Doing System Dynamics Collaboratively w/ Social Scientists

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Diagnostic Problem Solving in an OR Crisis

THE SCENARIO
- 29-yr old female, emergency appendectomy patient
- Ventilator bellows straining
- Distant breathing sounds
- Monitor indicates blood O\textsubscript{2} levels falling dangerously low

What’s the clinical problem?
- bronchospasm
- ventilator machine problem
- allergy/anaphylaxis
- block in tube
- pneumo-thorax
- “patient light”
- kink in tube
- malignant hyperthermia
Data Sources

- Videos and transcripts
- Post-simulation debriefing summaries
- \( N = 39 \)
<table>
<thead>
<tr>
<th>Time (Min)</th>
<th>Words</th>
<th>Actions</th>
<th>Vital Signs</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00</td>
<td>Dr. Plummer: Yes. [To Helper] Just give half a cc, like point five. So just 500 mics of epinephrine going in. [The patient has] has got a history of asthma. [To the surgeon] I wouldn’t proceed at the moment. <strong>Surgeon:</strong> I know. I’m holding on.</td>
<td>Dr. Plummer: hand bagging (manually breathing for the patient) Helper gives Epi 500 mics. At Dr. Plummer’s request, Helper listens to the chest. Dr. Plummer still hand bagging. Dr. Plummer checks the depth of the endotracheal tube. Helper listens to the chest. Helper Anesthesiologist turns up anesthetic agent [Isoflurane]</td>
<td>Peak airway pressure gauge reads high HR: 93 BP: 126/81 CO2 23 O2 sat 89 (Post epinephrine)</td>
</tr>
<tr>
<td>12:30</td>
<td><strong>Dr. Plummer:</strong> [To Helper] Would you have a listen to her again? Here is my stethoscope. So the epinephrine is getting there. I’ve got some CO2, just very poor air entry.... I essentially couldn’t hear anything before when I listened. We’ll just turn up the isoflurane, try to use that too. <strong>Helper Anes:</strong> Turn it up? <strong>Dr. Plummer:</strong> Just a tiny bit. It’s currently working on 2 percent, it’s... 100 percent oxygen.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13:00</td>
<td><strong>Helper Anes:</strong> Did you give any inhalers? <strong>Surgeon:</strong> Is she getting any better? <strong>Dr. Plummer:</strong> Not at the moment. I’ve given her four squirts down the tube [addressing Helper’s last question]. It’s definitely getting CO2 (returning). Initially Dan listened and said it wasn’t down the right main bronchus. It’s at 22 centimeters [the depth of the endotracheal tube]. I’m happy with that. <strong>Helper Anes:</strong> I can’t hear any breath sounds here. <strong>Dr. Plummer:</strong> Yes, she’s got very… she is very hard to bag. I’m getting high PIPs [inspiratory pressures]. <strong>Surgeon:</strong> Do you think it’s a bronchospasm? <strong>Dr. Plummer:</strong> I think it is bronchospasm at the moment. She’s just starting to turn the corner.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bronchospasm</td>
<td></td>
<td></td>
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<tr>
<td>---</td>
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<td>---</td>
</tr>
<tr>
<td>1.</td>
<td>O</td>
<td>1</td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>&lt; Relaxation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>1</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tube placement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>1</td>
<td></td>
<td>O</td>
</tr>
<tr>
<td></td>
<td>&lt; Anesthesia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ventilator prob.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>O</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&lt; Blood volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>O</td>
<td>O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Collapsed lung</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>O</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blocked tube</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>1</td>
<td></td>
<td>O</td>
</tr>
<tr>
<td>O² Saturation</td>
<td>97</td>
<td>97</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>92</td>
<td>93</td>
<td>92</td>
</tr>
<tr>
<td>Time</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>22</td>
<td>24</td>
</tr>
</tbody>
</table>
## Problem Solving Modes in Source Data

