ENVISION21

Deep Learning

SYSTEMS THINKING RUBRIC

GRADES K-2

CATALINA FOOTHILLS SCHOOL DISTRICT

TUCSON, ARIZONA

General Description and Suggestions for Use

The district's strategic plan, Envision21: Deep Learning, forms the basis for a focus on cross-disciplinary skills/proficiencies necessary for preparing our students well for a 21st century life that is increasingly complex and global. These skills, which are CFSD's "deep learning proficiencies" (DLPs) are represented as 5c + s = dlp. They are the 5Cs: (1) Citizenship, (2) Critical Thinking and Problem Solving, (3) Creativity and Innovation, (4) Communication, (5) Collaboration + S: Systems Thinking. CFSD developed a set of rubrics (K-2, 3-5, 6-8, and 9-12) for each DLP.

These rubrics were developed using a backward design process to define and prioritize the desired outcomes for each DLP. They provide a common vocabulary and illustrate a continuum of performance. By design, the rubrics were not written to align to any specific subject area; they are intended to be contextualized within the academic content areas based on the performance area(s) being taught and assessed. In practice, this will mean that not every performance area in each of the rubrics will be necessary in every lesson, unit, or assessment.

The CFSD rubric for **Systems Thinking** was designed as a cross-disciplinary tool to support educators in teaching and assessing the performance areas associated with this proficiency:

- **Change Over Time**
- **Interdependencies**
- **Consequences**
- **System as Cause**
- **Leverage Actions**
- **Big Picture**
- **Self-Regulation and Reflection**

This tool is to be used primarily for formative instructional and assessment purposes; it is not intended to generate psychometrically valid, high stakes assessment data typically associated with state and national testing. CFSD provides a variety of tools and templates to support the integration of **Systems Thinking** into units, lessons, and assessments. When designing units, teachers are encouraged to create authentic assessment opportunities in which students can demonstrate mastery of content and the deep learning proficiencies at the same time.

The approach to teaching the performance areas in each rubric may vary by subject area because the way in which they are applied may differ based on the field of study. Scientists, mathematicians, social scientists, engineers, artists, and musicians (for example), all collaborate, solve problems, and share their findings or work within their professional communities. However, the way in which they approach their work, the tools used for collaboration, and the format for communicating their findings may vary based on the profession. These discipline-specific expressions of the 5Cs + S may require some level of customization based on the subject area. Each rubric can also be used to provide students with an opportunity to self-assess the quality of their work in

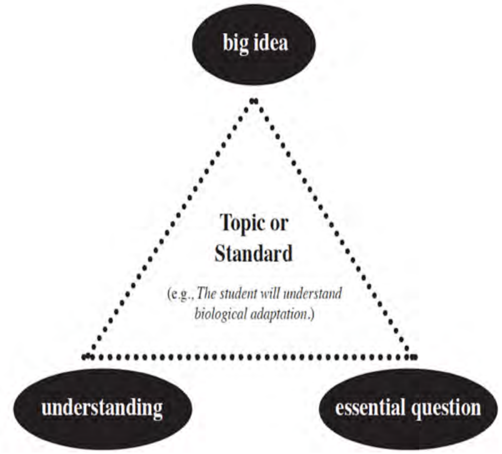
relation to the performance areas. Student-friendly language or "I can" statements can be used by students to monitor and self-assess their progress toward established goals for each performance area.

Transfer

CFSD educators prioritize understanding and transfer to ensure that learning extends beyond the school experience. This 2019 version of the DLP, **Systems Thinking**, includes long-term **transfer goals** that describe autonomous applications of student learning in college, career, and civic life. "Drill and direct instruction can develop discrete skills and facts into automaticity…but they cannot make us truly able. Understanding is about *transfer*, in other words. To be truly able requires the ability to transfer what we have learned to new and sometimes confusing settings. The ability to transfer our knowledge and skill effectively involves the capacity to take what we know and use it creatively, flexibly, fluently, in different settings or problems, on our own" (Wiggins and McTighe, 2011, p. 40).

Big Ideas

This 2018 version of the DLP, **Systems Thinking,** includes a set of Understandings and Essential Questions (UEQs) developed by an interdisciplinary team of K-12 teachers and administrators with guidance from Jay McTighe, author of *Understanding by Design*. These big ideas will guide teachers toward the thoughtful design of assessments, units, and lessons that will facilitate transfer of deep learning. "Because big ideas are the basis of unified and effective understanding, they provide a way to set curriculum and instructional priorities…they illuminate experience; they are the linchpin of transfer…" (Wiggins and McTighe, 2011, p.71). "Understandings are the specific insights, inferences, or conclusions about the big idea you want your students to leave with" (Wiggins and McTighe, 2011, p. 80). "Essential questions make our unit plans more likely to yield focused and thoughtful learning and learners" (McTighe, 2017; McTighe & Wiggins, 2013, p. 17). The figure on the right represents the interrelationship among big ideas, understandings, and essential questions.



The **DLP Understandings** are written for K-12 because they express lasting, transferable goals for student learning. Understandings are meant to be revisited over time and across contexts. The continuity of working toward the same goals will help students deepen their understanding from Kindergarten to 12th grade. Understandings are primarily planning tools, although teachers may choose to share them with their students, if appropriate. Communicating an Understanding does not give away "the answer," since simply stating an Understanding is not the same as truly grasping its meaning.

The **Essential Questions** are teaching and learning tools that help students unpack the Understandings. They support inquiry and engagement with deep learning and therefore may vary in complexity across grade levels.

Systems Thinking Transfer Goals and UEQs

Transfer Goals	
Students will be able to independently use their learning to. . . • Employ the habits of a systems thinker to better understand situations, make effective decisions, and plan for the future.	
Understandings	**Essential Questions**
Students will understand that. . .	**Students will keep considering. . .**
• A system is comprised of interrelated and interdependent parts which serve a specific purpose; changing one part of a system affects other parts.	• What is a system? • How do elements of a system affect each other? • How do the elements fit into the system as a whole? • Why are things the way they are? • What are the causal relationships within a system?
• Systems thinking enables us to look at problems and situations in new ways, which can lead to new solutions and insights.	• How can we use systems thinking to make predictions and solve problems?
• Systems thinkers use specific habits, tools, and vocabulary to represent, describe, and analyze systems and solve problems.	• What makes an effective systems thinker? • How can we use the habits of a systems thinker to help us understand and analyze a system? • How can we come to understand and improve a system? • Which tool(s) will be most effective in analyzing the relationships within the system?
• Systems thinkers observe and connect information in order to understand systems.	• What makes an effective systems thinker?
• A system's structure drives its behavior.	• Why are things the way they are?
• Examining a system from different perspectives helps us identify various mental models and better understand the system.	• How do mental models affect our thoughts and actions? • Why are things the way they are?

• Recognizing patterns of change enables prediction and guides planning for the future.	• What has changed and why? • How can looking at what *has* happened help us predict what *will* happen? • How can we use what we know and have learned to plan for the future? • How does understanding one system help us understand another system?
• Actions can have short-term, long-term, and/or unintended consequences; we can strategically choose leverage actions that produce or increase desired results.	• How do we know the effects of our actions? • How do we know which action or change will make the greatest difference? • How can even a small action or change make a difference?

Self-Regulation and Reflection Transfer Goals and UEQs

Transfer Goals	
Students will be able to independently use their learning to. . . • Improve performance and persevere through challenges by applying deliberate effort, appropriate strategies, and flexible thinking.	
Understandings	**Essential Questions**
Students will understand that. . .	**Students will keep considering. . .**
1. Effective learners set goals, regularly monitor their thinking, seek feedback, self-assess, and make needed adjustments.	• How am I doing? How do I know? What are my next steps? • What is the most effective way to monitor my progress? • How do I know which feedback will help me improve my work? • How can I get useful feedback? • How do I prioritize my work?
2. We can always improve our performance through deliberate effort and use of strategies.	• How can I keep getting better at systems thinking?

The deep learning proficiencies (5c+ s) are highly interconnected. For example, productive collaboration is contingent upon effective communication. Efficient and effective problem solving often requires collaboration skills. Divergent and convergent thinking, which are traits of Creativity and Innovation, are directly related to critical thinking. Our students will need to use a combination of proficiencies to solve problems in new contexts beyond the classroom. Therefore, it is important to be clear about which proficiency and/or performance area(s) are the focus for student learning, and then to assist students in understanding the connections between them and how they are mutually supportive.

What does Score 1.0 – Score 4.0 mean in the rubrics?

The rubrics are intended to support student progress toward mastering the deep learning proficiencies (DLPs). Four levels of performance are articulated in each rubric: Score 1.0 (Novice), Score 2.0 (Basic), Score 3.0 (Proficient), and Score 4.0 (Advanced). The descriptions follow a growth model to support students in developing their skills in each performance area. Scores 1.0 (Novice) and 2.0 (Basic) describe positive steps that students might take toward achieving Score 3.0 (Proficient) or Score 4.0 (Advanced) performance.

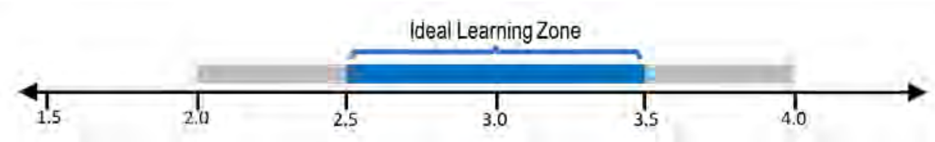
When using the rubrics to plan for instruction and assessment, teachers need to consider the knowledge and skills described in the Score 2.0 column (Basic) to be embedded in the Score 3.0 (Proficient) and 4.0 (Advanced) performance. The Novice level (Score 1.0) indicates that the student does not yet demonstrate the basic skills within the performance area, but that he/she exhibits related readiness skills that are a stepping-stone to a higher level of proficiency. Descriptions at the Novice level also include likely misconceptions that the student might exhibit.

The descriptive rubrics are designed to illustrate students' depth of knowledge/skill at various levels in order to facilitate the instructional and assessment process for all learners. At some performance levels, the indicators may remain the same, but the material under study is more or less complex depending on the grade level band (for example: the complexity of the material at grades 6-8 differs from that of grades 3-5 or 9-12).

The following descriptions explain the four levels on the rubric:

- Score 1.0 (Novice): Describes student performance that demonstrates readiness skills and/or misconceptions and requires significant support.
- Score 2.0 (Basic): Describes student performance that is below proficient, but that demonstrates mastery of basic skills/knowledge, such as terms and details, definitions, basic inferences, and processes.
- Score 3.0 (Proficient): Describes student performance that is proficient – the targeted expectations for each performance area of the DLP.
- Score 4.0 (Advanced): Describes an exemplary performance that exceeds proficiency.

The image below represents the ideal learning zone for students as 2.5 – 3.5.



Glossary

Long-term consequences: Intended or unintended consequences that have longer lasting effects and that are harder to anticipate.

Short-term consequences: Short-term or immediate effects that are often easier to identify or predict. Many humans make decisions just based on short-term consequences.

*Transfer: Before a student can successfully transfer, he/she must first master the other skills within each performance area.

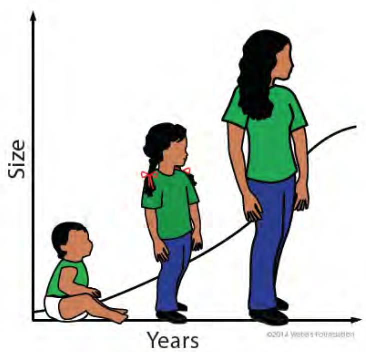
With adult support/guidance: In this rubric, working with adult support or guidance refers to a teacher walking an individual student through the process step-by-step. "With adult support" does not include whole class scaffolding strategies such as graphic organizers, turn and talk, etc.

