SD Note-Taking
Across the Curriculum

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A Note-Taking Challenge

• Effective note-taking:
  
a skill students need in every academic discipline
  … when reading textbooks
  … when listening to lectures

• One challenging note-taking task:
  
representing a discipline's causal structures
  … hypotheses and theories
  … how and why things happen the way they do
Some Questions that Disciplines Pose

• How does the body regulate its temperature?
• How do product markets determine prices?
• How do hurricanes form?
• Why do people pollute?
A Problem

- Even verbatim notes do not guarantee comprehension of hypotheses and theories.

- The student may merely memorize and repeat.

- What is missing: a translation technique that structures information in a way that is
  - faithful to the textbook explanation
  - yet comprehensible to the student.
A Solution

“The most basic thing that can be said about human memory is that unless detail is placed in a structured pattern, it is rapidly forgotten.” (Bruner, 1960)

“System dynamics is a framework into which facts can be placed so that learning becomes more relevant and meaningful.” (Forrester 1994)

SD note-taking is part of that framework.
SD note-taking is a structured process of translating textbook theories into SD models.

A **partial** SD translation identifies a theory in text and converts that theory into causal links and loops.

- Tasks assigned to my economics students in the US
- Richardson’s *Feedback Thought in Social Science and Systems Theory*

A **full** SD translation involves three extra steps:

1. formulating the stock and flow structure of the theory
2. simulating the model
3. testing the theory’s predictive claims

(references in appendix)

**SD Note-Taking** refers to a **partial SD translation**
End product of an SD note-taking exercise:

- a set of causal links (and maybe a loop) representing how a process is believed to work, in the social or natural sciences
- evidence of student-constructed understanding

Resulting “notes”—whether accurate or not—provide a forum for discussion that can

…correct student misconceptions

…improve teacher explanations

…enhance learning about dynamic processes in any discipline
Modeling Process: 2 Approaches

1. Behavior-Structure Approach
   - define problem dynamically
   - identify key stocks & flows
   - develop dynamic hypothesis
   - formulate & simulate the model

2. Note-Taking Approach
   - identify effect and various causes
   - explain one-way effect of various causes
   - look for feedback effects
   - explain feedback effects
   - draw and interpret causal loop diagram
The Epidemic Game

Dynamic Hypothesis:
reference mode behavior is generated by net effect of loop R and loop C.
Taking SD Notes on Epidemics

In epidemics spread by person-to-person contact, the incidence of new cases depends on the number of current cases, the number remaining susceptible, and the proportion of total possible contacts between infectious cases and susceptible individuals that lead to infection.

(Encyclopedia of Public Health)
Identifying Cause & Effect

In epidemics spread by person-to-person contact, the incidence of new cases depends on the number of current cases, the number remaining susceptible, and the proportion of total possible contacts between infectious cases and susceptible individuals that lead to infection.

- number of current cases
- number remaining susceptible
- proportion of total possible contacts between infectious cases and susceptible individuals that lead to infection

incidence (noun) the occurrence, rate, or frequency of a disease, crime, or something else undesirable
Explaining Cause & Effect

depends on cause

number of current cases
The more cases we currently have, the higher the rate of new cases.

number remaining susceptible
The more susceptibles remaining, the higher the rate of new cases.

proportion of total possible contacts between infectious cases and susceptible individuals that lead to infection
The higher the proportion of contacts leading to infection, the higher the rate of new cases.

rate of new cases

+ + +

depends on cause
effect
**Identifying Feedback Effects**

New cases add to the number of current cases.

- **Number of current cases**: The more cases we have, the higher the rate of new cases.

- **Number remaining susceptible**: The more susceptibles, the higher the rate of new cases.

- **Rate of new cases**: The more cases and susceptibles, the higher the rate of new cases.

- **Proportion of total possible contacts between infectious cases and susceptible individuals that lead to infection**: The higher the proportion of contacts leading to infection, the higher the rate of new cases.
The more cases we have, the higher the rate of new cases.

The more susceptibles, the higher the rate of new cases.

New cases subtract from the number of susceptibles.

New cases add to the number of current cases.

The higher the proportion of contacts leading to infection, the higher the rate of new cases.

\[
\text{proportion of total possible contacts between infectious cases and susceptible individuals that lead to infection} = \frac{\text{rate of new cases} \times \text{number of current cases}}{\text{number remaining susceptible}}
\]
Causal Loop Diagram: Game vs Text

**Game**

- Susceptibles → C: daily rate of infections → R
  - Probability of infection when infecteds contact susceptibles
  - Total population
  - Daily contacts per infected person

- C: number of current cases → R
  - Number of remaining susceptible

**Text**

- C: rate of new cases → R
  - Proportion of total possible contacts between infectious cases and susceptible individuals that lead to infection
  - Probability of infection when infecteds contact susceptibles
  - Total population
  - Daily contacts per infected person

- R: number of current cases → C
  - Number remaining susceptible
1. IDENTIFY CAUSE & EFFECT

In epidemics spread by person-to-person contact, the incidence of new cases depends on the number of current cases, the number remaining susceptible, and the proportion of total possible contacts between infectious cases and susceptible individuals that lead to infection.

