The Meaning for 3-6 Grade Students
Learning Systems Thinking

Chiang-Kuo Tu
Doctoral Student
Department of Business Management
National Sun Yat-sen University, Kaohsiung, Taiwan
TEL/FAX: 886-75252367
E-mail address: e6218923@ms13.hinet.net

Abstract

Over the past three years I have been applying systems thinking tools (such as BOTG, CLD, and systems archetypes) as a viewpoint of seeing wholes to introduce to 3-6 grade students. In my program, using simple games, pictures, videos, and writings, I lead kids to discover, understand, and discuss the system stories hidden in those teaching materials. The first part of this paper describes my program and introduces some ideas for teaching ST to 3-6 grade students.

According to my experiments, another finding is that kids are changing in some aspects. For example, their observation, thinking and presenting ability are enhancing. Moreover, kids are building their systems thinking skill. Though my experiments get much meaningful result, more important thing is to inquire ourselves "what's the meaning for kids practicing ST" or "what's the fundamental influence on kids". To study this issue, the second part of this paper discusses my experiment result and its meaning.

The Importance of Developing K-12 Systems Education

We can't manage dynamic complexity systems by fragmented view

For many decades, system dynamics researchers have explored a lot of dynamic complexity issues on world existence and development, urban growth and its limits, industrial dynamic structure, and business, ecosystem and social system management etc. Forrester(1998) had found the nature of those issues as follows:

a. Cause and effect are not closely related in time or space.
b. Low-leverage policies receive most of the attention.
c. High-leverage policies wrongly applied.
d. We cause our own troubles but put the blame elsewhere.
e. Conflict between short-term and long-term policies.
f. Collapse of goals and values from pressures and failure to meet goals.

Therefore, we can not anymore handle those issues by fragmenting the world. And learning how to see wholeness is critical to cope with dynamic complexity systems.

It's difficult for adults to learn about systems thinking

Learning about dynamic complexity systems, people have to build models, including mental models, systems thinking models, or computer-simulation models. Through modeling process modelers can examine, challenge, and improve their own mental

models. They can be aware of the counterintuitive consequences and understand how to manage those dynamic complexity systems. However, the most difficult thing is that entrenched mental models will thwart changes that could come from systems thinking. (Senge, 1990) That is to say adults' mental models which formed by their experience maybe resist changes, reflection, and systemic thinking. Thus, besides continuing to let adults learn about systems thinking, we devote ourselves to another creative path. That is "guiding k-12 kids learning systems thinking". And we believe that we can build kids' systemic thinking capability only when we participate in and affect kids' cognition construction.

Rethinking learning: an expectation to kids education
American systems educators really inspire us with open mind and insightful meaning.

> *I believe we should give students a more effective way of interpreting*
> *the world around them. They should gain a greater and well- founded*
> *confidence for managing their lives and the situations they encounter.*
> This article is excerpted from the Keynote address given by Dr. Jay Forrester
> at the June, 1994 Systems Thinking and Dynamic Modeling Conference.

> *Love to learn*
> *Will to risk*
> *Try it*
> *Explore it*

> This idea is excerpted from the address given by Mary Scheetz at the July,
> 1996 Systems Thinking and Dynamic Modeling Conference.

According to Senge's(1990) idea of building learning organization, people must sustain to generate and practice five aspects of discipline. Thus, Lucas(1996) considered that students should build three core competencies, including aspirations- goals of the soul, conversations- walking the talk, and dealing with complexity- understanding interdependencies. Furthermore, Forrester(1992) mentioned the concept of learner-centered learning. It will change the interrelationships between students and teachers. And according to learners' needs we should reconstruct a new instruction theory.
To sum up, the above-mentioned opinions bring us to rethink what's the vision of education and the condition of learning.

Practice of Developing K-12 Systems Education in Taiwan

Setting
The His-Fu Cultural Foundation of Taiwan is a non-profit organization to develop organizational learning and systems education, including adult education, k-12 education, and community education. Since 1992, this institution has been instructed by Prof. Showing H. Young, who is the founder of Systems Thinking and Organizational Learning Lab. in Taiwan. His-Fu is committed to become a learning organization. Since 1995, it has contributed to k-12 education and positioned itself as an organizer to integrate professional resources of systems thinking and organizational learning with

professional resources of k-12 education.