### Failure Modes

<table>
<thead>
<tr>
<th>Variable</th>
<th>Stalled</th>
<th>Fixated</th>
<th>Vagabonds</th>
<th>Adaptive</th>
<th>Test of difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>2 (5%)</td>
<td>11 (28%)</td>
<td>17 (44%)</td>
<td>9 (23%)</td>
<td>–</td>
</tr>
<tr>
<td>Subjects who resolved the airway problem</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>ChiSq(3) = 28.4***</td>
</tr>
<tr>
<td>Different Treatment Steps for a Diagnosis</td>
<td>1.0 (0.0)</td>
<td>2.0 (1.1)</td>
<td>1.5 (0.5)</td>
<td>3.6 (0.7)</td>
<td>F(3,35) = 17.0***</td>
</tr>
<tr>
<td>Considerations of Favorite Diagnosis</td>
<td>3.0 (0.0)</td>
<td>10.0 (5.7)</td>
<td>5.4 (2.3)</td>
<td>5.9 (2.2)</td>
<td>F(3,35) = 5.0**</td>
</tr>
<tr>
<td>Number of Different Diagnoses Considered</td>
<td>1.5 (0.7)</td>
<td>3.8 (1.7)</td>
<td>6.1 (1.3)</td>
<td>5.0 (1.4)</td>
<td>F(3,35) = 9.1***</td>
</tr>
</tbody>
</table>

Note -- means are given with standard deviation in parentheses. ** p < .01; *** p < .001
Action-Oriented Problem Solving

1. Taking Action
2. Time Needed to Take Steps
3. Cultivating
4. Time Needed to Cultivate
5. Actions Steps Completed
6. Accuracy of Leading Diagnosis
7. Plausibility of Alternative Diagnosis
8. Cues Available
9. Plausibility from New Cues
10. Updating
11. Time Needed to Update
12. Change Trigger
13. Effect of Current Plausibility on Cultivating
14. Effect of Plausibility on Cue Interpretation
15. Weight on Cues
16. Self-Fulfilling Interpretation Loop
The Collaboration Begins
An Early Model of the Doctors’ Problem
An Early Model of the Doctors’ Problem
An Early Model of the Doctors’ Problem
An Early Model of the Doctors’ Problem
An Early Model of the Doctors’ Problem

Current Diagnosis

Understanding of Current Diagnosis

Reloading Current Diagnosis

Truth for Max Tx Effectiveness

Accuracy of Diagnosis

Max Cause Removal

Problem Cause

Removing Cause

Min Time to Fix

Changing Diagnosis

Change Threshold

Change Trigger

Change Pressure

Effect of Trend on Pressure

Depth for Max Tx Effectiveness

Tx Effectiveness

Returns to Exploitation

ReSetting Diagnosis

Diagnosis Increment

MedDiag3 1/8/07
A Few Weeks Later

From Confidence, Error, and Ingenuity, JWR and JBM, Jan 2007
Repeating Three Behavior Modes

... by changing three parameters

<table>
<thead>
<tr>
<th>Units</th>
<th>Confidence in New Diagnosis</th>
<th>Propensity to Treat and Study</th>
<th>Strength of Confidence Effect</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixating</td>
<td>0.75</td>
<td>1</td>
<td>1</td>
<td>Overconfident in proposed diagnosis</td>
</tr>
<tr>
<td>Diagnostic Vagabonding</td>
<td>0.5</td>
<td>0.3</td>
<td>3</td>
<td>Cautious to take action</td>
</tr>
<tr>
<td>Adapting</td>
<td>0.5</td>
<td>1</td>
<td>1</td>
<td>Willing to question and to act</td>
</tr>
</tbody>
</table>
The Collaboration Continues
• **Acting:** Following the steps of a diagnostic algorithm, making cues available.
Interpreting and Updating: Making sense of new information to update beliefs.