Sources

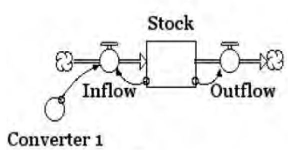
The following sources directly influenced the revision of CFSD's rubrics:

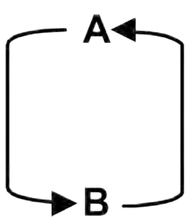
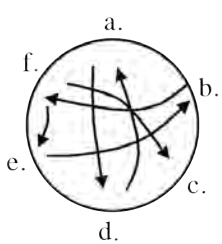
- Catalina Foothills School District. (2011, 2014, 2016, 2018). Rubrics for 21st century skills and rubrics for deep learning proficiencies. Tucson, Arizona.
- Waters Center for Systems Thinking, https://waterscenterst.org/

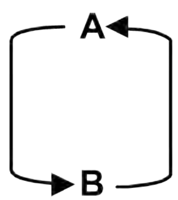
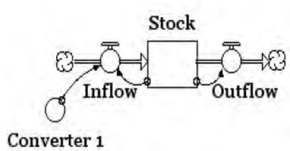
A **system** is a collection of elements that interact with each other over time to function as a whole (Waters Center for Systems Thinking, 2018). A **systems thinker** is anyone who uses the **Habits of a Systems Thinker** (see end of document) in combination with the concepts and visual tools of systems thinking to increase understanding of systems and how they influence both short- and long-term consequences. Many systems thinking concepts are embedded either explicitly or implicitly within the Habits of a Systems Thinker. The CFSD Systems Thinking rubrics include the concepts of Change Over Time, Interdependencies, Consequences, System-as-Cause, Leverage Actions, and Big Picture. Systems thinking provides students with a more effective way to interpret the complexities of the world in which they live—a world that is increasingly dynamic, global, and complex.

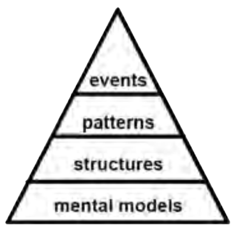
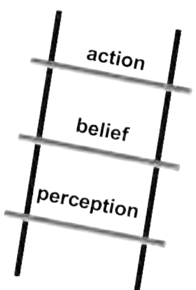
Change Over Time, page 8 	**Consequences, page 10** 	**Leverage Actions, page 12** 
Interdependencies, page 9 	**System-as-Cause, page 11** 	**Big Picture, page 13** 

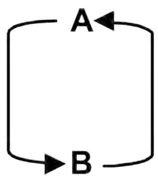
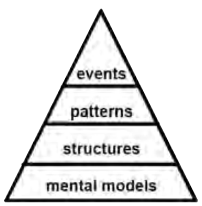
SYSTEMS THINKING

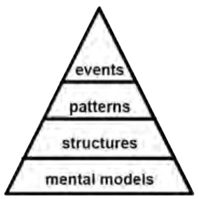
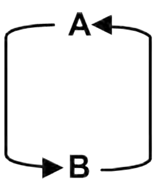
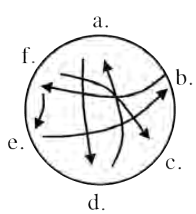
DLP Performance Area	1.0 (Novice) The student may exhibit the following readiness skills for Score 2.0:	2.0 (Basic) When presented with a grade-appropriate task, the student:	3.0 (Proficient) In addition to Score 2.0, the student:	4.0 (Advanced) In addition to Score 3.0, the student may:
CHANGE OVER TIME  **Behavior-over-time graphs**  **Stock-flow maps**	**Identification and Explanation:** Identifies examples of key terms such as *change*, *variable*, *before*, *after*, and/or *over time* from provided examples and definitions. **Representation:** Retells a sequence of events by ordering a provided set of pictures *(for example: orders pictures showing the lifecycle of a chicken).* **Transfer*:** Uses change over time vocabulary *(for example: similar, change, and/or over time)* to describe an everyday situation or an experience in their life *(for example: book, social dynamic, sports, etc.).* See possible student misconceptions following the rubric.	**Identification and Explanation:** Describes an immediate or short-term change that occurs *(for example: it was sunny when we went to recess, but then the sky got darker when the weather changed to rain").* Describes a change as a series of events that connect over time *(for example: My friend and I were mad at each other yesterday. Then we spent time apart from each other today, and now we are not mad at each other).* **Representation:** Explains the "story" of a trend line on a provided behavior-over-time graph *(for example: uses a provided graph to explain how a character's emotion changed over the course of a book, or uses a provided graph to explain how the amount of money in a bank account changes over time).* **Transfer*:** Identifies common elements of two situations involving change over time.	**Identification and Explanation:** Describes a change that occurs over time. Lists and orders events. Identifies elements of a system that change over time (*for example: the amount of precipitation in an ecosystem or how a character's courage changes across a story*). **Representation:** Plots a change over time, given a graph with pre-defined *x* and *y* axes *(for example: plots a trend line showing how a student's energy level changes throughout the school day, justifying why energy levels increase and decrease).* **Transfer*:** Generalizes the key elements of situations that change over time (*for example: "Change over time in both of these stories is the character changing her feelings about a friend or friendship."*).	**Identification and Explanation:** Describe general trends in change over time related to one another *(for example: the growth of plants correlates with the increase in water and light).* Explain why elements of a system change over time *(for example: create a stock-flow map showing the causes of an animal population's growth/decline over time).* **Representation:** Construct a behavior-over-time graph to plot a general change over time, including defining a time frame (x axis) and a scale for changes in an accumulation (*y* axis) *(for example: From "There's a Bird on my Head," by Mo Willems – constructs a graph that shows how Gerald's anxiety increases slowly over the first half of the book, very quickly when the birds have babies, and rapidly decreases once the birds leave his*

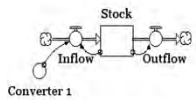
				head. Explains this graph through writing or speech.). **Transfer*:** Apply conclusions about change over time in one situation to a situation of a similar type (*for example: how a baby chick grows over time to how a puppy grows over time).*
INTERDEPENDENCIES  **Causal loops**  **Connection circles**	**Identification and Explanation:** Identifies examples of key terms such as *cause*, *effect*, *interdependent*, and/or *relationship* when provided with definitions and examples. **Representation:** Labels events on a provided systems tool to distinguish events that are causes and effects *(for example: draws an arrow on a connection circle at the cause and leading to the effect).* **Transfer*:** Identifies key concepts such as *cause and effect*, *dependent*, and/or *interdependent* when provided definitions and examples. See possible student misconceptions following the rubric.	**Identification and Explanation:** Identifies simple cause and effect situations in provided examples *(for example: smoke causes a fire alarm to go off; practicing reading causes increased stamina for reading to self; cutting down trees in the rainforest leads to habitat loss).* **Representation:** Represents key elements in a system *(for example: draws and/or labels different parts of a plant).* **Transfer*:** Identifies common elements of cause/effect relationships.	**Identification and Explanation:** Identifies and explains a single cause-and-effect loop in a single system *(for example: increasing bee populations [pollinators] lead to higher plant populations that leads to increasing food for the bees which supports bee populations*). Uses key terms including *cause*, *effect*, *interdependent*, and/or *connection* to describe an interdependent relationship. **Representation:** Represents connections between key elements of a system *(for example: uses a connection circle to show the relationships between: hunger, thirst, eating, drinking, energy, and physical activity).* **Transfer*:** Generalizes the key elements of a system with interdependent relationships	**Identification and Explanation:** Distinguish whether a loop represents a reinforcing or balancing process (*for example: as predator numbers increase, prey population decreases, which leads to decreased predator numbers, which is a balancing loop. Or, as a student eats healthy foods, they have more energy to play, and they add more healthy foods to their diet, which is a reinforcing loop).* **Representation:** Represent a circular causal relationship between two elements of a system (*for example: uses a causal loop to show the reinforcing feedback between kindness and acts of kindness).* **Transfer*:** Compare interdependencies in one situation to a situation of a similar type (*for example: the number of predators such as*

			and provides relevant examples *(for example: "These kinds of systems have two or more parts that need each other to be successful," so plants and animals in the desert ecosystem would be an example because . . .).*	*mountain lion populations related to the number of prey such as deer population in an ecosystem parallels the number of a plant population to the number of a pollinating species such as bees*).
CONSEQUENCES  **Causal loops**  **Stock-flow maps and computer models**	**Identification and Explanation:** Identifies examples of *short-term consequences* and *long-term consequences, intended consequences*, and *unintended consequences* from provided events. **Representation:** Lists results occurring from actions. **Transfer*:** Explains key terms needed for transfer such as *action*, *consequences*, *short-term*, *long-term*, *intended* and/or *unintended* when provided with examples or definitions. See possible student misconceptions following the rubric.	**Identification and Explanation:** Explains a consequence for a specific action *(for example: Mercy Watson climbed into bed when she was scared, so the bed broke.).* **Representation:** Connects results or consequences occurring from actions on a provided causal loop diagram. **Transfer*:** Identifies and compares the characteristics of short- and long-term consequences *(see characteristics of short- and long-term consequences below; for example: In music class, a student acted out because he/she was only thinking about getting others to laugh and was not thinking about how his/her action would interrupt learning – people often forget to think about long-term consequences).*	**Identification and Explanation:** Explains the difference between a short-term consequence and long-term consequence, and provides a relevant example from a given text or a personal experience *(for example: I cut in line so I got to use the swings first, but then I had to write an apology to the student I cut in line.).* **Representation:** Identifies short-term and/or long-term consequences of a particular action on a provided causal loop diagram. **Transfer*:** Generalizes the key elements of a situation involving actions and consequences (*for example: "This situation involves an individual who breaks rules" or "In this situation, a solution fixes the problem, but creates others in other areas"*).	**Identification and Explanation:** Identify and explain short-term and long-term intended consequences of a particular action (*for example: explains how reducing water use at home will result in short-term economic benefit to the homeowner, and long-term benefit to the desert ecosystem).* **Representation:** Represent short- and long-term intended consequences through a causal loop diagram, stock-flow map, computer model/simulation, and/or kinesthetic activity. **Transfer*:** Apply conclusions about the consequences in one situation to a situation of a similar type (*for example: consequences of the actions of one character to the actions of a character in a different text).*

			Compares common elements of actions and consequences in two situations using a provided comparison graphic organizer.	
SYSTEM AS CAUSE  Iceberg  Ladder of inference	**Identification and Explanation:** Identifies examples of different systems *(for example: a plant system, an ecosystem, a gear system*). Chooses examples of *observable events and patterns of behavior* from provided samples or lists. **Representation:** Labels system components on a systems tool *(for example: iceberg or a ladder of inference)* using provided terms. **Transfer*:** Defines key vocabulary necessary to transfer concepts such as observable events, patterns of behavior, structures, mental models, similar and/or different. See possible student misconceptions following the rubric.	**Identification and Explanation:** Identifies elements of a familiar system (*for example: in a classroom system, the students, the teacher, the lesson activities, the work, and the assessments would be elements of a classroom system*). **Representation:** Classifies examples of system components such as observable events, patterns of behavior, structures, and/or mental models of a provided, familiar representation of a system. **Transfer*:** Identifies common elements of a system.	**Identification and Explanation:** Identifies a system's observable events and possible patterns of behavior using a systems tool, such as the iceberg (*for example: observation of students using active listening during discussions; possible pattern of behavior might be using signals to indicate a wish to share, or using a talking stick during discussions, etc.)*. **Representation:** Visually represents observable events and patterns of behavior of a familiar system on a systems tool. **Transfer*:** Identifies two systems with similarities at the level of observable events, patterns of behavior, structures of the system, or mental models.	**Identification and Explanation:** Identify a system's structures and mental models that result in observable patterns and events. **Representation:** Visually represent system structures and mental models of a familiar system on a systems tool. **Transfer*:** Compare two systems at all the levels of observable events, patterns of behavior, structures of the system, and mental models (*for example: compare a classroom and a city or town*).