Vision statement for k-12 education

a. Give students a more effective way of interpreting the world around them.

b. Make kids gain a greater confidence for managing their lives.

Project Goals

a. A happy learning experience by playing games.

b. To enhance their creativity.

c. To enhance their presenting ability.

d. To enhance their analyzing ability.

e. To enhance their ability to understand interrelationships.

Concrete activity

a. Training voluntary teachers to build their systems thinking capabilities.

b. Developing systems thinking games to accumulate teaching materials and courses.

c. Introducing systems education to some schools.

d. Practicing some school's 3-6 grade teaching experiments.

e. Developing summer/winter camps for 3-6 grade kids.

A Program for 3-6 Grade Kids

Education philosophy

a. According to the above-mentioned perspective of Forrester, we expect to give students a more effective way of interpreting the world around them and makes kids gain a greater confidence for managing their lives.

b. Senge's five disciplines: personal mastery, mental models, shared vision, team learning, and systems thinking, which affect our teachers' teaching value and attitude to improve interactions in class.

c. Lucas's building three competencies become our concrete objective to lead kids to explore and realize what they really want, practice self-inquiry and dialogue with partners, and discover and study in dynamic complexity systems.

Learning theory

a. Using virtual world (Issacs and Senge, 1992) to represent real world: Kids have opportunities to experiment and practice without any risk. And games designed by compressed time and space help kids understand connection between their actions and consequences in 1-3 hours.

b. Offering a lower risk learning environment: Everyone can talk about its opinions and open for other's inquiry without any fear.

c. Encouraging and guiding reflective discussion.

d. Building formal instruction steps: We realize CBLE learning cycle into five concrete instruction steps. (Figure 1.)

e. Following experiential learning theory. (Kolb, 1984)

Learning objective: systems thinking tools

a. Understanding and using BOTG.(behavior over time graph)

b. Understanding and using CLD.(causal loop diagram)

c. Understanding and using systems archetypes.

Instruction Steps　　　　**Learning Cycle**

```
┌──────────────────────┐        ┌────────────────────────────────┐
│ 1.Introducing systems │   ═    │ Finding strategy to manage      │
│   story               │        │ virtual world                   │
└──────────────────────┘        └────────────────────────────────┘
         │                                    │
         ▼                                    ▼
   ┌──────────────┐          ┌──────────┐
   │ 2.Playing    │    ═     │ Action   │
   │   games      │          └──────────┘
   └──────────────┘                 │
         │                          ▼
         ▼                   ┌────────────────────┐
   ┌──────────────────┐  ═   │ Outcomes and       │          feedback
   │ 3.Reflect on     │      │ evaluation         │
   │   process        │      └────────────────────┘
   └──────────────────┘              │
         │                           ▼
         ▼                   ┌────────────────────┐
┌───────────────────────┐ ═ │ Crafting mental    │
│ 4.Construct systems   │   │ models             │
│   concepts            │   └────────────────────┘
└───────────────────────┘           │
         │                           ▼
         ▼                   ┌────────────────────────┐
   ┌──────────────────┐  ═   │ Connecting concrete    │
   │ 5.Reflection on  │      │ experience             │
   │   real life      │      └────────────────────────┘
   └──────────────────┘
```
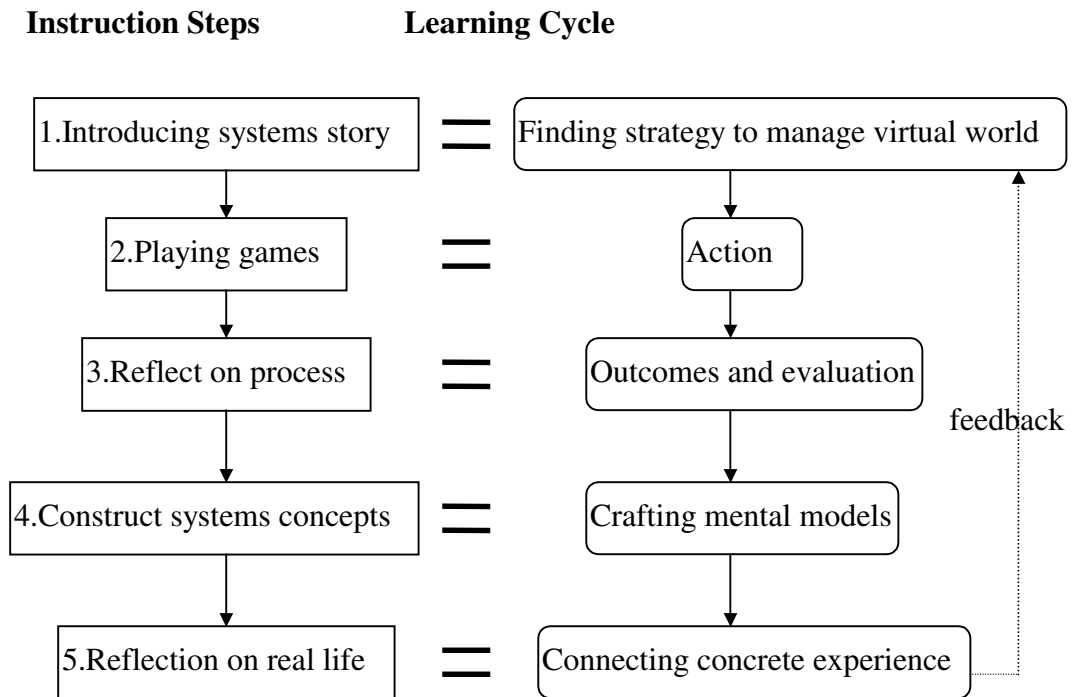
Figure 1. Instruction Steps and Learning Cycle

