



# Methods for Measuring Systems Thinking Skills of High School Students

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## What is Systems Thinking?

Systems thinking helps people consider the **big picture** to better understand the interconnectedness of the variables that exist within a system.<sup>1</sup> Many systems incorporate a **complex series of variables** that depend on each other and react in different ways. Systems thinking allows learners to understand these **relationships** and how they exist within and between systems. When students think on a systems scale, they can focus on the stocks and flows of resources, feedback loops, time delays, and boundaries.<sup>2</sup> One of the many benefits of systems thinking is the ability to help students think about complex environmental concepts and issues at long-term and global scales. Studies have shown that students who are taught to use systems thinking demonstrate a higher level of **understanding of complex natural systems** than those who are not.<sup>3</sup>

The National Next Generation Science Standards are transitioning U.S. education from content-based standards to performance-based expectations.<sup>4</sup> Students should develop **21<sup>st</sup> century skills** (i.e., problem solving, critical thinking, decision making, etc.) to **have the capacity to address impending environmental issues** on a global scale.<sup>5</sup> Building systems thinking skills among students can provide an effective framework for improving their understanding and ability to address these complex problems.

## New Climate Education Resource

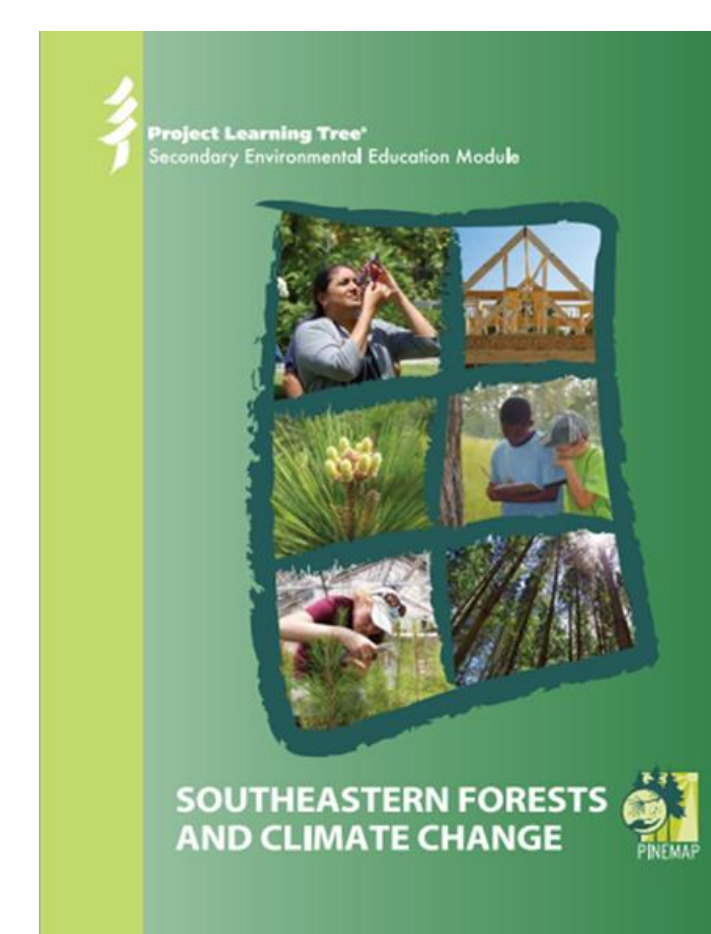
The Project Learning Tree® secondary module, *Southeastern Forests & Climate Change*, contains 14 activities that focus on climate science and address adaptation and mitigation strategies. This resource has a heavy focus on **systems thinking** as a means to address such a complex topic. Each activity has a Systems Thinking Connection section and reflection questions that help teachers to highlight and reinforce these skills. There are also supplemental Systems Enrichment Exercises for 5 of the activities that target the development of systems thinking skills and provide opportunities for students to practice applying these skills to new content.

The module development team from the University of Florida is currently conducting the summative evaluation of the module. This evaluation explores the effectiveness of the entire module; methods for assessing students' systems thinking skills; and strategies for instructing teachers to effectively incorporate systems thinking into their daily science education lessons.

## Methods

My dissertation research seeks to understand how to measure students' systems thinking skills as well as their dispositions toward engaging in systems thinking in new situations.

- Participants include 17 teachers and over 1,300 students from 7 different southeastern states that are involved in the summative evaluation of the module.
- Teachers completed 5 assigned activities that focus on environmental science and systems during the spring semester of 2015.
- Each student completed a pre and post content test
  - 21 multiple choice content questions including basic system dynamic principles
- Each student completed a pre and post Systems Survey
  - 3 open-ended systems thinking questions to allow for more in-depth answers
- Classroom observations were conducted with 4 teachers and 11 Environmental Science and AP Environmental Science classes
  - 1 teacher from North Carolina and 3 teachers from Florida
- Student interviews were conducted with 21 students
  - 4 open-ended questions looking for the presence of systems thinking skills



**Systems Thinking Connection**

THROUGH THIS ACTIVITY, students see that cause-effect relationships in a forest look something like a web. This weblike structure is typical in complex systems as are the feedback loops described in the background section of this activity. Feedback loops play a large role in the stability (and instability) of complex systems. Indeed, the enormous web of cause-effect relationships and the prevalence of numerous feedback loops are the major reasons why making precise predictions about climate behavior is so difficult. Two additional Systems Enrichment Exercises help students practice making systems diagrams.

