Introduction to Systems Thinking

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Our systems thinking module is...

Broadly applicable

New for students

Amenable to short treatments

Fun
Motivation

Abundant clean water

Renewable clean energy

Safe roads and bridges

Protection from disasters

Access to modern healthcare

Sustainable ag & manufacturing

NASA

WHO

GE
What is systems thinking?

Exercise

Two people take 2 hours to dig a hole 5 feet deep.

How deep would the hole be if 4 people dug for 6 hours?
What is systems thinking?

Correct answer

- 2 people
- 4 people
- 48 people

Hole depth (ft) vs. Time (h) graph:
- 2 people: Blue line
- 4 people: Green line
- 48 people: Red line

Time (h) scale:
- 0
- 2
- 4
- 6

Hole depth (ft) scale:
- 0
- 10
- 20
- 30

Correct answer point:
- 2 people: (2, 6)
- 4 people: (6, 30)
- 48 people: (6, 30)
What is systems thinking?

More realistic answers?

1. Deeper soil layers might be harder to excavate.
2. The job might not have the proper permit.
3. The people might refuse to work for 6 hours straight.
4. A lack of ladders or shovels or space might prevent progress.
5. They might hit bedrock or the water table (or gold or oil or ancient relics or an underground cable or vicious carnivores).
6. The maximum depth might have been specified as 5 feet.
7. Greenpeace or the neighbors might protest.
8. The workers might not have proper training in ABET outcome d.
9. The work might be scheduled for a religious holiday.
10. The original workers might have had excavating equipment.
11. Et cetera
What is systems thinking?

- Solving complex, dynamic, ill-defined problems
- Designing systems as well as components
- Communicating with the wider community
- Working with people from other disciplines and cultures
- Meeting social, ethical, and environmental responsibilities while addressing challenges from engineering and science.
- Managing projects and operating within business and political environments

See also http://www.public.iastate.edu/~rehmann/STpaper.pdf
Tools of systems thinking

- Rich picture
- Causal loop diagrams
- Behavior-over-time graphs
Example of the tools: rich picture

Theater operations

Identify connections

Example from MindTools
Example of the tools: causal loop diagram

$s =$ same, $o =$ opposite

Explain relationships
Example of the tools: behavior-over-time graph

Sketch trends

Nonlinear, feedback

Investment

Good reviews

Ticket sales

Unoccupied seats

Total number of seats

Profit

Time
(Video)
http://www.youtube.com/watch?v=J030bU51ZEM
Rich pictures

What’s going on here?

Pictures
Connections
Facts
Subjective information
Conflict
Structure
Process

Draw an unsuccessful engineering student

Vanasupa et al. (2008)
Exercise: Solve ISU’s housing problem

ISU is **1200 beds short**.

Draw a rich picture showing the social, political, economic, environmental, cultural, ethical, and other issues related to this problem.

- How did you work together to draw the rich picture?
- How will that interaction benefit students?
Exercise: Evaluate these rich pictures

Did they think broadly? Do the connections make sense? Is there feedback?