LEVERAGE ACTIONS  Causal loops  Iceberg	**Identification and Explanation:** Identifies desirable and undesirable effects of an action. **Representation:** Illustrates a desirable outcome and an undesirable outcome (using pictures, written words, verbal report, artistic representation) or chooses pictures that depict desirable and undesirable outcomes. **Transfer*:** Defines and provides examples of key vocabulary about basic leverage concepts such as *desirable*, *undesirable*, *leverage*, and/or *similar*. See possible student misconceptions following the rubric.	**Identification and Explanation:** Describes the basic concept of leverage action (*i.e., an action that would bring about a desirable effect).* **Representation:** Labels events as a "cause" or an "effect" using a provided systems tool *(for example: draws arrows on a connection circle from cause to effect).* **Transfer*:** Identifies one or more common attributes of leverage or leverage actions *(for example: an action that has a desirable effect, an action that has the potential to change how a system functions, etc.).*	**Identification and Explanation:** Identifies potential leverage actions within a specific situation (*for example: different ways a student could make a positive impact on their school environment*). **Representation:** Depicts cause and effect relationships within a system using systems diagrams *(for example: stock-flow map, causal loop).* **Transfer*:** Generalizes the key elements of a situation with multiple possible leverage actions (*for example: "This situation offers several ways a person could help our classroom.").*	**Identification and Explanation:** Identify and explain a more high-leverage action that made a change within a system *(for example: when farmers in Arizona changed how they planted, the soil system was improved).* Rank potential leverage actions within a system using the criteria of desirable effectiveness *(for example: criteria for ranking leverage actions might include time it would take to implement, number of unintended consequences that might result, long-term efficacy of action, etc.).* **Representation:** Represent potential high-leverage actions within a system (*for example: all the places humans could intervene in the water cycle, through a causal loop diagram, stock-flow map, system dynamics computer model, or iceberg).* **Transfer*:** Compare leverage action(s) in two similar systems *(for example: compare the leverage actions of one character in a story to the leverage actions of another character in a different story*; the boy *in The Curious Garden makes his community*

				better through service and leading by example. The cows in Click, Clack, Moo make their community better through letter writing and protests. Or similarly, comparing the tactics of Cesar Chavez and Martin Luther King, Jr.
BIG PICTURE  Iceberg  Causal loops  Connection circles	**Identification and Explanation:** Identifies parts of a system from provided information (*for example: matches names of parts of plants to a diagram of a plant*). **Representation:** Selects pictures or drawings to represent a sequence of events. Selects labels or written descriptions for diagrams. **Transfer*:** Defines key vocabulary about basic system concepts such as *system*, *attributes*, *cycle*, *sequence*, and/or *connected*. See possible student misconceptions following the rubric.	**Identification and Explanation:** Explains sequential events or parts of a system in isolation from other events/parts of the system (*for example: explains the function of the roots of a plant without connecting that function to the other parts of the plant*). **Representation:** Lists goals, problems, and/or behaviors of the actors/parts of a system on a provided organizer. **Transfer*:** Identifies one or more common attributes of how a system operates *(for example: a system can appear organized and a system can also appear chaotic. A system can be operated by one person, a group of people, or no one).*	**Identification and Explanation:** Identifies multiple parts of a system and explains the basic details or functions of the parts as they work together (*for example: explains how each part of a plant serves a specific function and connects all parts as needed for the plant's survival*). **Representation:** Creates a representation of the parts of a system and shows connections among the parts using a systems tool (*for example: the predators of the desert and the prey of the desert in a simple connection circle).* **Transfer*:** Generalizes the key elements of how a system operates (*for example: "This lunchroom is out of control because it is too crowded or there are no rules"; Classrooms function better when everyone has the*	**Identification and Explanation:** Identify and explain behaviors, goals, problems, and/or relationships among parts within a system as a series of interrelated details or events. *(for example: how a plant's success and survival is related to its physical environment).* **Representation:** Create a representation of a whole-system perspective using a systems tool (*for example: how coyotes, rabbit and plant populations relate to one another using a stock-flow map).* **Transfer*:** Apply conclusions about how one system operates to a system of a similar type (*for example: an orchestra conductor with the orchestra and the music teacher during a school chorus performance).*

 **Stock-flow maps and computer models**			*same mental models about learning).* Identifies common elements of a system in two situations.	
SELF-REGULATION AND REFLECTION	**Reflection:** Identifies own strengths and weaknesses as a systems thinker with adult support. **Planning:** Sets personal goals for applying systems thinking habits and tools with adult support. **Mindset:** Explains the relationship between effort and success *(for example: "The harder I work at this, the better I'll be at it"; "I will work harder in this class from now on.").* See possible student misconceptions following the rubric.	**Reflection:** Identifies own strengths and weaknesses as a systems thinker. **Planning:** Sets personal goals for applying systems thinking habits and tools. **Mindset:** Demonstrates a desire to improve *(for example: employs more practice, sets goals for improvement, asks for help from others instead of giving up).*	**Reflection:** Assesses application of the habits and tools of a systems thinker in response to feedback and/or the rubric. Describes the learning that resulted from systems thinking. **Planning:** Sets goals for applying systems thinking based on feedback and/or the rubric. **Mindset:** Demonstrates a growth mindset (the belief that he or she can get "smarter" at systems thinking through effective effort) in response to setbacks and challenges *(for example: persists on difficult tasks, takes risks in the learning process, accepts and uses feedback/criticism, is comfortable making mistakes, explains failure from a growth mindset perspective).*	**Reflection:** Accurately reflect on the application of systems thinking habits and tools; use reflection and/or feedback to revise thinking or to improve ideas. Question and critique own thinking process. **Planning:** Seek out, select, and use resources and strategies to achieve goals for improving the application of systems thinking habits and tools. **Mindset:** Proactively improve own areas of weakness by employing effective strategies to increase growth mindset *(for example: perseverance, taking risks, effective decision-making, actively seeking others' feedback, deliberate practice, finding and using external resources [skilled peers, other adult experts] to enrich and extend learning).*

Possible Misconceptions: K-2 Systems Thinking

The following chart lists possible misconceptions about **Systems Thinking**. Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

Students might exhibit the following misconception, belief, or perception that…		
Change Over Time	**Identification and Explanation**	• All change happens in the same way. • Once change is initiated, it will follow the same rate or trend over time. • Any action will result in immediate change.
	Representation	• Change-over-time graphs all take the same shape. • Actions (verbs) and things (nouns) are interchangeable as stocks and flows. • Reinforcing and balancing loops are value judgments (for example: reinforcing = good and balancing = bad).
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
Interdependencies	**Identification and Explanation**	• Two things are related because they happen at the same time. • Correlation equals causation.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

Possible Misconceptions: K-2 Systems Thinking

The following chart lists possible misconceptions about **Systems Thinking**. Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

Students might exhibit the following misconception, belief, or perception that…		
Consequences	**Identification and Explanation**	• There are only intended consequences. • One type of consequence (short- or long-term, intended or unintended) is more important than another.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
System as Cause	**Identification and Explanation**	• My perception of a situation is accurate. • Events just "happen" for no reason or are caused by external factors. • My perspective, beliefs, and/or actions do not influence the system, situation, or behavior of others. • Implementing a structure or strategy once should lead to a change in events. • Once the patterns and/or observable events change, the structures are no longer needed to maintain the outcome.
	Representation	• All information about the system is of equal value. • We can fully understand a system by analyzing isolated parts. • Complicated or lengthy explanations or representations are inherently better.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

Possible Misconceptions: K-2 Systems Thinking

The following chart lists possible misconceptions about **Systems Thinking**. Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

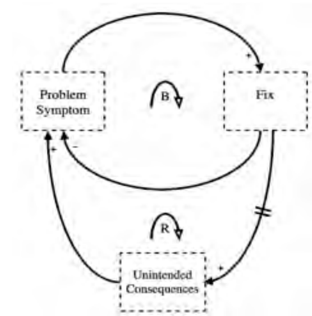
Students might exhibit the following misconception, belief, or perception that…		
Leverage Actions	**Identification and Explanation**	• All leverage actions are equally impactful. • Any action is a leverage point because it is part of the system. • A leverage point must be large and obvious. • A leverage action must come from an external source.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
Big Picture	**Identification and Explanation**	• We cannot begin to explore the big picture until we fully understand all the details. • The details don't matter in relation to the big picture. • A system only has one perspective, or only one perspective that matters. • Big-picture understanding is static; once we identify it, it never changes.
	Representation	• All elements of the system are of equal importance. • Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

Possible Misconceptions: K-2 Self-Regulation and Reflection

The following chart lists possible misconceptions about **Self-Regulation and Reflection.** Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

<table>
<tr><th colspan="3">Students might exhibit the following misconception, belief, or perception that…</th></tr>
<tr><td rowspan="3">Self-Regulation and Reflection</td><td>Reflection</td><td>Reflection is all about what I think; other people's perspectives don't matter.
Only the teacher's perspective matters when it comes to identifying strengths and weaknesses.
I don't have any weaknesses.
I don't have any strengths.
All weaknesses affect my performance in the same way.
Reflection is a waste of time; I don't need to reflect to improve.</td></tr>
<tr><td>Planning</td><td>A goal is the same thing as a plan.
Any goal is a worthy goal.
Short-term goals aren't important.
I don't need a plan; if I set a goal, I will achieve it.
I should set goals in areas where I am already successful.
I should set the same goal over and over.
Someone else will give me resources and ideas about how to improve.</td></tr>
<tr><td>Mindset</td><td>Systems thinking is a talent and not a skill; I am as good at it as I'll ever be.
If I'm really good at something, I won't encounter any challenges.
If I experience a setback, I've failed.
Others' feedback can't help me.
Mistakes are bad; smart people don't make mistakes.
The safe route leads to guaranteed success.</td></tr>
</table>

Archetype: A multi-loop causal loop diagram that represents behavior commonly seen in complex systems. The archetypes are named - for example, “Fixes That Fail.” In these systems, a problem is solved by some fix (a specific solution) that causes an immediate positive effect. Nonetheless, the “side effects” of this solution, after a time delay, make the problem worse.



Feedback: The interaction between two stocks that affect each other in turn.

- Balancing Feedback: “Effect of an action returned (fed back) to oppose the very action that caused it. Balancing feedback has a correcting or stabilizing effect on the system, and it reduces the difference (variance) between where the system is (the current status) and where it should be (the target value, or objective). For example, demand and supply in an economy work on each other to reach a stable (equilibrium) state through the feedback of information about price and availability. If supply is known to be greater than demand, price falls. Low price forces suppliers to pull out of the market, causing shortage that results in increase in price. High price attracts more supplies than there is demand ... and so on until a rough parity is achieved. Criticism can also be a balancing feedback if it results in the desired change in the recipient's behavior.” (BusinessDictionary.com)

- Reinforcing Feedback: “Effect of an action, change, or decision returned to amplify or bolster what caused it. Reinforcing feedback drives a system increasingly faster in the direction it is already going whether away from its goal (called a vicious circle) or towards it (called a virtuous circle). It may destroy the system by pushing it beyond its limits unless the circle runs out of steam or is countered by a balancing feedback. A small ball of snow rolling downhill is an example of vicious circle. As its size continues to grow, it picks up ever-increasing amounts of snow. This process stops only when the giant ball of snow disintegrates under its own weight or runs out of slopes to roll down. Compound interest is an example of a virtuous circle. A praise or a reward can also be a reinforcing feedback if it results in the desired change in the recipient's behavior.” (BusinessDictionary.com)

Flow: Rate of increase or decrease of a quantity that accumulates in a stock.

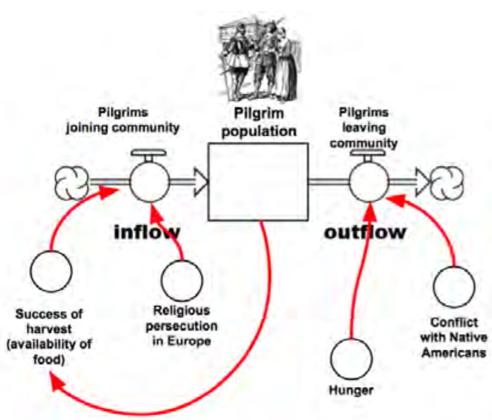
Limits: A definition of the boundaries and extent of the system, including which physical, environmental, structural, or temporal elements are relevant, and which aren’t; systems may be nested within one another. Defining the limits of a system is a crucial part of the analysis of the system.