**Systems Enrichment Exercises**

SOME OF THE MOST IMPORTANT FEEDBACK LOOPS regarding forests and climate are not included in Activity 5 because they are occurring on a global scale rather than on the scale of a single forest. In the systems enrichment options for this activity, students can explore these broad-scale feedback loops in more detail.

In **Feedback Loops in the News** students read a New York Times article in which writer Justin Gillis identifies feedback loops on a global scale. After reading the article, students draw a systems diagram, showing the relationships suggested in the article, and use that article to discuss the role that feedback loops play in the behavior of the system. See the instructions on the Activity 5 webpage for more details.

In **How Earthworms Got Me into College** students read a story that exemplifies a recurring lesson in systems thinking: how seemingly small changes can turn into large changes as they ripple through an entire system. In this story the narrator learns about the broad impacts that seemingly unimportant species—earthworms—can have on an entire forest ecosystem. Students use a causal loop diagram to understand the web of cause-effect relationships in the forest ecosystem. Other links are provided for instructors who wish to pursue these examples further. See the instructions on the Activity 5 webpage for more details.



## Assessing Systems Thinking Skills

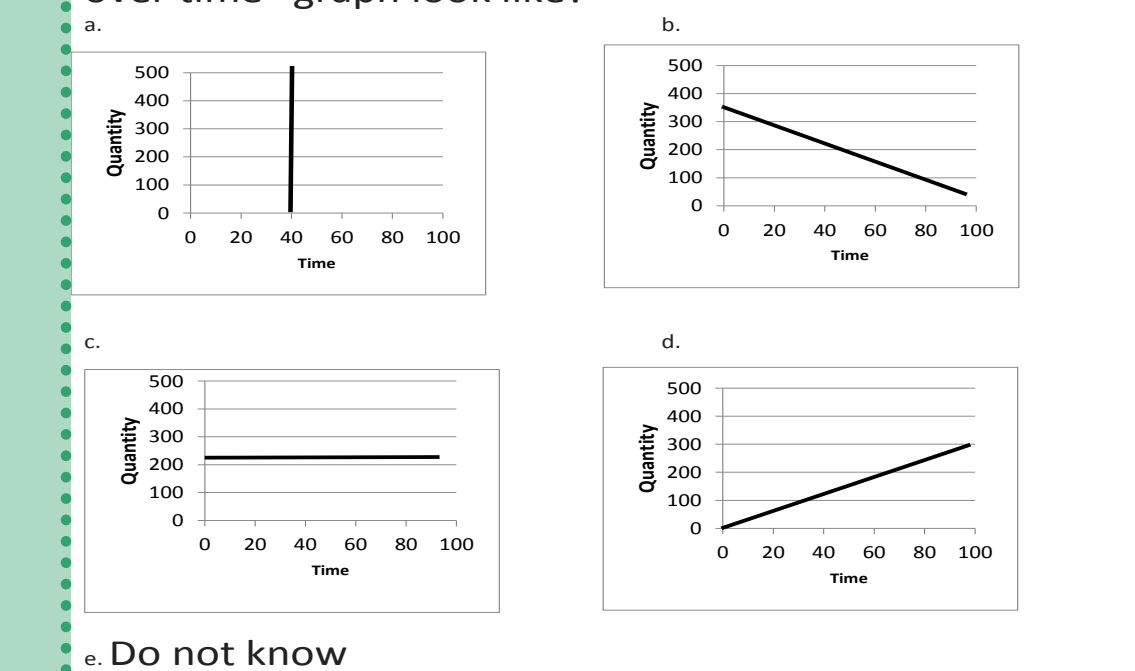
### Sample Questions

- Multiple choice content questions covered content from the activities and basic system dynamic principles.

The amount of carbon on Earth is an example of a/an:

- closed system, with the same amount of carbon staying in each pool
- closed system, with carbon moving between different pools
- open system, with the same ratio of carbon staying in each pool
- open system, with carbon moving between different pools
- Do not know

If the amount of carbon dioxide in the atmosphere has a higher inflow than outflow, what would the "behavior over time" graph look like?



- Systems Survey questions asked about properties of systems, direct and indirect impacts of systems, and to apply systems thinking skills to a new system.

The digestive system, a forest, and an airport are all examples of a system. Name at least three properties of a system.

Many people's actions have a variety of impacts on forests. List as many direct and indirect impacts your personal daily actions could have on a forest system.

- Student interview questions asked them to explain systems, recognize systems, create a systems diagram, and describe their learning preferences.

Can you identify and explain an example of a system that you are apart of in your everyday life?

Using the variables on the cards here create a climate system diagram. Use the arrows to show connections between the variables.

## Analysis

Teachers are currently submitting all student. Classroom observations and student interviews were completed on May 29, 2015.

- Quantitative methods will be used to compare learning gains on content pre and post tests.
- Qualitative methods, including a grounded theory approach, will be used to code and analyze the Systems Surveys, classroom observations, and student interviews.
- Analysis will be done to compare:
  - Regular environmental science classes against AP environmental sciences classes
  - Classes that completed the supplemental Systems Enrichment Exercises against those that did not
  - Classes from different states and different teachers
  - Teachers who attended workshops against those that did not

## Next Steps...

- All data from the schools must be submitted by June 30, 2015.
- All data will be compiled, organized, entered, coded and analyzed.
- Analysis will be completed by August with the aid of a PINEMAP Undergraduate Fellow.
- Analysis of qualitative data will require the development of an instrument that will gauge level of systems thinking ability.
- Systems Survey and instrument will be refined for second round of testing in Fall 2016.

