SYSTEMS THINKING: Visual Tools for Increasing Student Learning

Systems Thinking and Dynamic Modeling Conference
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Mary Scheetz, Portland Public Schools, Portland, OR
Joan Yates, Catalina Foothills School District, Tucson, AZ

Connections with Best Practice

- Classroom Instruction That Works
- Dimensions of Learning
INSTRUCTIONAL STRATEGIES THAT AFFECT STUDENT ACHIEVEMENT

Identifying similarities and differences
Summarizing and note taking
Reinforcing effort and providing recognition
Homework and practice
Nonlinguistic representations
Cooperative Learning
Setting objectives and providing feedback
Generating and testing hypotheses
Questions, cues, and advance organizers


INSTRUCTIONAL STRATEGIES THAT AFFECT STUDENT ACHIEVEMENT

NONLINGUISTIC REPRESENTATIONS

Visual Tools
Physical Models
Mental Pictures
Pictures and Pictographs
Kinesthetic Activity

INSTRUCTIONAL STRATEGIES THAT AFFECT STUDENT ACHIEVEMENT

NONLINGUISTIC REPRESENTATIONS

VISUAL TOOLS

Brainstorming Webs

Task-specific Organizers

Thinking-Process Maps


THINKING-PROCESS MAPS

Concept Mapping

Systems Thinking

Thinking Maps

INSTRUCTIONAL STRATEGIES THAT INCREASE STUDENT LEARNING

NONLINGUISTIC REPRESENTATIONS

VISUAL TOOLS

THINKING-PROCESS MAPS

SYSTEMS THINKING
Stocks/Accumulations
Behavior-Over-Time Graphs
Causal Loops
Stock/Flow Diagrams
Dynamic Modeling

Dimensions of Learning

Dimension 1: Attitudes and Perceptions
Dimensions of Learning

- Dimension 1: Attitudes and Perceptions
- Dimension 2: Acquire and Integrate Knowledge
- Dimension 3: Extend and Refine Knowledge
Dimensions of Learning

Dimension 1: Attitudes and Perceptions
Dimension 2: Acquire and Integrate Knowledge
Dimension 3: Extend and Refine Knowledge
Dimension 4: Use Knowledge Meaningfully

Dimension 5: Productive Habits of Mind
Dimensions of Learning

Dimension 4: Use Knowledge Meaningfully

Decision Making

Dimensions of Learning

Dimension 4: Use Knowledge Meaningfully

Decision Making       Problem Solving
Dimensions of Learning

Dimension 4: Use Knowledge Meaningfully

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Systems thinking: Seeing what’s below the surface

Iceberg...Seeing What’s Below the Surface

What is seen
- Events
  - What happened?

What is generally unseen
- Patterns of Behavior
  - What’s been happening?
  - What are the trends?
  - What changes have occurred?

- Underlying Structures
  - What has influenced the patterns?
    (e.g. policies, laws, physical structures)
  - What are the relationships among the parts?

- Mental Models
  - What assumptions, beliefs, and values do people hold about the system?

Adapted by Waters Foundation, CFSD from Innovation Associates, Inc.
2/99
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Iceberg...Seeing What's Below the Surface
What is seen
What is generally unseen

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Balancing Tubes Activity
Systems Thinking and Dynamic Modeling Concepts

- Change over time
  - patterns and trends
  - accumulations

- Circular Causality
  - interdependencies
  - reinforcing and balancing relationships

- Leverage
  - structure generates behavior
  - short and long term consequences
  - trade-offs
  - temporal and spatial boundaries

Systems Thinking/Dynamic Modeling Tools & Corresponding Concepts

- Behavior-over-time graph (BOTG)
  - change over time / trends / patterns of behavior

- Causal loop diagram (CLD) (incl. systems archetypes)
  - circular causality / feedback relationships

- Stock/flow diagram (S/F)
  - interdependencies / accumulations

- System dynamics computer model
  - “What if...” / quantitative

- ST/DM games & activities
  - characteristics of complex systems
**Accumulations/Stocks**

- Nouns, in the STELLA language, are called “stocks.”
- …are represented by rectangles.
- Examples: Water, Population, Cash, Anger, Hunger, Trust, Commitment

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**Accumulations in the story**

- What aspects/variables within the story change?
- List aspects/variables.
Behavior-Over-Time... Graphs

- Show the trend or pattern of change of a variable over time.
- X axis is always time
- Y axis is always the variable being graphed
- ...can be drawn on a separate graph form or within stocks.