<table>
<thead>
<tr>
<th>Technical content</th>
<th>0 = not addressed</th>
<th>1 = minimally addressed</th>
<th>2 = somewhat addressed</th>
<th>3 = adequately addressed</th>
<th>4 = well addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Problem description</strong></td>
<td>Students do not describe the problem at all.</td>
<td>Students give a cursory description of the problem.</td>
<td>Students describe the problem briefly but do not explain how it involves 5 of the 7 areas.</td>
<td>Students describe the problem and motivate the systems approach by explaining how it involves 5 of the 7 areas.</td>
<td>Students explain why the problem is important and integrate their discussion of the 5 of 7 areas well into the rest of the talk.</td>
</tr>
<tr>
<td><strong>Key variables</strong></td>
<td>Students identify no key variable.</td>
<td>Students allude to key variables. Key variables are implied.</td>
<td>Students identify several variables involved in the problem but do not identify the key variable.</td>
<td>Students identify a key variable but other possibilities seem more fitting.</td>
<td>Students identify a key variable and explain concisely how it captures the essence of the problem.</td>
</tr>
<tr>
<td><strong>Rich pictures to show connections</strong></td>
<td>Students present no rich picture.</td>
<td>The rich picture is carelessly drawn, and the connections show little thought.</td>
<td>The rich picture shows few elements, and connections are merely lines drawn to the key element.</td>
<td>The rich picture is drawn well. It includes several elements from 5 of the 7 areas; connections show considerable thought.</td>
<td>The picture is attractive and interesting; the connections drawn suggest careful thought and contemplation based on research.</td>
</tr>
<tr>
<td><strong>Causal-loop diagrams to show relationships</strong></td>
<td>Students present no causal-loop diagrams.</td>
<td>Students present only one or two CLDs and they are not connected in any way. Relationships are based solely on intuition or feeling.</td>
<td>Students present several unconnected CLDs. The relationships are reasonable but not supported convincingly.</td>
<td>Students present a CLD that connects most of the elements in the rich picture and give plausible arguments for the relationships.</td>
<td>Students present a CLD that connects all of the elements in the rich picture and argue convincingly for the relationships using their research.</td>
</tr>
<tr>
<td><strong>Graphs to show behavior over time</strong></td>
<td>Students do not show behavior over time.</td>
<td>Students present one BOT graph that was drawn hastily and without much thought.</td>
<td>Students present a BOT graph and explain the behavior briefly.</td>
<td>Students present a BOT graph for one scenario that is carefully contemplated.</td>
<td>Students present BOT graphs for a few interesting scenarios. The graphs illustrate the strength of the systems thinking approach.</td>
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</tbody>
</table>
Increase in Iowa’s gas tax
Applications of the modules

Transition to ISU

Freshman seminar: Intro to pillars (3 weeks each)

Sophomore seminar: Pillars in more depth (7 weeks each)

Capstone experiences

Time
Freshman seminar: Engr 110X

Definition of ST, intro to tools

Student work: Rich picture (& other tools)

Week 1

Week 2

Week 3

Student presentations

2010

2011

2012
Sophomore seminar: Engr 210X

Learning outcome:

For complex, ill-defined, dynamic problems involving engineering, social, ethical, cultural, environmental, business, and political issues, second-year E2020 scholars will

• Identify connections between subsystems with rich pictures
• Explain relationships with causal-loop diagrams
• Sketch the behavior over time of key variables in the system.
Sophomore seminar: Engr 210X

- Week 1 & 2: Lecture
- Week 3: Project statement, key variables, description of at least 5 of 7 issue areas, information sources
- Week 4: Rich picture and description
- Week 5: Causal-loop diagrams and descriptions
- Week 6: Behavior-over-time graphs and descriptions
- Week 7: Presentations, Final report: final drafts of diagrams and descriptions + reflection on lessons learned
Assessment

Reflections from students:

• Students knew **little about ST before** the module and **much more after it**.
• The module will **help in planning projects**.
• Multidisciplinary aspects will **improve collaboration**.
• Students **appreciated having tools** to express the behavior graphically.
• Students **enjoyed** the activities.
• The module **changed how students view engineering**.
Assessment

Email survey for Engr 110X:

“I have an understanding of the systems thinking pillar…”

![Bar chart showing responses for 2009-2010 and 2010-2011 cohorts. The chart shows the number of responses for Strongly disagree, Disagree, Neutral, Agree, and Strongly agree categories. The 2010-2011 cohort has higher responses for Agree and Strongly agree categories compared to the 2009-2010 cohort.]
Assessment

Ratings from 3 instructors of student work in Engr 210X

<table>
<thead>
<tr>
<th></th>
<th>Rating</th>
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<tbody>
<tr>
<td>Problem description</td>
<td>3</td>
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<tr>
<td>Key variables</td>
<td>2.5</td>
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<td>Rich pictures</td>
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<tr>
<td>Causal loop diagrams</td>
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<td>Behavior-over time graphs</td>
<td>3</td>
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<tr>
<td>Lessons learned</td>
<td>3</td>
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<tr>
<td>Sources</td>
<td>3</td>
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</table>
ST in LC?

- Freshman orientation
- Service learning
- Time management
- Club projects
- Homework teams
- Freshman design
ST in LC?

Observations and suggestions:

1. Students tend to get information from their own heads.
   a. Coach them to find an article or two, or
   b. Use a topic that is familiar.

2. Students need coaching with key variable and feedback.
Summary: The module is...

- Broadly applicable
- New for students
- Amenable to short treatments
- Fun