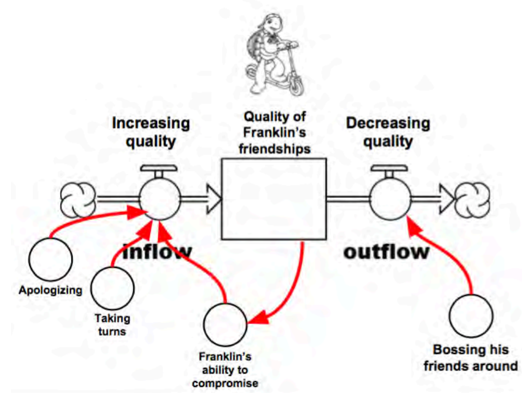
Stock: (Accumulation): A quantity that can be built up or depleted over time.

Time Delay: A gap in time between a cause and its effect within a system. Time delays may make systems hard to understand or predict.

Curricular Examples for Interdependencies: The following examples from grades K-2 may give teachers an idea of how to use stock-flow maps:

Subject Area	Stock	Flow	Converters	Potential Feedback Relationships
Science	Number of trees (Natural Resources)	• Increasing • Decreasing	• Planting new trees (increasing) • Cutting down to build houses (decreasing)	Planting trees specifically for housing instead of taking from nature (balancing feedback)
English Language Arts	Quality of Franklin's friendships (from *Franklin is Bossy*)	• Increasing • Decreasing	• Apologizing and taking turns (increasing) • Bossing his friends (decreasing)	Franklin's ability to compromise (reinforcing feedback)
Social Studies	Amount of money in a business' bank account (Economics)	• Increasing • Decreasing	• Sales of product (increasing) • Expenses (decreasing)	Increasing or decreasing the price based on the demand of the product (balancing feedback)
History	Pilgrim population	• Increasing • Decreasing	• People joining Pilgrim community and availability of food (increasing) • People leaving for new areas; hunger, and conflict with Native Americans (decreasing)	Success in planting their own food, building shelter (reinforcing feedback)





Curricular Examples for System as Cause:

Subject Area	System	Events	Patterns	Structures	Mental Models
Science	Chick population	Chicks hatch	• Embryo development over time • Heat over time	• Chick population stock-flow map • Loop showing how the incubator maintains the correct temperature	• All chickens should survive (Kinder) • Male chicks should be killed (Farmers)
Social Studies (Building Classroom Community)	Classroom Good Behavior Points	Students earn class points	• Points earned each day over time • Points earned each year	• Stock-flow map with points earned (no outflow) • Reinforcing loop showing how earning points increases good behavior and good behavior increases earning points.	• Students earn points because they want rewards • When students earn points, they are more likely to reflect on their behavior and are able to track trends in behavior.

Used with permission from the Waters Center for Systems Thinking.

Systems Thinking Rubric

Grades 3-5

Catalina Foothills School District

Tucson, Arizona

General Description and Suggestions for Use

The district's strategic plan, Envision21: Deep Learning, forms the basis for a focus on cross-disciplinary skills/proficiencies necessary for preparing our students well for a 21st century life that is increasingly complex and global. These skills, which are CFSD's "deep learning proficiencies" (DLPs) are represented as 5c + s = dlp. They are the 5Cs: (1) Citizenship, (2) Critical Thinking and Problem Solving, (3) Creativity and Innovation, (4) Communication, (5) Collaboration + S: Systems Thinking. CFSD developed a set of rubrics (K-2, 3-5, 6-8, and 9-12) for each DLP.

These rubrics were developed using a backward design process to define and prioritize the desired outcomes for each DLP. They provide a common vocabulary and illustrate a continuum of performance. By design, the rubrics were not written to align to any specific subject area; they are intended to be contextualized within the academic content areas based on the performance area(s) being taught and assessed. In practice, this will mean that not every performance area in each of the rubrics will be necessary in every lesson, unit, or assessment.

The CFSD rubric for **Systems Thinking** was designed as a cross-disciplinary tool to support educators in teaching and assessing the performance areas associated with this proficiency:

- **Change Over Time**
- **Interdependencies**
- **Consequences**
- **System as Cause**
- **Leverage Actions**
- **Big Picture**
- **Self-Regulation and Reflection**

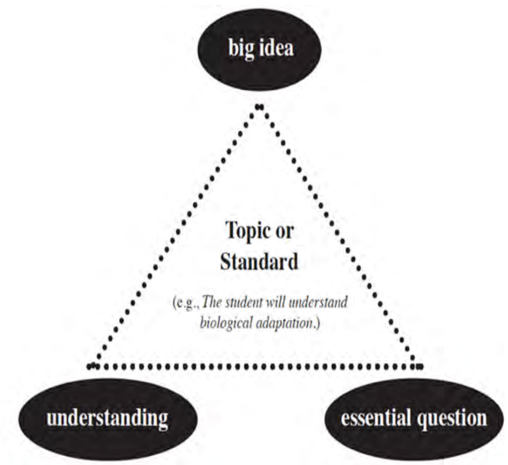
This tool is to be used primarily for formative instructional and assessment purposes; it is not intended to generate psychometrically valid, high stakes assessment data typically associated with state and national testing. CFSD provides a variety of tools and templates to support the integration of **Systems Thinking** into units, lessons, and assessments. When designing units, teachers are encouraged to create authentic assessment opportunities in which students can demonstrate mastery of content and the deep learning proficiencies at the same time.

The approach to teaching the performance areas in each rubric may vary by subject area because the way in which they are applied may differ based on the field of study. Scientists, mathematicians, social scientists, engineers, artists, and musicians (for example), all collaborate, solve problems, and share their findings or work within their professional communities. However, the way in which they approach their work, the tools used for collaboration, and the format for communicating their findings may vary based on the profession. These discipline-specific expressions of the 5Cs + S may require some level of customization based on the subject area. Each rubric can also be used to provide students with an opportunity to self-assess the quality of their work in

relation to the performance areas. Student-friendly language or "I can" statements can be used by students to monitor and self-assess their progress toward established goals for each performance area.

Transfer
CFSD educators prioritize understanding and transfer to ensure that learning extends beyond the school experience. This 2019 version of the DLP, **Systems Thinking**, includes long-term **transfer goals** that describe autonomous applications of student learning in college, career, and civic life. "Drill and direct instruction can develop discrete skills and facts into automaticity…but they cannot make us truly able. Understanding is about *transfer*, in other words. To be truly able requires the ability to transfer what we have learned to new and sometimes confusing settings. The ability to transfer our knowledge and skill effectively involves the capacity to take what we know and use it creatively, flexibly, fluently, in different settings or problems, on our own" (Wiggins and McTighe, 2011, p. 40).

Big Ideas
This 2019 version of the DLP, **Systems Thinking,** includes a set of Understandings and Essential Questions (UEQs) developed by an interdisciplinary team of K-12 teachers and administrators with guidance from Jay McTighe, author of *Understanding by Design*. These big ideas will guide teachers toward the thoughtful design of assessments, units, and lessons that will facilitate transfer of deep learning. "Because big ideas are the basis of unified and effective understanding, they provide a way to set curriculum and instructional priorities…they illuminate experience; they are the linchpin of transfer…" (Wiggins and McTighe, 2011, p.71). "Understandings are the specific insights, inferences, or conclusions about the big idea you want your students to leave with" (Wiggins and McTighe, 2011, p. 80). "Essential questions make our unit plans more likely to yield focused and thoughtful learning and learners" (McTighe, 2017; McTighe & Wiggins, 2013, p. 17). The figure on the right represents the interrelationship among big ideas, understandings, and essential questions.



The **DLP Understandings** are written for K-12 because they express lasting, transferable goals for student learning. Understandings are meant to be revisited over time and across contexts. The continuity of working toward the same goals will help students deepen their understanding from Kindergarten to 12th grade. Understandings are primarily planning tools for teachers, although teachers may choose to share them with their students, if appropriate. Communicating an Understanding does not give away "the answer," since simply stating an Understanding is not the same as truly grasping its meaning.

The **Essential Questions** are teaching and learning tools that help students unpack the Understandings. They support inquiry and engagement with deep learning and therefore may vary in complexity across grade levels.

Systems Thinking Transfer Goals and UEQs

Transfer Goals	
Students will be able to independently use their learning to. . . • Employ the habits of a systems thinker to better understand situations, make effective decisions, and plan for the future.	
Understandings	**Essential Questions**
Students will understand that. . .	**Students will keep considering. . .**
• A system is comprised of interrelated and interdependent parts which serve a specific purpose; changing one part of a system affects other parts.	• What is a system? • How do elements of a system affect each other? • How do the elements fit into the system as a whole? • Why are things the way they are? • What are the causal relationships within a system?
• Systems thinking enables us to look at problems and situations in new ways, which can lead to new solutions and insights.	• How can we use systems thinking to effect change, make predictions, and/or solve problems? • How can we maintain balance between the "big picture" and important details?
• Systems thinkers use specific habits, tools, and vocabulary to represent, describe, and analyze systems and solve problems.	• What makes an effective systems thinker? • How can we use the habits of a systems thinker to help us understand and analyze a system? • How can we come to understand and improve a system? • Which tool(s) will be most effective in analyzing the relationships within the system?
• Systems thinkers observe and connect information in order to understand systems.	• What makes an effective systems thinker? • What are the causal relationships within a system? • How can we maintain balance between the "big picture" and important details?
• A system's structure drives its behavior.	• How do structures drive behavior? • Why are things the way they are?

• Examining a system from different perspectives helps us identify various mental models and better understand the system.	• How do mental models affect our thoughts and actions? • Why are things the way they are?
• Recognizing patterns of change enables prediction and guides planning for the future.	• What has changed and why? • How can analyzing patterns help us predict or plan for the future? • What patterns or trends have emerged over time? • How does understanding of one system transfer to understanding of another system?
• Actions can have short-term, long-term, and/or unintended consequences; we can strategically choose leverage actions that produce or increase desired results.	• What are the causal relationships within a system? • What are the systemic effects of actions in a system? • How does determining possible short-term, long-term, and/or unintended consequences help us make decisions? • How do we determine where a small change might have a long-lasting, desired effect?

Self-Regulation and Reflection Transfer Goals and UEQs

Transfer Goals	
Students will be able to independently use their learning to. . . • Improve performance and persevere through challenges by applying deliberate effort, appropriate strategies, and flexible thinking.	
Understandings	**Essential Questions**
Students will understand that. . .	**Students will keep considering. . .**
1. Effective learners set goals, regularly monitor their thinking, seek feedback, self-assess, and make needed adjustments.	• How am I doing? How do I know? What are my next steps? • What is the most effective way to monitor my progress? • How do I know which feedback will help me improve my work? • How can I get useful feedback? • How do I prioritize my work?
2. We can always improve our performance through deliberate effort and use of strategies.	• How can I keep getting better at systems thinking?

The deep learning proficiencies (5c+ s) are highly interconnected. For example, productive collaboration is contingent upon effective communication. Efficient and effective problem solving often requires collaboration skills. Divergent and convergent thinking, which are traits of Creativity and Innovation, are directly related to critical thinking. Our students will need to use a combination of proficiencies to solve problems in new contexts beyond the classroom. Therefore, it is important to be clear about which proficiency and/or performance area(s) are the focus for student learning, and then to assist students in understanding the connections between them and how they are mutually supportive.

<u>What does Score 1.0 – Score 4.0 mean in the rubrics?</u>

The rubrics are intended to support student progress toward mastering the deep learning proficiencies (DLPs). Four levels of performance are articulated in each rubric: Score 1.0 (Novice), Score 2.0 (Basic), Score 3.0 (Proficient), and Score 4.0 (Advanced). The descriptions follow a growth model to support students in developing their skills in each performance area. Scores 1.0 (Novice) and 2.0 (Basic) describe positive steps that students might take toward achieving Score 3.0 (Proficient) or Score 4.0 (Advanced) performance.

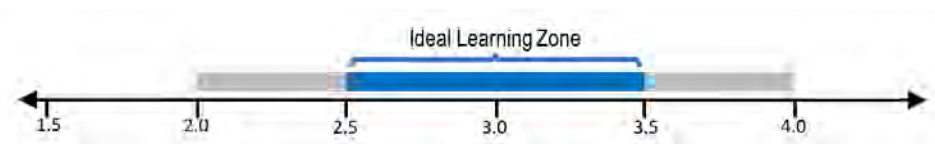
When using the rubrics to plan for instruction and assessment, teachers need to consider the knowledge and skills described in the Score 2.0 column (Basic) to be embedded in the Score 3.0 (Proficient) and 4.0 (Advanced) performance. The Novice level (Score 1.0) indicates that the student does not yet demonstrate the basic skills within the performance area, but that he/she exhibits related readiness skills that are a stepping-stone to a higher level of proficiency. Descriptions at the Novice level also include likely misconceptions that the student might exhibit.