2. EXPLAIN ONE-WAY CAUSE & EFFECT

\[ \text{rate of new cases} = \text{number of current cases} + \text{number remaining susceptible} + \text{proportion of total possible contacts between infectious cases and susceptible individuals that lead to infection} \]

3. IDENTIFY & EXPLAIN FEEDBACK EFFECTS

4. DRAW & INTERPRET CAUSAL LOOP DIAGRAM

\[ \text{remaining susceptibles} \rightarrow \text{rate of new cases} \rightarrow \text{current cases} \]

\[ \text{proportion of total possible contacts between infectious cases and susceptible individuals that lead to infection} \]
The explanation for the rapid growth of England's North American colonies lies in the existence of a large “surplus” population. Early seventeenth-century England contained a large number of migrant farmhands and unemployed and under-employed workers. Most English migrants to North America were recruited from the lower working population--farm workers, urban laborers, and artisans--who were suffering from economic distress, including sharply falling wages and a series of failed harvests. Many English immigrants were indentured servants, who agreed to serve a term of service in exchange for transportation across the Atlantic.

Mintz (Digital History, 2007)
The explanation for the rapid growth of England's North American colonies lies in the existence of a large surplus population. Early seventeenth-century England contained a large number of migrant farmhands and unemployed and under-employed workers. Most English migrants to North America were recruited from the lower working population--farm workers, urban laborers, and artisans--who were suffering from economic distress, including sharply falling wages and a series of failed harvests. Many English immigrants were indentured servants, who agreed to serve a term of service in exchange for transportation across the Atlantic.

**effect**  
depends on  
**cause**

- surplus population (in England) willing to be indentured servants
- institution of indentured servitude
The more surplus people in England willing to be indentured servants, the faster the growth rate of England’s North American colonies.
growth of England’s North American colonies increased the willingness of the surplus population in England to be indentured servants.

The more surplus people in England willing to be indentured servants, the faster the growth rate of England’s North American colonies.
The growth of England’s North American colonies increased the willingness of the surplus population in England to be indentured servants, which in turn accelerated the growth rate of England’s North American colonies.
1. IDENTIFY CAUSE & EFFECT

The explanation for the rapid growth of England's North American colonies lies in the existence of a large surplus population. Early seventeenth-century England contained a large number of migrant farmhands and unemployed and under-employed workers. Most English migrants to North America were recruited from the lower working population--farm workers, urban laborers, and artisans--who were suffering from economic distress, including sharply falling wages and a series of failed harvests. Many English immigrants were indentured servants, who agreed to serve a term of service in exchange for transportation across the Atlantic.

2. EXPLAIN ONE-WAY CAUSE & EFFECT

growth of England’s North American colonies + surplus population in England willing to be indentured servants

3. IDENTIFY & EXPLAIN FEEDBACK EFFECTS

4. DRAW & INTERPRET CAUSAL LOOP DIAGRAM

growth of England’s North American colonies + surplus population in England willing to be indentured servants
You just turned 10 years old. You have received $100 in cash gifts every birthday since you were born. Each time you received those cash gifts, you saved half in your piggy bank. How much money do you have in the piggy bank?

Fisher (Lessons in Mathematics: A Dynamic Approach 2001)
You just turned 10 years old. You have received $100 in cash gifts every birthday since you were born. Each time you received those cash gifts, you saved half in your piggy bank. How much money do you have in the piggy bank?

effect depends on cause

money in the piggy bank

- amount of cash gifts per year
- fraction of gifts saved
- years of saving
**Explain One-Way Cause & Effect**

- **Effect depends on Cause**
  - An increase in cash gifts adds more money to the bank
  - Amount of cash gifts per year
  - Money in the piggy bank
    - Fraction of gifts saved
    - The higher the fraction saved, the more money in the bank
    - Years of saving
    - The longer the period of saving, the more money in the bank
You are now 14 years old. When you were 10 years old, you took the $500 that was in your piggy bank, and you put that money in a real bank that has been paying you 5% interest each year. Over the past four years, you have not put additional money to the account and you have not withdrawn any money from that account. How much money is in your real bank now?

Fisher (Lessons in Mathematics: A Dynamic Approach 2001)
Identify Cause & Effect

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• initial deposit
• interest earnings per year
• years of saving

money in the real bank
effect depends on cause

- **cause**
  - the higher the interest rate
  - the larger the interest earnings

- **interest earnings per year**
  - the larger the interest earnings
  - the more money in the bank

- **initial deposit**
  - the larger the initial deposit,
    - the more money in the bank

- **years of saving**
  - the longer the period of saving
    - the more money in the bank

- **money in the real bank**

**Depends on:**

- the larger the initial deposit,
  - the more money in the bank

**Effect:**

- the larger the interest earnings
  - the more money in the bank
Identify & Explain Feedback Effects

- The more money in the bank, the larger the interest earnings.
- The higher the interest rate, the larger the interest earnings.
- The larger the interest earnings, the more money in the bank.
- The larger the initial deposit, the more money in the bank.
- The longer the period of saving, the more money in the bank.