BOTGs from the story

- What aspects/variables within the story change?
  - List aspects/variables.

- How does each aspect/variable change?
  - Draw a BOTG of how each aspect changes.
BOTGs from the story

Dirt on Mrs. Jones’ floor

- Time
- Time

Use of electricity

- Time
- Time

Circular Causality: Causal Loops

- Show causal relationships and circular feedback within a system.
- A cause becomes an effect, becomes a cause, becomes an effect, and so on.
- Two types: reinforcing and balancing
Reinforcing Causal Loop Diagram

Balancing Causal Loop Diagram
Reinforcing or Balancing?

Causal Loop Diagrams from the story

- What aspects/variables within the story change?
  - List aspects/variables.

- How does each aspect/variable change?
  - Draw a BOTG of how each aspect changes.

- How do the identified aspects/variables affect each other?
  - Draw a CLD representing how aspects of the story affect each other. (Refer to the BOTGs/Stocks worksheet.)
Fixes that Fail Archetype

Problem
Symptom

Fixes that Fail Archetype

Problem
Symptom

Fix

B

o

s
Fixes that Fail
Archetype

Problem
Symptom

B

Fix

Unintended
Consequence

S

R

S

Fixes that Fail from *Mrs. Frisby and the Rats of NIMH*

Accumulation
of Dirt

B

Vacuum Use

S

Factories
& Electricity Prod.
& Soot
Circular Causality: Stock/Flow Diagrams

- …show interdependencies and feedback within a system by identifying major accumulations and the factors that increase and decrease over time.
- Icons, which come from dynamic modeling, may also include connectors and converters.

Vacuum Use

Accumulation of Dirt

Electricity Production
Stock/Flow Diagrams from the story

- What aspects/variables within the story change?
  - List aspects/variables.

- How does each aspect/variable change?
  - Draw a BOTG of how each aspect changes.

- How do the identified aspects/variables affect each other?
  - Draw a CLD representing how aspects of the story affect each other. (Refer to the BOTGs/Stocks wksht.)

- Add to the Stock/Flow diagram representing how aspects of the story affect one another.
Dynamic Modeling

“A computer model of a system is a stock/flow diagram with supporting mathematical equations which link the factors of the system. As changes are made to the factors in the system, the behavior of the system, as indicated by output graphs, changes.” (STELLA, HPS-Inc.)

A Simple Dynamic Model from the story
Student Samples

ICEBERG ANALYSIS SAMPLE - Remember the Titans

What is seen

Events
- New coach hired
- Team goes to camp
- Interracial rooming assignments
- 2 star players become friends
- 1 star player is in an accident
- Team wins the championship

Patterns of Behavior
- What trends have been happening over time?

Operational Thinking
- Closed-Loop Thinking
- Quantitative Thinking

Underlying Structures
- What has influenced the patterns? (e.g., policies, laws, physical structure)
- What are the relationships among the parts?

Mental Models
- What assumptions, beliefs, and values do people hold about the system?
- Did you include these in your diagram?

Coach’s persistence
- Interracial interaction
- Segregation
- Prejudice
- Lack of understanding
- Inability to work together

System as Cause Thinking
- Scientific Thinking

What is generally not seen

Operational Thinking
- Closed-Loop Thinking
- Quantitative Thinking

System as Cause Thinking
- Scientific Thinking

Coach’s Persistence
- Team
- Prejudice
- Town
- Star Players’ Friendship
- New coach hired
- Team goes to camp
- Interracial rooming assignments
- 2 star players become friends
- 1 star player is in an accident
- Team wins the championship
BOTG - Counseling Example

Parents’ nagging

Grade percentage

“friendship skills”
causal loop diagram

- Friendship skills used
- You’re nice feelings about others
- Other’s nice feelings about you
- Friendships
CLD - Elementary School Social Studies

After playing the Friendship Game, first grade students return to their classroom to debrief their experience. This reinforcing causal loop diagram is used with students during this debrief.