The descriptive rubrics are designed to illustrate students' depth of knowledge/skill at various levels in order to facilitate the instructional and assessment process for all learners. At some performance levels, the indicators may remain the same, but the material under study is more or less complex depending on the grade level band (for example: the complexity of the material at grades 6-8 differs from that of grades 3-5 or 9-12).

The following descriptions explain the four levels on the rubric:

- Score 1.0 (Novice): Describes student performance that demonstrates readiness skills and/or misconceptions and requires significant support.
- Score 2.0 (Basic): Describes student performance that is below proficient, but that demonstrates mastery of basic skills/knowledge, such as terms and details, definitions, basic inferences, and processes.
- Score 3.0 (Proficient): Describes student performance that is proficient – the targeted expectations for each performance area of the DLP.
- Score 4.0 (Advanced): Describes an exemplary performance that exceeds proficiency.

The image below represents the ideal learning zone for students as 2.5 – 3.5.



Glossary

Long-term consequences: Intended or unintended consequences that have longer lasting effects and that are harder to anticipate.

Short-term consequences: Short-term or immediate effects that are often easier to identify or predict. Many humans make decisions just based on short-term consequences.

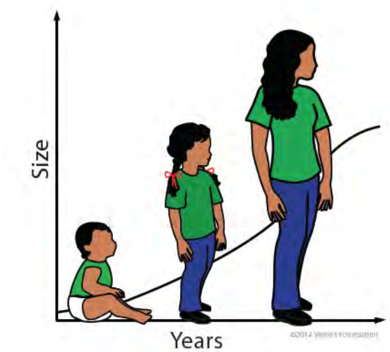
*Transfer: Before a student can successfully transfer, he/she must first master the other skills within each performance area.

Sources

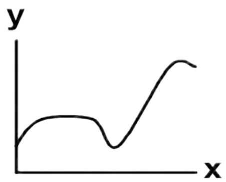
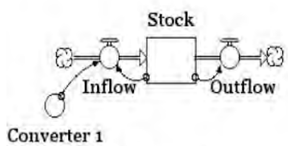
The following sources directly influenced the revision of CFSD's rubrics:

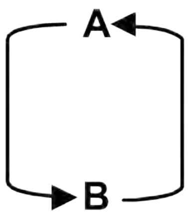
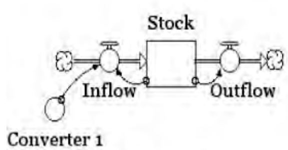
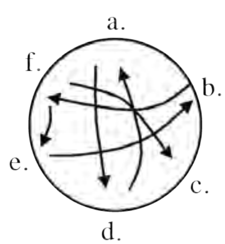
- Catalina Foothills School District. (2011, 2014, 2016, 2018). Rubrics for 21st century skills and rubrics for deep learning proficiencies. Tucson, Arizona.
- Waters Center for Systems Thinking, https://waterscenterst.org/

A **system** is a collection of elements that interact with each other over time to function as a whole (Waters Center for Systems Thinking, 2018). A **systems thinker** is anyone who uses the **Habits of a Systems Thinker** (see end of document) in combination with the concepts and visual tools of systems thinking to increase understanding of systems and how they influence both short- and long-term consequences. Many systems thinking concepts are embedded either explicitly or implicitly within the Habits of a Systems Thinker. The CFSD Systems Thinking rubrics include the concepts of Change Over Time, Interdependencies, Consequences, System-as-Cause, Leverage Actions, and Big Picture. Systems thinking provides students with a more effective way to interpret the complexities of the world in which they live—a world that is increasingly dynamic, global, and complex.

Change Over Time, page 8	**Consequences, page 10**	**Leverage Actions, page 12**
		
Interdependencies, page 9	**System-as-Cause, page 11**	**Big Picture, page 12**
		

SYSTEMS THINKING

DLP Performance Area	1.0 (Novice) The student may exhibit the following readiness skills for Score 2.0:	2.0 (Basic) When presented with a grade-appropriate task, the student:	3.0 (Proficient) In addition to Score 2.0, the student:	4.0 (Advanced) In addition to Score 3.0, the student may:
CHANGE OVER TIME  **Behavior-over-time graphs**  **Stock-flow maps**	**Identification and Explanation:** Identifies key terms such as “rate of change,” “element,” “trend,” and “pattern” when provided with examples or definitions. **Representation:** Labels events on a provided behavior-over-time graph. **Transfer*:** Identifies common elements of two situations involving change over time. See possible student misconceptions following the rubric.	**Identification and Explanation:** Describes a change that occurs over time. Lists and orders events. **Representation:** Charts a change over time, given a graph with pre-defined *x* and *y* axes. **Transfer*:** Generalizes the key elements of situations that change over time (*for example: “This situation involves an individual whose actions are influenced by her environment” or “I can see a steady increase followed by a sudden drop”*).	**Identification and Explanation:** Describes general trends in change over time *(for example: the increased support for American Independence correlates with the increase in Britain’s repressive trade laws).* Identifies elements of a system that change over time. **Representation:** Constructs a behavior-over-time graph, annotated with evidence to support claims, to chart a general change over time, including defining a time frame (x axis) and a scale for changes in an accumulation (*y* axis) (*for example: line graph showing a general trend*). **Transfer*:** Applies conclusions about change over time in one situation to a situation of a similar type (*for example: perseverance over time for two characters in different texts*).	**Identification and Explanation:** Describe the nature of specific trends in changes over time (*for example: a gradual decrease of Native Americans in the American West, or the uneven increase in the number of wolves in Arizona).* Analyze why elements of a system change over time. **Representation:** Construct a detailed behavior-over-time graph (*for example: depicts transitions, annotates with evidence supporting claims, etc.*) to chart specific changes over time (including specific changes in rate, relationship between general trend and transition points). **Transfer*:** Apply understanding of an identified change over time to analyze a situation of a different type that operates in a similar manner (*for example: a fictional character’s perseverance over time compared to that of an historical figure*).

INTERDEPENDENCIES  Causal loops  Stock-flow maps  Connection circles	**Identification and Explanation:** Identifies key terms including "feedback loop," "reinforcing," "balancing," "cause," and "effect" in provided examples. Identifies simple cause and effect situations in provided examples. **Representation:** Represents key elements in a system *(for example: draws and/or labels different parts of a plant).* Explains a given systems tool using systems terminology. **Transfer*:** Identifies common elements of cause/effect relationships in similar events or situations. See possible student misconceptions following the rubric.	**Identification and Explanation:** Identifies and explains a single cause-and-effect loop in a single system *(for example: increasing bee populations [pollinators] lead to higher plant populations that leads to increasing food for the bees which supports bee populations*). **Representation:** Represents connections between key elements of a system (*for example: uses a connection circle to demonstrate as Despereaux's courage increases, his fear decreases).* **Transfer*:** Generalizes the key elements of a system with interdependent relationships (*for example: "This system has two groups that depend on each other" or "This system involves interdependent parts").*	**Identification and Explanation:** Distinguishes whether a loop represents a reinforcing or balancing process (*for example: as predator numbers increase, prey population decreases, which leads to decreased predator numbers...which is a balancing process, or as a muscle pair contracts, it pulls on bones and joints to create a specific movement in a desired direction, which is a reinforcing process because the dynamic would be sustaining*). **Representation:** Represents a circular causal relationship between two elements of a system (*for example: uses a stock-flow map or causal loop diagram*). **Transfer*:** Compares interdependencies in one situation to a situation of a similar type (*for example: the increase in a predator population, such as mountain lions, in response to an increase in a prey population, such as deer, in an ecosystem parallels the increase in a plant population in response to an increase in a pollinating species such as bats*).	**Identification and Explanation:** Identify and explain causality in a system of multiple connected loops. Explain the behavior over time of any variable, or stock in the system in relation to another variable or stock *(for example: hawk, songbird, and insect populations are linked in two connected loops. See below).* **Representation:** Represent causality in a system of multiple connected loops (*for example: uses a stock-flow map or causal loop diagram*). Identify when causality can best be represented with a stock-flow map or causal loop diagram (*for example, the interdependence between Arizona population growth and amount of available natural resources can best be represented with a stock-flow map).* **Transfer*:** Apply conclusions about key interdependencies in one situation to a situation of another type (*for example: the interdependent functions of a factory or manufacturing plant are similar to the interdependent parts of a cell).*

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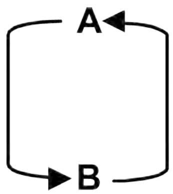
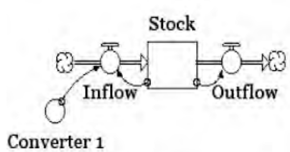
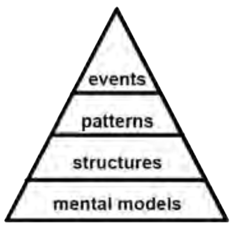
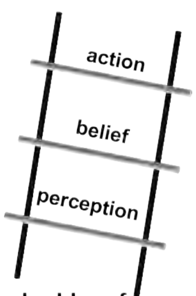
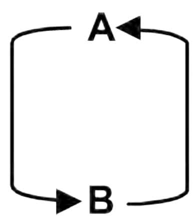
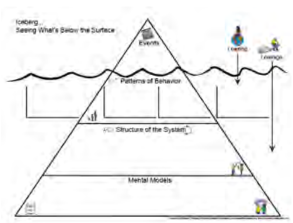
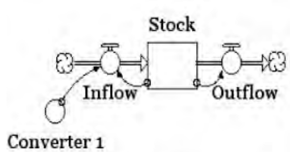
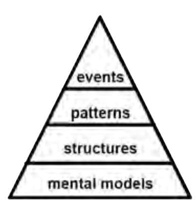
CONSEQUENCES  Causal loops  **Stock-flow maps and computer models**	**Identification and Explanation:** Explains a consequence for an action. Classifies examples of "short-term consequences" and "long-term consequences," "intended consequences," and "unintended consequences" from provided events. **Representation:** Lists results occurring from actions. **Transfer*:** Identifies and compares the characteristics of short- and long-term consequences. See possible student misconceptions following the rubric.	**Identification and Explanation:** Explains the difference between a short-term consequence and long-term consequence. Explains the difference between intended and unintended consequences. **Representation:** Identifies short-term and/or long-term consequences of a particular action on a provided causal loop diagram. **Transfer*:** Generalizes the key elements of a situation involving actions and consequences (*for example: "This situation involves an individual who breaks rules" or "In this situation, a solution fixes the problem, but creates others in other areas"*). Compares common characteristics of actions and consequences in two situations using a provided comparison graphic organizer.	**Identification and Explanation:** Identifies and explains short-term and long-term intended consequences of a particular action (*for example: Explains how reducing water use at home will result in short-term economic benefit to the homeowner, and long-term benefit to the desert ecosystem).* **Representation:** Represents short- and long-term intended consequences through a causal loop diagram, stock-flow map, computer model/simulation, and/or kinesthetic activity. **Transfer*:** Applies conclusions about the consequences in one situation to a situation of a similar type (*for example: consequences of the actions of early Plymouth Pilgrims to the actions of early Western settlers).*	**Identification and Explanation:** Identify and explain observed short- term and long-term unintended consequences as a result of an action or series of actions (*for example: explains a case in which "the most obvious solution" made a situation worse in the long term*). Predict and explain potential unintended consequences of an action (*for example: how a proposed solution could potentially backfire*). **Representation:** Show the short- and long-term intended and unintended consequences of actions within a complex system using a systems archetype (*for example: using a Fixes That Fail archetype to represent the slavery compromises prior to the Civil War).* **Transfer*:** Apply conclusions about consequences in one situation to a situation of another type (*for example: the effects of increasing the distance of the load from the fulcrum in a simple machine to the effects of carrying a heavy object on a joint such as the elbow).*

