MA provided subject matter knowledge
• Existing toolkit used to develop simulations
• Iterative development though live testing at University of Indiana and VA Bedford (first Lean Healthcare Academy)

Specialized Simulation needed to establish credibility with intended audience
“Clinic” Simulation

- Typical outpatient clinic – primary care, treatment
- Steps representative; not meant to be accurate depiction of any one process
- Same steps as simple sim, but more complex flow
- Lego people used: Different color legs, bodies and head denote condition of patients
- High variation, non-normal distributions, and strong correlations – some patients are “difficult” all the way through process
- Burdensome “chart” and “insurance record” paperwork
Simulated Clinic VSM

- **Patient Generator**: 10 pt/rd
- **Registration**: 15-120 (45)
- **Triage**: Record Patient and Chart
- **Exam**: CLEAR HEAD
- **Diag 1**
- **Diag 2**
- **Diag 3**
- **Patient Log**
- **Discharge**

50% Test Positive or Failed
Previous test Positive

BLACK or BLUE BODY

10 pt/rd
Simulated Clinic VSM

Patient Generator

10 pt/rd

Patient Registration

Record chaos
Patient Add Chart

Triage

CLEAR HEAD

Exam

Diag 1

Diag 2

Diag 3

Test Positive or Failed

Previous test Positive

BLACK or BLUE BODY

Hospital

Discharge

Patient Log

15-120 (45)

chaos

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Lean Improvements

• **Standard work – chaos reduction**
  • No change in simulation, only actions of participants

• **Elimination of unneeded steps**
  • i.e. examinations for patients with known diagnosis

• **Simplification of flow paths**
  • separate waiting rooms

• **Balancing of resources**
  • Purchase “machines,” hire “people”

• **“Local Lean”**
  • Make individual processes run better

• **Global cooperation**
  • Coordinate with other clinics, hospitals

*All done in the context of a continuous improvement process*
Other Health Care Value Streams Simulated

- **Hospital**
  - Registration, Triage, Beds, Surgery
  - Problems dominated by resource limits (beds, specialist time)
- **Supply Chain**
  - Supply of drugs, disposables, and equipment
  - Coordination issues, minor “until it isn’t”
- **Lower fidelity than clinics**
  - Less effort, but also less knowledge
- **Some local improvements modeled**
• Four Clinics
  • different capabilities and patient mixes
• Hospital
• Supply Chain
• Local improvements did not fix systematic issues!

Health Care
Enterprise Simulated

Dramatic ah-ha’s for health care professionals
Enterprise Lean Improvements

• “Electronic Records” – visual patient status

• Use of cross disciplinary IPTs
  • Visual Control team - maintain visual patient record
  • Error free process team - standard work for patient flow in clinics; visual control and triggers
  • Diagnostic team - Enterprise wide resource audit and sharing plan
  • Hospital Transport Team - Priority and transport; hospital check in/out with EMR
  • Supply team - Seamless pull system (paperless, but captures all information)
  • Hospital Team - revisit / error-proof hospital process

• Actual improvements often easy; a few local lean improvements needed to align with enterprise
Assessment

“Exercises seemed to be valuable – good active participation.”

We learned a lot

Credibility established with professionals

Ah-ha’s at both local and enterprise level