Forms a reinforcing loop, often implicated in studies of fixation
Model
Data
Theory
Cultivating Alternatives: Searching for and contemplating the merits of alternatives.
Action-Oriented Problem Solving

- **Actions Steps Completed**
- **Cues Available**
- **Plausibility from New Cues**
- **Updating**
- **Plausibility of Leading Diagnosis**
- **Time Needed to Update**
- **Change Trigger**
- **Effect of Current Plausibility on Cultivating**
- **Time Needed to Take Steps**
- **Cultivating**
- **Taking Action**
- **Accuracy of Leading Diagnosis**
- **Effect of Plausibility on Cue Interpretation**
- **Self-Fulfilling Interpretation Loop**

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Effect of Plausibility on Cue Interpretation

Weight on Cues = (1 – Plaus of Leading Dx)
Adaptive Problem Solving: Finding and Accepting the Correct Diagnosis

Plausibility

Effect of Plausibility on Cue Interpretation

Plausibility of Leading Diagnosis
Fixation: Strong Effect of Plausibility

Plausibility

Time (Minute)

Diagnosis 1:

Diagnosis 2:

Effect of Plausibility on Cue Interpretation

Dimensionless

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Vagabonding: Weak Effect of Plausibility

Effect of Plausibility on Cue Interpretation

Plausibility of Leading Diagnosis

Correct Diagnosis

Time (Minute)

Dimensionless

0 1 25
Action-Oriented Problem Solving

- Actions Steps Completed
  - Taking Action
  - Time Needed to Take Steps
- Plausibility of Alternative Diagnosis
  - Cultivating
  - Time Needed to Cultivate
- Cues Available
- Accuracy of Leading Diagnosis
- Plausibility from New Cues
- Weight on Cues on Cue Interpretation
- Effect of Plausibility on Cue Interpretation
- Effect of Current Plausibility on Cultivating
- Plausibility of Leading Diagnosis
  - Updating
  - Time Needed to Update
- Change Trigger

Self-Fulfilling Interpretation Loop

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Sensitivity to the Pace of Acting

Plausibility of Leading Diagnosis

Time (Minute)

Dimensionless

Faster Acting

0 0 25

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Threshold Values of the Pace of Taking Action

Time Needed to Cultivate = 2

Time Needed to Cultivate = 4

Time Needed to Cultivate = 6

Time Needed to Cultivate = 8
Action-oriented problem solving: Boundary conditions

1. **Action-based inquiry** – action is required to generate new cues; cues are used to update explanations and action strategies;

2. **Temporal dynamism** -- the world keeps changing as explanations or strategies for action are devised and revised;

3. **Action-endogeneity** -- actions change the problem solving environment.
Dynamic problem solving comprises acting, interpreting, and cultivating alternatives.

The outputs of sensemaking and choice are inputs to each other.

Self-fulfilling interpretation can be beneficial.

- “OVER-Confidence” can lead to failure.
- “UNDER-Confidence” can also lead to failure.

The pace of acting, the pace of cultivating, and the strength of the interpretation effect interact in a compensatory manner.

Each component process offers a possible remedy to “out-of-balance” problem solving.
Small models are beautiful!

But, they are not easy.

1. Grounded theory and data
2. Collaboration
3. Communication
Grounded Theory and Data

Start with real, thick descriptive data

Iterate among model, data, and theory

Ask questions of the data

Use the model as a boundary object
Collaboration

• Choose awesome collaborators!
  • Mutual respect
  • Moderate boundaries
  • Skillful at discourse

• Choose a problem you all care about - and define it dynamically

• Allow for plenty of iterations to develop shared understanding

• Keep the model, the data, and the theory in the process

• Learn to collaborate with reviewers
Collaboration

• Balance the rigor of conceptualizing and formulating versus playfulness and curiosity

• Love your model enough to squeeze out the wisdom, but not so much that you can’t let go

WE NEED TO GET GOOD AT THIS:

• Develop skills to co-create with others
• Don’t impose a modeler’s view of structure
• Humbly admit you’re not the modeler
• Access your ignorance
Communication

• Create models of the appropriate size
• Connect with theory and practice for your constituents
• Build intuition and understanding
  • Shift the focus away from the model and towards the lessons
• Choose your audience wisely

WE NEED TO GET GOOD AT ALL THIS!

Adapted from Repenning (2003) Selling system dynamics to (other) social scientists, SDR, 19:4
Thank You !!