CLD - Elementary School Social Studies

After creating a BOTG which showed the exponential growth of sports in the 1900s, students created a reinforcing causal loop diagram to explain their thinking.
Fixes that Fail

Stress \rightarrow B \rightarrow \text{Alcohol Use} \rightarrow O \rightarrow \text{Health} \rightarrow R \rightarrow \text{Productivity} \rightarrow S

Systems Archetype (Fixes That Fail):

- **B**: British need for money to support soldiers in colonies
- **S**: Tax money Colonists paid to the British
- **R**: British need for more soldiers
- **O**: Colonists’ anger at being taxed by the British
Stock/Flow Map - Elementary School Social Studies -2nd Grade Mini Society Unit

One objective of the Mini Society unit is for students to understand the concept of scarcity. This S/F map was used to examine the accumulation and drain of markers in the 2nd grade classroom.

**Markers**

- putting in
- leaving caps off
- use of markers
- how many times used each day

Mrs Swartz adds

- Markers
- throwing away

**Lynx and Hares Simulation**

**Middle/High School**

Lynx births

Lynx deaths

Lynx birth rate

Lynx natural death rate

Lynx kill rate

Lynx starvation rate

Hare births

Hare deaths

Hare birth rate

Hare natural death rate
Action Research

- “The students demonstrated their understanding of the concept of archetypes and were able to identify examples and analyze connections between the past and the present. The results indicate that the use of systems tools is very beneficial to students’ ability to identify and make connections between the past and the present and thus ‘learn’ from history.” (7th grade social studies)

- “…overall, parents seemed to have a sense of what their children are capable of in terms of higher level thinking and presenting to an audience.” (7th grade literature)

- “It is clear, however, that STELLA enhanced my pre-calculus students’ understanding of the fundamental natures of each of the types of functions.” (High school pre-calculus)

Action Research (cont.)

- “Over 90% of my students indicated that using SD modeling helped them or greatly helped them understand linear concepts.” (6th grade math)

- “…70% of the students met the criteria of performing at a 4 or better on the assessment rubric, the noted increase from 30% demonstrates significant growth proving this is without a doubt a powerful way to assist students in integrating inferences, interpretations, and conclusions into their writing.” (6th, 7th, 8th grade math)

- “Feedback in water systems is a highly abstract concept, and while many students struggled to understand the multiplicity of feedback loops here, they were able to grasp the idea of at least 2 successive effects from one initial water chemistry imbalance within their case study.” (High school chemistry)

- Using STELLA modeling to assess environmental impact, 100 % rated at meets or exceeds standard - change from over 50 % not meeting during pre-assessment. (High school field study)
Student Quotations

- “Can we use BOTGs for our next writing assignment? It makes writing so easy.”
- “…that math is a very important part of graphs and the simulations. It is like a language in a way. Math isn’t just numbers. It is actually saying something.”
- “It helps doing the simulation because I understand the book better.”
- “Patterns are recognizable everywhere and it’s easy to notice them. We can relate our lives to these patterns to help ourselves.”

STUDENT QUOTATIONS (cont.)

- “You can do anything if you set your mind to it, no matter how young you are or how many problems you run into.”
- “It improves the life skills of basic problem solving and interacting with co-workers and family because you are better at perceiving behaviors.”
- In the past three years, an average of 74% of the seniors (in CFSD) surveyed in the spring answered yes to this question: Was using SD concepts/tools/simulations an effective means for you to learn class material?”
WAYS TO LEARN MORE

- Web Sites
- Resource Materials
- Training and Workshops
- Site Visits
- Conferences

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Ladder of Inference

The Reflexive Loop

- I take ACTIONS based on my beliefs
- I develop BELIEFS about the world
- I draw CONCLUSIONS
- I make ASSUMPTIONS based on the meanings I added
- I add MEANINGS (cultural & personal)
- I select "DATA" from what I perceive

"Perceivable Data & Experiences"

Adapted from The Fifth Discipline Fieldbook. Last modified - 1/1999
THE STORY OF MRS. JONES AND HER VACUUM CLEANER
Examples of causal loops and stock and flow diagrams

**Causal Loop Diagrams**
- **R** = reinforcing feedback
- **B** = balancing feedback

**Stock and Flow Diagram**
Uses icons of dynamic modeling but can be drawn on paper.
Reinforcing and balancing interrelationships are represented in a more explicit manner.