Program design

This is a 21 hours program. Kids come to our class every day for three hours. And this program has been experimented from 1/2/99 to 7/2/99.

Grade Level: 3-6 grade

Table 1. Curriculum structure

Time	Title	Lesson Objectives
1999.2.1.	Systems in My Life	. To build teams let every person contact with each other. . By playing games let kids understand the purpose of learning systems thinking. . By interacting with each other, team members can feel the systems of their interrelationships.
1999.2.2.	Find the Truth With an Open Mind	. After playing some games or seeing some pictures, students will be interested in finding the truth with an open mind. . What's the characters of systems thinker?
1999.2.3.	Systems Thinking Practice (1)	. Introduce BOTG. . Introduce casual-effect relationships. . Introduce casual feedback thinking.
1999.2.4.	Systems Thinking Practice (2)	. Kids practice drawing a real case by ST tools. . Introduce systems story-telling steps.
1999.2.5.	Who is the killer?	. By setting a virtual water-polluted world, kids can connect their actions with consequences. . Find the structure behind the system.

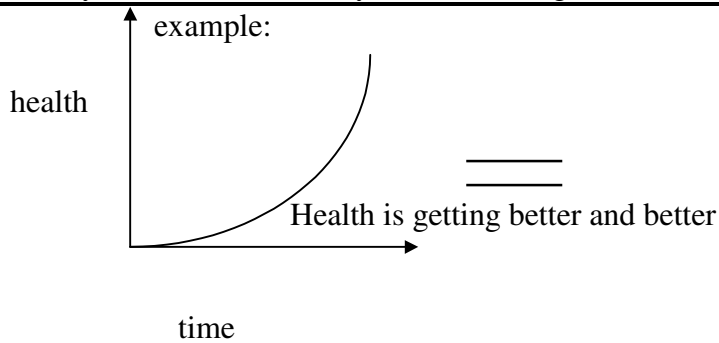| Time	Title	Lesson Objectives
1999.2.6.	Tragedy of Commons	. Introduce one systems archetype: tragedy of commons. . Experience a virtual game full of unanticipated consequence.
1999.2.7.	Sharing Learning Experience	. Recall the learning experience by sharing acquaintance with each other. . Give feedback to each other.