Interest earnings per year:
- The larger the initial deposit, the more money in the bank.
- The longer the period of saving, the more money in the bank.

Money in the bank:
- The more money in the bank, the larger the interest earnings.
- The longer the period of saving, the more money in the bank.

Interest rate:
- The higher the interest rate, the larger the interest earnings.
- The larger the interest earnings, the more money in the bank.

Initial deposit:
- The larger the initial deposit, the more money in the bank.
- The more money in the bank, the larger the interest earnings.

Years of saving:
- The longer the period of saving, the more money in the bank.
- The more money in the bank, the larger the interest earnings.
the more money in the bank, the larger the interest earnings

initial deposit

+ money in the bank

the larger the initial deposit, the more money in the bank

+ years of saving

the longer the period of saving, the more money in the bank

interest earnings per year

the larger the interest earnings, the more money in the bank

interest rate

the higher the interest rate, the larger the interest earnings
When there is a general impression that the price of some commodity is likely to rise, from an extra demand, a short crop, obstructions to importation, or any other cause, there is a disposition among dealers to increase their stocks, in order to profit by the expected rise. This disposition tends in itself to produce the effect which it looks forward to, a rise of price; and if the rise is considerable and progressive, other speculators are attracted...[resulting] in a further advance [in price].

Mill (Principles of Political Economy, 1848)
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**effect** depends on **cause**

- expectations of rising prices
- quantities purchased by speculators
Explain One-Way Cause & Effect

**effect** depends on **cause**

- **price**
  - +
  - **quantities purchased by speculators**
  - +
  - **expectations of rising prices**

- the more speculators purchase, the more prices will rise
- the more prices are expected to rise, the more speculators will purchase
Identify & Explain Feedback Effects

the more prices rise,
the more prices are expected to rise

price

quantities purchased by speculators

expectations of rising prices

the more speculators purchase,
the more prices will rise

the more prices are expected to rise,
the more speculators will purchase
Draw & Explain Causal Loop Diagram

- Price
  - Expectations of rising prices
  - Quantities purchased by speculators
  - +

Diagram:

- R
  - +
If the hydrogen-ion concentration in the blood is altered ever so slightly towards the acid direction, the especially sensitized part of the nervous system which controls breathing is at once made active and by increased ventilation of the lungs carbonic acid is pumped out until the normal state is restored.

Cannon (The Wisdom of the Body, 1932)
If the hydrogen-ion concentration in the blood is altered ever so slightly towards the acid direction, the especially sensitized part of the nervous system which controls breathing is at once made active and by increased ventilation of the lungs carbonic acid is pumped out until the normal state is restored.

**effect**

depends on

**cause**

- ventilation of the lungs
- gap between current & normal acid level
- normal acid level

current acid level in hydrogen-ion concentration in the blood
An increase in lung ventilation reduces the acid level

effect depends on cause

- current acid level in hydrogen-ion concentration in the blood
- ventilation of the lungs
- an increase in the acid level above the norm causes lung ventilation to increase
- gap between current & normal acid level
- an increase in the normal level reduces the gap
- normal acid level
An increase in lung ventilation reduces the acid level

- **current acid level in hydrogen-ion concentration in the blood**

- **An increase in current acid level increases the gap**

- **gap between current & normal acid level**
  - an increase in the normal level reduces the gap
  - an increase in the acid level above the norm causes lung ventilation to increase

- **normal acid level**

- **ventilation of the lungs**
Current acid level in hydrogen-ion concentration in the blood reduces ventilation of the lungs, which reduces the acid level. An increase in the acid level above the norm causes lung ventilation to increase, which reduces the gap between current and normal acid level. An increase in the current acid level increases the gap.
Thank you for your participation.
Stay in touch.

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Note to CD Owners: This copy of the slide show was prepared prior to the conference. Feel free to email me if you want to receive the slides actually delivered at the conference. Most likely, there will be no difference, but it is possible that minor changes were made at the last moment.
A Few References for Full SD Translations


SD Note-Taking: __________________

1. IDENTIFY CAUSE & EFFECT
2. EXPLAIN ONE-WAY CAUSE & EFFECT

3. IDENTIFY & EXPLAIN FEEDBACK EFFECTS
4. DRAW & INTERPRET CAUSAL LOOP DIAGRAM
**SD Note-Taking: History**

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### 2. EXPLAIN ONE-WAY CAUSE & EFFECT

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### SD Note-Taking: Economics

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