SYSTEM AS CAUSE  Iceberg  Ladder of inference	**Identification and Explanation:** Identifies elements of a system from provided examples (*for example: in a classroom system, the students, the teacher, the lesson activities, the work, and the assessments would be elements of a classroom system*). **Representation:** Labels elements of a system with provided systems tools *(for example: iceberg or a ladder of inference).* **Transfer*:** Identifies common elements of a system. See possible student misconceptions following the rubric.	**Identification and Explanation:** Identifies observable events and patterns of behavior in a familiar system (*for example: observations/events – students performing well on a test; pattern of behavior – homework completion and earlier test results*). **Representation:** Classifies given information as observable events, patterns of behavior, structures, and/or mental models of a provided system. **Transfer*:** Identifies two systems with similarities at the levels of observable events, patterns of behavior, structures of the system, and/or mental models.	**Identification and Explanation:** Identifies a system's structures and mental models using a systems tool, such as the iceberg (*for example: underlying structures - lesson design and peer tutoring; and mental model - "all students can be successful with deliberate practice and feedback"*). **Representation:** Visually represents observable events, patterns of behavior, structures of the system, and mental models. *[If using an iceberg: uses systems thinking tools on different levels of the iceberg to model the system (for example: behavior-over-time graphs [BOTGs] on the patterns level; stock-flow maps, causal loops, and archetypes on the structures level; ladder of inference on the mental models level.)]* **Transfer*:** Compares two systems at all the levels of observable events, patterns of behavior, structures of the system, and mental models (*for example: compare a classroom and a city or town*).	**Identification and Explanation:** Explain how a system's underlying structures, mental models, and patterns of behavior result in observable events (*for example: we can attribute improved student performance to underlying structures such as lesson design and peer tutoring, which emerge from the mental model that "all students can be successful with deliberate practice and feedback"*). **Representation:** Select information and use tools to represent a unified, concise, and coherent analysis of the structure of a system. **Transfer*:** Apply conclusions about the structure of a system to another system (*for example: what might happen if we applied the mental models of a successful classroom to a city or town?)*

LEVERAGE ACTIONS  Causal loops   **Stock-flow maps and computer models**	**Identification and Explanation:** Describes the basic concept of leverage action, *i.e., an action that would bring about a desirable effect.* Identifies desirable and undesirable effects of an action. **Representation:** Labels events as a "cause" or an "effect" on a provided systems tool. **Transfer*:** Identifies one or more common attributes of leverage or leverage actions *(for example, an action that has a desirable effect, an action that has the potential to change how a system functions, etc.).* See possible student misconceptions following the rubric.	**Identification and Explanation:** Identifies potential leverage actions within a specific situation (*for example, different ways an explorer could survive in an unknown environment*). **Representation:** Depicts cause and effect relationships within a system using systems diagrams such as a stock-flow map or causal loop. **Transfer*:** Generalizes the key elements of a situation with multiple possible leverage actions (*for example: "This situation offers several ways a person could increase their savings."*).	**Identification and Explanation:** Identifies and explains high-leverage actions that made a change within a system *(for example: when farmers in Arizona changed how they planted, the soil system was improved).* **Representation:** Represents potential high-leverage actions within a system (*for example: all the places humans could intervene in the water cycle through a causal loop diagram, stock-flow map, system dynamics computer model, or other means*). **Transfer*:** Compares and contrasts leverage action(s) in two similar systems (*for example, compares the leverage actions of General Washington in the American Revolution to the leverage actions of General Grant in the Civil War*).	**Identification and Explanation:** Rank potential leverage actions within a system, using the criteria of desirable effectiveness *(for example: criteria for ranking leverage actions might include time it would take to implement, effort needed to implement, number of unintended consequences that might result, long term efficacy of action, etc.).* **Representation:** Represent how high-leverage actions function within a system (*for example: identifying ways humans could intervene in the water cycle to create feedback which would amplify / magnify leverage in the system).* **Transfer*:** Apply conclusions about leverage actions from one system to another (*for example: similarities between actions to stop a fire and actions to stop rumors from spreading*).
BIG PICTURE  Iceberg	**Identification and Explanation:** Defines key terms such as" big picture", "system", and "function". **Representation:** Identifies isolated actors, parts, or events of a system (*for example: labels a diagram of the Three Branches of Government showing each*	**Identification and Explanation:** Identifies multiple parts of a system and explains the basic details or functions of the parts and how they work together (*for example: how each part of a plant serves a specific function*). **Representation:** Lists issues, goals, problems, behaviors,	**Identification and Explanation:** Identifies and explains behaviors, goals, problems, and/or relationships among parts within a system as a series of interrelated details or events (*for example: how an animal's behavior is related to its physical environment).*	**Identification and Explanation:** Explain behavior of the system as a whole: identifies and explains behaviors, goals, and/or problems within a system from a wide, "big picture" view, rather than focusing on details. Analyze interactions among multiple systems (*for example:*

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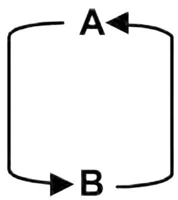
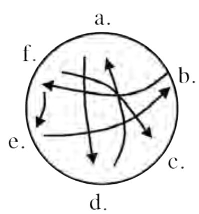
 Causal loops  Connection circles	*branch, without connecting checks and balances).* **Transfer*:** Identifies one or more common attributes of how a system operates *(for example: a system can be organized and operated by one or more people or groups in some way, etc.).* See possible student misconceptions following the rubric.	and/or relationships among actors/parts within a system *(for example: a connection circle showing how parts of the system cause changes in each other).* **Transfer*:** Generalizes how the key elements of a system operate (*for example: "There is one person in control who makes many rules").* Identifies how common elements of a system operate in two situations.	**Representation:** Creates a representation of interrelationships among parts of a system (*for example: how coyotes, rabbit and plant populations relate to one another--leaving out other factors, such as water, disease, other predators, etc.*). **Transfer*:** Applies conclusions about how one system operates to a system of a similar type (*for example: a marching band moving on a field and a military unit marching in a drill*).	*how different human body systems interact to sustain life and movement).* **Representation:** Create a representation of the system's most important set of structures and relationships by taking a whole-system perspective on an issue or process (*for example: a set of interconnected stock-flow maps or an iceberg model).* **Transfer*:** Apply conclusions about how one system operates to a system of another type (*for example: the behavior of a cell and the behavior of a factory*).
SELF-REGULATION AND REFLECTION	**Reflection:** Identifies own strengths and weaknesses as a systems thinker. **Planning:** Sets personal goals for applying systems thinking habits and tools. **Mindset:** Explains the relationship between effort and success *(for example: "The harder I work at this, the better I'll be at it"; "I will work harder in this class from now on.").* See possible student misconceptions following the rubric.	**Reflection:** Assesses application of the habits and tools of a systems thinker in response to feedback and/or the rubric. **Planning:** Sets goals for applying systems thinking based on feedback and/or the rubric. **Mindset:** Demonstrates a desire to improve *(for example: employs more practice, sets goals for improvement, asks for help from others instead of giving up).*	**Reflection:** Accurately reflects on the application of systems thinking habits and tools; uses reflection and/or feedback to revise thinking or to improve ideas. Questions and critiques own thinking process. Describes the learning that resulted from systems thinking. **Planning:** Seeks out, selects, and uses resources and strategies to achieve goals for improving the application of systems thinking habits and tools. **Mindset:** Demonstrates a growth mindset (the belief that	**Reflection:** Analyze patterns and trends in own thinking process. Evaluate the application of systems thinking habits and tools throughout the process. Seek out and act on feedback from peers, teacher, and experts to improve. **Planning:** Analyze patterns and prior performances to set new goals for applying systems thinking habits and tools; revise goals in response to ongoing reflection. **Mindset:** Proactively improve own areas of weakness by employing effective strategies to increase growth mindset *(for*

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			he or she can get "smarter" at systems thinking through effective effort) in response to setbacks and challenges *(for example: persists on difficult tasks, takes risks in the learning process, accepts and uses feedback/criticism, is comfortable making mistakes, explains failure from a growth mindset perspective).*	*example: perseverance, taking risks, effective decision-making, actively seeking others' feedback, deliberate practice, finding and using external resources [skilled peers, other adult experts] to enrich and extend learning).*

Possible Misconceptions: 3-5 Systems Thinking

The following chart lists possible misconceptions about **Systems Thinking**. Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

Students might exhibit the following misconception, belief, or perception that…		
Change Over Time	**Identification and Explanation**	• All change happens in the same way. • Once change is initiated, it will follow the same rate or trend over time. • Any action will result in immediate change.
	Representation	• Change-over-time graphs all take the same shape. • Actions (verbs) and things (nouns) are interchangeable as stocks and flows. • Reinforcing and balancing loops are value judgments (for example: reinforcing = good and balancing = bad).
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
Interdependencies	**Identification and Explanation**	• Two things are related because they happen at the same time. • Correlation equals causation.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

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Students might exhibit the following misconception, belief, or perception that…		
Consequences	**Identification and Explanation**	• There are only intended consequences. • One type of consequence (short- or long-term, intended or unintended) is more important than another.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
System as Cause	**Identification and Explanation**	• My perception of a situation is accurate. • Events just "happen" for no reason or are caused by external factors. • My perspective, beliefs, and/or actions do not influence the system, situation, or behavior of others. • Implementing a structure or strategy once should lead to a change in events. • Once the patterns and/or observable events change, the structures are no longer needed to maintain the outcome.
	Representation	• All information about the system is of equal value. • We can fully understand a system by analyzing isolated parts. • Complicated or lengthy explanations or representations are inherently better.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

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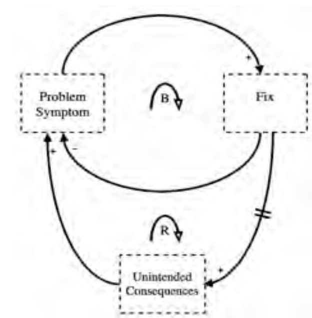
Students might exhibit the following misconception, belief, or perception that…		
Leverage Actions	**Identification and Explanation**	• All leverage actions are equally impactful. • Any action is a leverage point because it is part of the system. • A leverage point must be large and obvious. • A leverage action must come from an external source.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
Big Picture	**Identification and Explanation**	• We cannot begin to explore the big picture until we fully understand all the details. • The details don't matter in relation to the big picture. • A system only has one perspective, or only one perspective that matters. • Big-picture understanding is static; once we identify it, it never changes.
	Representation	• All elements of the system are of equal importance. • Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

Possible Misconceptions: 3-5 Self-Regulation and Reflection

The following chart lists possible misconceptions about **Self-Regulation and Reflection.** Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

Students might exhibit the following misconception, belief, or perception that…		
Self-Regulation and Reflection	**Reflection**	• Reflection is all about what I think; other people's perspectives don't matter. • Only the teacher's perspective matters when it comes to identifying strengths and weaknesses. • I don't have any weaknesses. • I don't have any strengths. • All weaknesses affect my performance in the same way. • Reflection is a waste of time; I don't need to reflect to improve.
	Planning	• A goal is the same thing as a plan. • Any goal is a worthy goal. • Short-term goals aren't important. • I don't need a plan; if I set a goal, I will achieve it. • I should set goals in areas where I am already successful. • I should set the same goal over and over. • Someone else will give me resources and ideas about how to improve.
	Mindset	• Systems thinking is a talent and not a skill; I am as good at it as I'll ever be. • If I'm really good at something, I won't encounter any challenges. • If I experience a setback, I've failed. • Others' feedback can't help me. • Mistakes are bad; smart people don't make mistakes. • The safe route leads to guaranteed success.



Archetype: A multi-loop causal loop diagram that represents behavior commonly seen in complex systems. The archetypes are named - for example, "Fixes That Fail." In these systems, a problem is solved by some fix (a specific solution) that causes an immediate positive effect. Nonetheless, the "side effects" of this solution, after a time delay, make the problem worse.

Feedback: The interaction between two stocks that affect each other in turn.