Experiment process and result

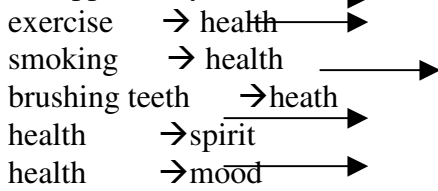| 1st. Day Curriculum Title: Systems in My Life |
|---|
| a. Movie 1.: Kids can feel that "A's action cause B's feelings. And B's feelings cause B's action. And then B's action cause A's feelings and A's action.", "So we are all in one interaction system. Sometime you can manage this interaction, but sometime you can't control it.".
b. Game 1.: How to stop a quarrel. By this game kids can experiment their action and understand its consequences. And then they know that "I can choose my action if I want".
c. Game 2.: Building our trust. Kids say that "It's difficult to trust my partner, but I do trust him gradually. That's because I can feel my partner really care about me. And I do the same thing to him.".
d. Instruction : Systems thinking can help us manage our interaction with others. |

2nd. Day Curriculum Title: Find the Truth With an Open Mind
a. Movie 1.: Detective Holmes has sensitive observation. He can collect the critical information of crime, aware of the whole story of crime, and then discover that case. Thus, all the kids want to learn Holmes's wisdom of finding the truth. b. Picture 1.: Beaver's story. Kids are all trying to find the possible reasons why tree is still upright with an open mind. c. Picture 2.: Owl's story. Kids are curious about the invisible consequences. d. Game 1.: Find the leverage point. Using round string made by newspaper, kids try to hold vertical on one palm. And they study in how to find a good way to hold this position. (adapted from Meadows's speech in 1996) e. Instruction: Use the book *Billibonk and the Big Itch* (Ramsey, 1998) to have a discussion on Holmes's wisdom of finding the truth, beaver's open mind, owl's deliberation, and leverage point. And find the solution for Billibonk's problem altogether. And kids are awaiting to become a systems thinker.

3rd. Day Curriculum Title: Systems Thinking Practice (1)

a. Story 1.: The condition is that one teacher is bitten by a cur (homeless dog). And invite kids to discuss the phenomenon of cur biting people. And we use this example to introduce BOTG, cause-effect relationships, and self-reinforcing loop and balancing loop.

b. Game 1.: Habits explorer. Kids are dicing and have opportunity to learning BOTG. They can understand the connection between a BOTG and its story. For

example:

health

Health is getting better and better

time

After kids can recognize BOTG, then dicing again, and another
opportunity to learn "A influence B (A　B)".
exercise　　→ health
smoking　　→ health
brushing teeth　→heath
health　　→spirit
health　　→mood

And then, learn how to recognize polarity of S (change in same direction) or O
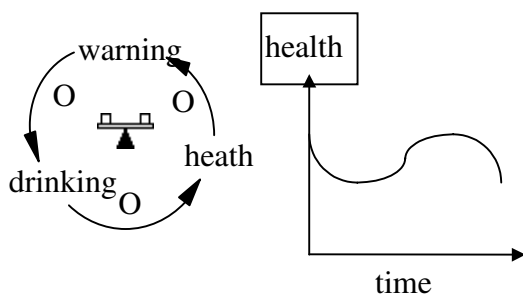(change in opposite direction)

　　　　s
exercise　　→ health

　　　　o
smoking　　→ health
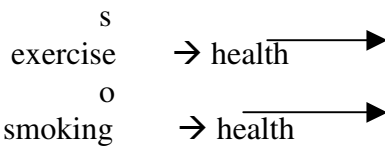
At last, learn the feedback loop, possible BOTG, and its story.

health

S
exercise
heath
S　　　　S
liking

time
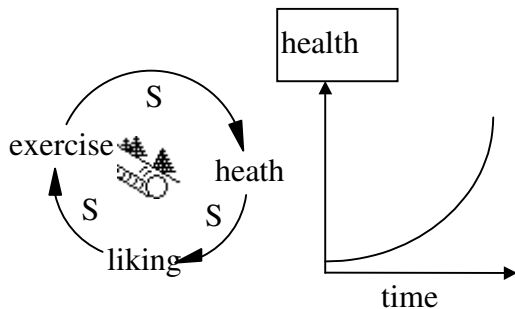
Story:
The more you take exercise, the more
you will be heathy And the more you
are healthy the more you like exercise.
And you will take more exercise.

warning
health
O　　　O
heath
drinking O

time

Story:
The more you drink, the less you are
healthy. The less you are healthy, the
more you warn yourself not to drink.
And the less you drink, the better your
health will be. However, you may drink
again.

c. Instruction: Using the story of cur biting people, let kids learn how to use BOTG, find
the cause-effect relationship, and recognize the self-reinforcing loop and
balancing loop.

4th. Day Curriculum Title: Systems Thinking Practice (2)

a. Six thinking steps: We generate six thinking steps to study in some special issues.

(1) What phenomenon are we caring about?
(2) What factors can make this phenomenon reinforcing?
(3) What factors can make this phenomenon balanced?
(4) What does this phenomenon affect?
(5) Find the critical circular forces, self-reinforcing loop(like snowball) and balancing loop (like brake or balance).
(6) Think what we can do, and what we can't.

b. Drawing a systems story: Kids can follow this six thinking steps and study in their own issue, and then represent on a big poster. This needs cooperation by team members.

c. Presenting the story: Kids can present their own systems story, including water pollution problem and social violence issue.

5th. Day Curriculum Title: Who is the killer?

a. Game 1.: Making money and pollute the river: In half an hour, kids experience that the river is polluted by their own action. And kids begin to find some solutions to recover their river.

b. Video 1.: But kids might defense for their action and not believe that this problem is in our real life. So, we choose to play this video about "Watching Taiwan's River", to prove that this is a very serious problem.

c. Instruction: What systems thinking can suggest:
(1) Remind people to aware their action, which they think it's no big deal, do cause this serious pollution and will influence on human's health and existence some day. (shortening cognitive delay)
(2) Tax the pollution producer. (decelerating the self-reinforcing loop)
(3) Firms must build the sewerage disposal system. (decreasing the rate-in)
(4) Research and develop new but less polluted product. (decreasing the rate-in)

6th. Day Curriculum Title: Tragedy of Commons

a. Story 1. : "The Fish Pond Story" is that "Once upon a time, there was a fish pond. We all lived by the fish in the pond, for eating and selling for profits. From now we would play the role of fisherman and begin to make use of the resources of this pond. Every fisherman's family has a fishing rod which is made by bamboo, fish bait, and magnet. And the fish is made by paper and staple. So every fisherman's family can choose that "how much they want to catch". After 5 minutes we will start to simulate the whole story. But remember that if the amount of fish in the pond become zero, everybody would die of hunger. So be careful and good luck!

b. Game Design:
(1) The initial vale of fish stock is 200.
(2) There are 8 fisherman's family. (8 teams)
(3).Every time period the pond open for one minute, and after one minute we count the performance of every team. And at the same time we begin to give birth to new fish.
(4).The birth rate is 10%.
(5).The new fish would grow up immediately.

c. Result: At beginning, kids always want to catch more and more fish. But after some time, the fish in pond are decreasing, and becoming zero at last. After this

game, we invite students to think how does our selfish goal cause damage to the environment, and how can we improve this situation to avoid tragedy of the commons.

d. Introducing systems archetype "Tragedy of Commons".

7th. Day Curriculum Title: Sharing Learning Experience

a. Sharing your feelings: Kids are arranged to express thanks to their team member or teacher.

b. Mission impossible: Every team receive one envelope and there's one challenge in it. That's some pictures, stories, and BOTG and CLD. And teachers instruct kids to present what they can understand. And kids can do this very well.

Conclusion and Discussion

In my program, using simple games, pictures, videos, and writings, I lead kids to discover, understand, and discuss the system stories hidden in those teaching materials. And then, I teach them practicing BOTG, CLD, and systems archetypes. So we can study and discuss the stories together in class by using same systems language. At last, I design a reflective process to transfer kids' experience in class to their real life. According to the above-mentioned teaching program, I found that kids are changing in some aspects. For example, kids enjoy playing and learning; they are willing to join team discussion; and their observation, thinking and presenting ability are enhancing. Moreover, kids are building their systems thinking skill.

The meaning of "Kids enjoy playing and learning in our class"

a. Learning through playing: In our classroom, we design many games or stories to attract kids to play. Some of these materials catch kids' curiosity and taste of play. And Some of these materials facilitate thinking, presentation, and group discussion. Therefore, kids playing games are not just for fun but they know they can learn something and they enjoy that.

b. Working as a team: Team building is very important to my program. The first two days can gradually build cohesion by introducing to each other, sharing experience with each other, and working as a team to go beyond challenges. Even there is some argument, but every team forms its own rules to organize and coordinate members. So every kid know their own behavior can influence on other team members' behavior.

c. Building confidence of learning: Our games are challenging. Even kids are complaining that it is too difficult, but they are willing to try and risk. That's because they have confidence in themselves. The learning field is without any risk of failure, and won't be laughed or blamed by others. So let kids have learning confidence is the important thing of designing games.

d. Competing with oneself not to anyone else: Kids learn to listen to other's ideas, but not to judge or compete with them. We hope that kids focus on finding the truth, discovering more creative ideas, and finishing the mission of their team. The behavior above is supported by teachers. And kids are getting used to this way of interaction. So It is important for teacher to influence kids how to see the world.