- Balancing Feedback: "Effect of an action returned (fed back) to oppose the very action that caused it. Balancing - feedback has a correcting or stabilizing effect on the system, and it reduces the difference (variance) between where the system is (the current status) and where it should be (the target value, or objective). For example, demand and supply in an economy work on each other to reach a stable (equilibrium) state through the feedback of information about price and availability. If supply is known to be greater than demand, price falls. Low price forces suppliers to pull out of the market, causing shortage that results in increase in price. High price attracts more supplies than there is demand ... and so on until a rough parity is achieved. Criticism can also be a balancing feedback if it results in the desired change in the recipient's behavior." (BusinessDictionary.com)

- Reinforcing Feedback: "Effect of an action, change, or decision returned to amplify or bolster what caused it. Reinforcing feedback drives a system increasingly faster in the direction it is already going whether away from its goal (called a vicious circle) or towards it (called a virtuous circle). It may destroy the system by pushing it beyond its limits unless the circle runs out of steam or is countered by a balancing feedback. A small ball of snow rolling downhill is an example of vicious circle. As its size continues to grow, it picks up ever-increasing amounts of snow. This process stops only when the giant ball of snow disintegrates under its own weight or runs out of slopes to roll down. Compound interest is an example of a virtuous circle. A praise or a reward can also be a reinforcing feedback if it results in the desired change in the recipient's behavior." (BusinessDictionary.com)

Flow: Rate of increase or decrease of a quantity that accumulates in a stock.

Limits: A definition of the boundaries and extent of the system, including which physical, environmental, structural, or temporal elements are relevant, and which aren't; systems may be nested within one another. Defining the limits of a system is a crucial part of the analysis of the system.

Stock: (Accumulation): A quantity that can be built up or depleted over time.

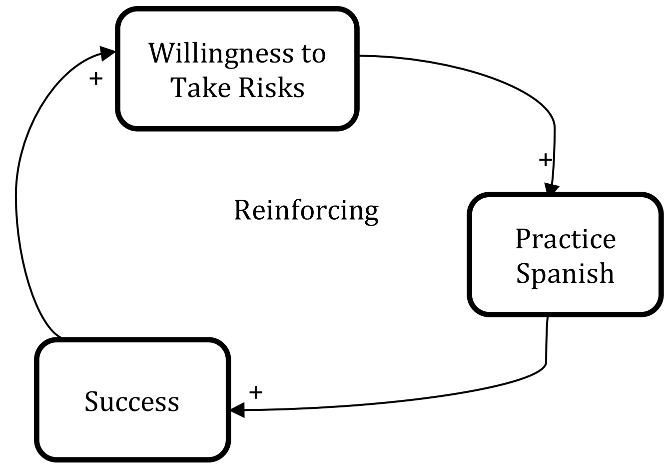
Time Delay: A gap in time between a cause and its effect within a system. Time delays may make systems hard to understand or predict.

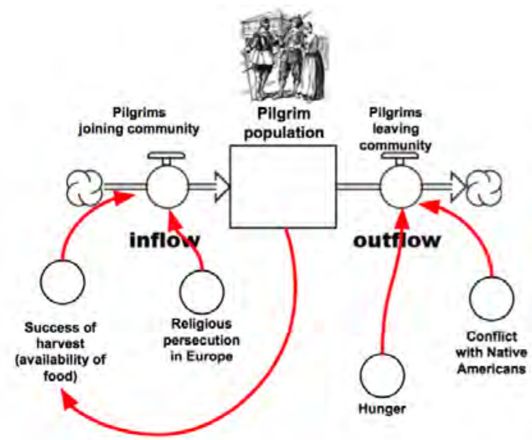
Curricular Examples for Interdependencies: The following examples may give teachers an idea of how to use stock-flow maps:

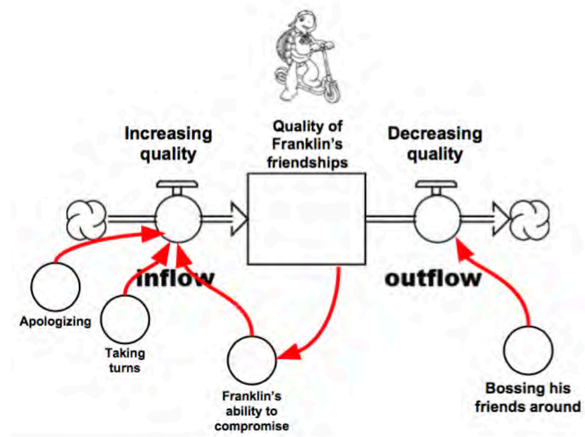
Subject Area	Stock	Flow	Converters	Potential Feedback Relationships
Science	Number of trees (Natural Resources)	• Increasing • Decreasing	• Planting new trees (increasing) • Cutting down to build houses (decreasing)	Planting trees specifically for housing instead of taking from nature (balancing feedback)
English Language Arts	Quality of Franklin's friendships (from *Franklin is Bossy*)	• Increasing • Decreasing	• Apologizing and taking turns (increasing) • Bossing his friends (decreasing)	Franklin's ability to compromise (reinforcing feedback)
Social Studies Revolutionary War	Number of British Soldiers in the Colonies	• Inflow/Increase • Outflow/Decrease	• Colonists' anger at the British • Deaths of soldiers • Soldiers return to UK • Conflicts with American Indians	The British mental model of what would happen: Increase in soldiers → decrease in anti-British acts → decrease in anti-British acts… (Balancing) What actually happened: As the number of soldiers increased → colonists' anger increased → Soldiers increased (England sent more to deal with angry colonists) → colonists' anger increased. . . (Reinforcing)
Math	Money in Bank Account	• Withdrawals • Deposits	• Interest • Paycheck • Mortgage/rent	In an interest generating savings account, interest is always added if there is money in the account (Reinforcing) This feedback is not present in a non-interest account.
Spanish	Feeling of Safety in a Classroom Willingness to Take	• Encouraging the feeling of safety • Discouraging the feeling of safety	• Student generated (these might include: • *Affecting the inflow* – words of encouragement, showing respect,	As a safe classroom community is cultivated → risk-taking increases Risk-taking increases → practicing

	Risks		active listening, celebrating mistakes, being kind • *Affecting the outflow* – mean comments, rude language, laughing at others' mistakes, having side conversations	Spanish increases → success increases → risk-taking increases… (Reinforcing)

This example came from a Spanish teacher at Manzanita. She would use this stock-flow map and causal loop to explain to students how a strong classroom community affects learning. She would have students share ideas for how they can encourage feelings of safety and how they could discourage feelings of safety. These ideas would become the converters on the stock-flow map.







Curricular Examples for System as Cause:

Subject Area	System	Events	Patterns	Structures	Mental Models
Science	Chick population	Chicks hatch	• Embryo development over time • Heat over time	• Chick population stock flow • Loop showing how the incubator maintains the correct temperature	• All chickens should survive (Kinder) • Male chicks should be killed (Farmers)
Social Studies (Building Classroom Community)	Classroom Good Behavior Points	Students earn class points	• Points earned each day over time • Points earned each year	• Stock-flow map with points earned (no outflow) • Reinforcing loop showing how earning points increases good behavior and good behavior increases earning points.	• Students earn points because they want rewards • When students earn points, they are more likely to reflect on their behavior and are able to track trends in behavior.

Used with permission from the Waters Center for Systems Thinking.

SYSTEMS THINKING RUBRIC
GRADES 6-8

CATALINA FOOTHILLS SCHOOL DISTRICT

TUCSON, ARIZONA

General Description and Suggestions for Use

The district's strategic plan, Envision21: Deep Learning, forms the basis for a focus on cross-disciplinary skills/proficiencies necessary for preparing our students well for a 21st century life that is increasingly complex and global. These skills, which are CFSD's "deep learning proficiencies" (DLPs) are represented as 5c + s = dlp. They are the 5Cs: (1) Citizenship, (2) Critical Thinking and Problem Solving, (3) Creativity and Innovation, (4) Communication, (5) Collaboration + S: Systems Thinking. CFSD developed a set of rubrics (K-2, 3-5, 6-8, and 9-12) for each DLP.

These rubrics were developed using a backward design process to define and prioritize the desired outcomes for each DLP. They provide a common vocabulary and illustrate a continuum of performance. By design, the rubrics were not written to align to any specific subject area; they are intended to be contextualized within the academic content areas based on the performance area(s) being taught and assessed. In practice, this will mean that not every performance area in each of the rubrics will be necessary in every lesson, unit, or assessment.

The CFSD rubric for **Systems Thinking** was designed as a cross-disciplinary tool to support educators in teaching and assessing the performance areas associated with this proficiency:

- **Change Over Time**
- **Interdependencies**
- **Consequences**
- **System as Cause**
- **Leverage Actions**
- **Big Picture**
- **Self-Regulation and Reflection**

This tool is to be used primarily for formative instructional and assessment purposes; it is not intended to generate psychometrically valid, high stakes assessment data typically associated with state and national testing. CFSD provides a variety of tools and templates to support the integration of **Systems Thinking** into units, lessons, and assessments. When designing units, teachers are encouraged to create authentic assessment opportunities in which students can demonstrate mastery of content and the deep learning proficiencies at the same time.

The approach to teaching the performance areas in each rubric may vary by subject area because the way in which they are applied may differ based on the field of study. Scientists, mathematicians, social scientists, engineers, artists, and musicians (for example), all collaborate, solve problems, and share their findings or work within their professional communities. However, the way in which they approach their work, the tools used for collaboration, and the format for communicating their findings may vary based on the profession. These discipline-specific expressions of the 5Cs + S may require some level of customization based on the subject area. Each rubric can also be used to provide students with an opportunity to self-assess the quality of their work in

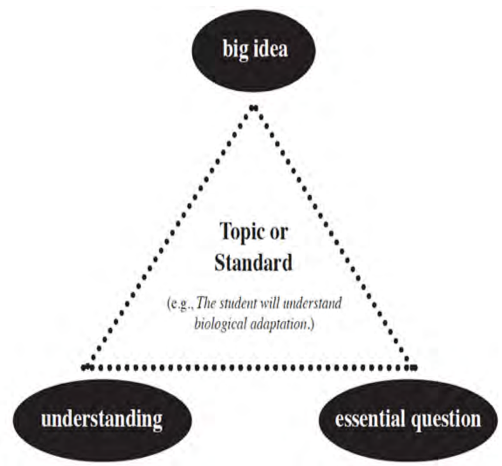
relation to the performance areas. Student-friendly language or "I can" statements can be used by students to monitor and self-assess their progress toward established goals for each performance area.

Transfer

CFSD educators prioritize understanding and transfer to ensure that learning extends beyond the school experience. This 2019 version of the DLP, **Systems Thinking**, includes long-term **transfer goals** that describe autonomous applications of student learning in college, career, and civic life. "Drill and direct instruction can develop discrete skills and facts into automaticity…but they cannot make us truly able. Understanding is about *transfer*, in other words. To be truly able requires the ability to transfer what we have learned to new and sometimes confusing settings. The ability to transfer our knowledge and skill effectively involves the capacity to take what we know and use it creatively, flexibly, fluently, in different settings or problems, on our own" (Wiggins and McTighe, 2011, p. 40).

Big Ideas

This 2019 version of the DLP, **Systems Thinking,** includes a set of Understandings and Essential Questions (UEQs) developed by an interdisciplinary team of K-12 teachers and administrators with guidance from Jay McTighe, author of *Understanding by Design*. These big ideas will guide teachers toward the thoughtful design of assessments, units, and lessons that will facilitate transfer of deep learning. "Because big ideas are the basis of unified and effective understanding, they provide a way to set curriculum and instructional priorities…they illuminate experience; they are the linchpin of transfer…" (Wiggins and McTighe, 2011, p.71). "Understandings are the specific insights, inferences, or conclusions about the big idea you want your students to leave with" (Wiggins and McTighe, 2011, p. 80). "Essential questions make our unit plans more likely to yield focused and thoughtful learning and learners" (McTighe, 2017; McTighe & Wiggins, 2013, p. 17). The figure on the right represents the interrelationship among big ideas, understandings, and essential questions.



The **DLP Understandings** are written for K-12 because they express lasting, transferable goals for student learning. Understandings are meant to be revisited over time and across contexts. The continuity of working toward the same goals will help students deepen their understanding from Kindergarten to 12th grade. Understandings are primarily planning tools for teachers, although teachers may choose to share them with their students, if appropriate. Communicating an Understanding does not give away "the answer," since simply stating an Understanding is not the same as truly grasping its meaning.