The meaning of "Kids can read BOTG, CLD, and systems archetype"

a. Practicing BOTG: When teachers introduce BOTG to kids, there is a lot of imagination on the pattern's up and down. Kids can realize the possible story behind BOTG. So we can see a lot of creativity and kids can practice their story-telling ability. Then we give them a systems story and kids practice finding the critical variable and its behavior over time. Through this process, kids are learning about seeing things in long-term view, and they begin to explore the reason why behavior goes up or down

b. Practicing CLD: We lead kids to recognize self-reinforcing loop with its dynamic story, and balancing loop with its dynamic story. Kids can realize self-reinforcing loop is similar to "snowball effect" which makes things increasing or decreasing. And more seriously does it display that "how small changes which are ignored can grow beyond our control". Furthermore, kids can find some real life phenomenon, for example: The Foot-Mouth Disease of Pig phenomenon in Taiwan, Egg tart demand increasing, and rumor effect. Another loop is balancing loop. Kids can realize that balancing loop is a brake which decelerating the snowball effect, for example: injecting vaccine for infected pig, merchant raising Egg tart's price, and rumor can be limited by clarification. Therefore, kids can understand the snowball effect and its possible brake and connect with real life experience, and they can also build their own theory of understanding the social issue. So kids are practicing their thinking ability and constructing their social cognition.

c. Practicing systems archetype: Advanced learning is that kids can use systems archetype "Fix that Fail" to represent their own experience, for example: telling lies cause parents don't trust him. "Shifting the Burden" help them reflect that putting off summer vacation homework is a symptomatic solution and doing homework everyday is a fundamental solution. "Escalation" can think over the strategy of "tit for tat", and kids can understand that violence to violence will do harm to both sides. So systems archetypes can help kids reflect their problem and habitual solution.

d. Six systems thinking steps: My experiments show that kids can practice systems thinking by six steps:
(1) What phenomenon are we caring about?
(2) What factors can make this phenomenon reinforcing?
(3) What factors can make this phenomenon balanced?
(4) What does this phenomenon affect?
(5) Find the critical circular forces, self-reinforcing loop(like snowball) and balancing loop (like brake or balance).
(6) Think what we can do, and what we can't.
So kids can practice systems thinking by some specific steps.

Reference

Forrester, J. W. (1998). Letting students learn about a complex world. This article is excerpted from the keynote address given by Dr. Jay Forrester at the June, 1998 Systems Thinking and Dynamic Modeling Conference.

Forrester, J. W. (1994). Learning through system dynamics as preparation for the 21st

century. *Creative Learning Exchange.* v3, No.3.

Forrester, J. W. (1992). System dynamics and learner-centered-learning in kindergarten through 12th grade education. Creative Learning Exchange papers, D-4337.

Issacs, W., and Senge, P. M. (1992). Overcoming limits to learning in computer- based learning environment. *European Journal of Operational Research.* 59(1), 183-196..

Kolb, D. A. (1984). *Experiential Learning*, Prentice-Hall, Englewood Cliffs, NJ.

Lucas, T. (1996). Using mapping and modeling with parents and teachers to build a learning organization. Presentation at 1996 Systems Thinking and Dynamic Modeling Conference.

Meadows, D. (1996). Use of gaming as a tool in education. Keynote address at the July, 1996 Systems Thinking and Dynamic Modeling Conference.

Ramsey, P. (1998). *Billibonk and the Big Itch*, Pegasus Communications, Inc., MA.

Scheetz, M. (1996). This idea is excerpted from the address given by Mary Scheetz at the July, 1996 Systems Thinking and Dynamic Modeling Conference.

Senge, P. M. (1990). *The Fifth Discipline*, Doubleday, New York