The **Essential Questions** are teaching and learning tools that help students unpack the Understandings. They support inquiry and engagement with deep learning and therefore may vary in complexity across grade levels.

Systems Thinking Transfer Goals and UEQs

Transfer Goals	
Students will be able to independently use their learning to. . . • Employ the habits of a systems thinker to better understand situations, make effective decisions, and plan for the future.	
Understandings	**Essential Questions**
Students will understand that. . .	**Students will keep considering. . .**
• A system is comprised of interrelated and interdependent parts which serve a specific purpose; changing one part of a system affects other parts.	• What is a system? • How do elements of a system affect each other? • How do the elements fit into the system as a whole? • Why are things the way they are? • What are the causal relationships within a system?
• Systems thinking enables us to look at problems and situations in new ways, which can lead to new solutions and insights.	• How can we use systems thinking to effect change, make predictions, and/or solve problems? • How can we maintain balance between the “big picture” and important details?
• Systems thinkers use specific habits, tools, and vocabulary to represent, describe, and analyze systems and solve problems.	• What makes an effective systems thinker? • How can we use the habits of a systems thinker to help us understand and analyze a system? • How can we come to understand and improve a system? • Which tool(s) will be most effective in analyzing the relationships within the system?
• Systems thinkers observe and connect information in order to understand systems.	• What makes an effective systems thinker? • What are the causal relationships within a system? • How can we maintain balance between the “big picture” and important details?
• A system’s structure drives its behavior.	• How do structures drive behavior? • Why are things the way they are?

• Examining a system from different perspectives helps us identify various mental models and better understand the system.	• How do mental models affect our thoughts and actions? • Why are things the way they are?
• Recognizing patterns of change enables prediction and guides planning for the future.	• What has changed and why? • How can analyzing patterns help us predict or plan for the future? • What patterns or trends have emerged over time? • How does understanding of one system transfer to understanding of another system?
• Actions can have short-term, long-term, and/or unintended consequences; we can strategically choose leverage actions that produce or increase desired results.	• What are the causal relationships within a system? • What are the systemic effects of actions in a system? • How does determining possible short-term, long-term, and/or unintended consequences help us make decisions? • How do we determine where a small change might have a long-lasting, desired effect?

Self-Regulation and Reflection Transfer Goals and UEQs

Transfer Goals	
Students will be able to independently use their learning to. . . • Improve performance and persevere through challenges by applying deliberate effort, appropriate strategies, and flexible thinking.	
Understandings	**Essential Questions**
Students will understand that. . .	**Students will keep considering. . .**
1. Effective learners set goals, regularly monitor their thinking, seek feedback, self-assess, and make needed adjustments.	• How am I doing? How do I know? What are my next steps? • What is the most effective way to monitor my progress? • How do I know which feedback will help me improve my work? • How can I get useful feedback? • How do I prioritize my work? • How can I maintain focus on areas of influence rather than on factors I cannot influence?
2. We can always improve our performance through deliberate effort and use of strategies.	• How can I keep getting better at systems thinking?

The deep learning proficiencies (5c+ s) are highly interconnected. For example, productive collaboration is contingent upon effective communication. Efficient and effective problem solving often requires collaboration skills. Divergent and convergent thinking, which are traits of Creativity and Innovation, are directly related to critical thinking. Our students will need to use a combination of proficiencies to solve problems in new contexts beyond the classroom. Therefore, it is important to be clear about which proficiency and/or performance area(s) are the focus for student learning, and then to assist students in understanding the connections between them and how they are mutually supportive.

<u>What does Score 1.0 – Score 4.0 mean in the rubrics?</u>

The rubrics are intended to support student progress toward mastering the deep learning proficiencies (DLPs). Four levels of performance are articulated in each rubric: Score 1.0 (Novice), Score 2.0 (Basic), Score 3.0 (Proficient), and Score 4.0 (Advanced). The descriptions follow a growth model to support students in developing their skills in each performance area. Scores 1.0 (Novice) and 2.0 (Basic) describe positive steps that students might take toward achieving Score 3.0 (Proficient) or Score 4.0 (Advanced) performance.

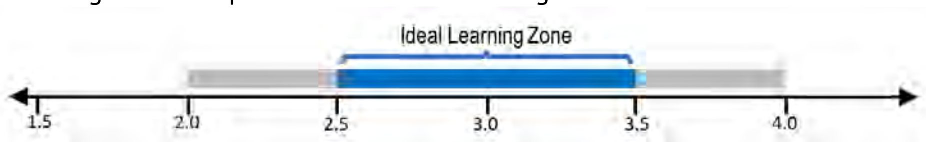
When using the rubrics to plan for instruction and assessment, teachers need to consider the knowledge and skills described in the Score 2.0 column (Basic) to be embedded in the Score 3.0 (Proficient) and 4.0 (Advanced) performance. The Novice level (Score 1.0) indicates that the student does not yet demonstrate the basic skills within the performance area, but that he/she exhibits related readiness skills that are a stepping-stone to a higher level of proficiency. Descriptions at the Novice level also include likely misconceptions that the student might exhibit.

The descriptive rubrics are designed to illustrate students' depth of knowledge/skill at various levels in order to facilitate the instructional and assessment process for all learners. At some performance levels, the indicators may remain the same, but the material under study is more or less complex depending on the grade level band (for example: the complexity of the material at grades 6-8 differs from that of grades 3-5 or 9-12).

The following descriptions explain the four levels on the rubric:

- Score 1.0 (Novice): Describes student performance that demonstrates readiness skills and/or misconceptions and requires significant support.
- Score 2.0 (Basic): Describes student performance that is below proficient, but that demonstrates mastery of basic skills/knowledge, such as terms and details, definitions, basic inferences, and processes.
- Score 3.0 (Proficient): Describes student performance that is proficient – the targeted expectations for each performance area of the DLP.
- Score 4.0 (Advanced): Describes an exemplary performance that exceeds proficiency.

The image below represents the ideal learning zone for students as 2.5 – 3.5.



Glossary

Long-term consequences: Intended or unintended consequences that have longer lasting effects and that are harder to anticipate.

Short-term consequences: Short-term or immediate effects that are often easier to identify or predict. Many humans make decisions just based on short-term consequences.

*Transfer: Before a student can successfully transfer, he/she must first master the other skills within each performance area.

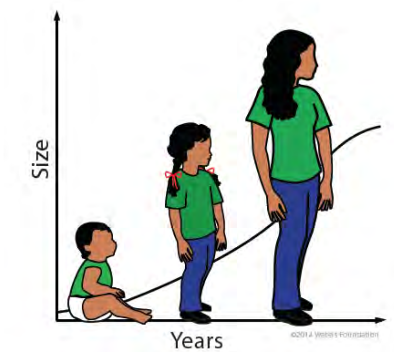
Sources

The following sources directly influenced the revision of CFSD's rubrics:

- Catalina Foothills School District. (2011, 2014, 2016, 2018). Rubrics for 21st century skills and rubrics for deep learning proficiencies. Tucson, Arizona
- Waters Center for Systems Thinking, https://waterscenterst.org/

A **system** is a collection of elements that interact with each other over time to function as a whole (Waters Center for Systems Thinking, 2018). A **systems thinker** is anyone who uses the **Habits of a Systems Thinker** (see end of document) in combination with the concepts and visual tools of systems thinking to increase understanding of systems and how they influence both short- and long-term consequences. Many systems thinking concepts are embedded either explicitly or implicitly within the Habits of a Systems Thinker. The CFSD Systems Thinking rubrics include the concepts of Change Over Time, Interdependencies, Consequences, System-as-Cause, Leverage Actions, and Big Picture. Systems thinking provides students with a more effective way to interpret the complexities of the world in which they live—a world that is increasingly dynamic, global, and complex.

Change Over Time, page 8



Consequences, page 10

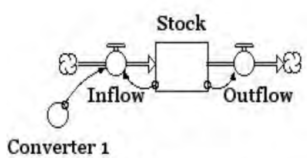
Leverage Actions, page 12

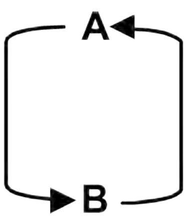
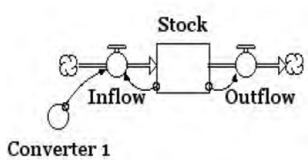
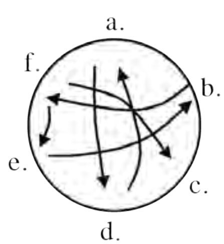
Interdependencies, page 9

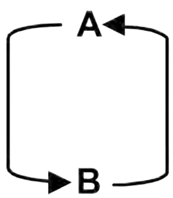
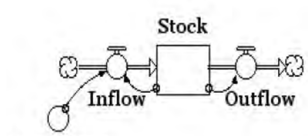
System-as-Cause, page 11

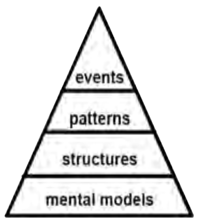
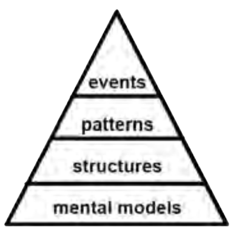
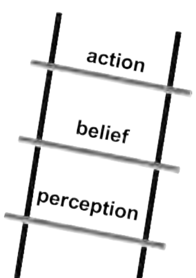
Big Picture, page 13

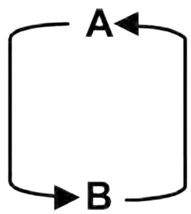
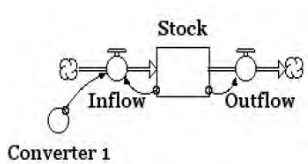
SYSTEMS THINKING

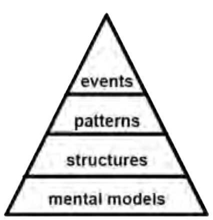
DLP Performance Area	1.0 (Novice) The student may exhibit the following readiness skills for Score 2.0:	2.0 (Basic) When presented with a grade-appropriate task, the student:	3.0 (Proficient) In addition to Score 2.0, the student:	4.0 (Advanced) In addition to Score 3.0, the student may:
CHANGE OVER TIME  **Behavior-over-time graphs**  **Stock-flow maps**	**Identification and Explanation:** Defines *accumulation*, *rate of change*, *element*, *trend,* and *pattern*. Describes a change that occurs over time. Lists and orders events. **Representation:** Charts a change over time, given a graph with pre-defined *x* and *y* axes. **Transfer*:** Generalize the key elements of a situation involving change over time (*for example: "This situation involves a person whose actions are influenced by her environment." or "I see a steady increase followed by a sudden fall"*). Identifies common elements of two situations involving change over time. See possible student misconceptions following the rubric.	**Identification and Explanation:** Describes general trends in change over time. Identifies elements of the system that change over time. **Representation:** Constructs a behavior-over-time graph to chart a general change over time, including defining a time frame (x axis) and a scale for changes in an accumulation (*y* axis) (*for example: line graph showing a general trend*). **Transfer*:** Applies conclusions about change over time in one situation to a situation of a similar type (*for example: perseverance over time for two characters in different texts*).	**Identification and Explanation:** Describes the nature of specific trends in changes over time (*for example: a gradual increase, a sudden drop, a stepwise increase, an increase approaching a limit*). Analyzes why elements of a system change over time. **Representation:** Constructs a detailed behavior-over-time graph (*for example: depicts transitions, annotates with evidence supporting claims, etc.*) to chart specific changes over time (including specific changes in rate, relationship between general trend and transition points). Constructs a stock-flow map to analyze why elements of a system change over time (*for example: includes individual behavior over time graphs within stocks to show behavior of the system over time*). **Transfer*:** Applies understanding of an identified change-over-time to analyze a situation of a different type that	**Identification and Explanation:** Identify and explain overarching patterns in change over time. Analyze the relationship between two or more elements that change over time. **Representation:** Create the most concise representation possible of a change over time, aggregating (generalizing) detailed information to represent the wider perspective on an issue or process. Represent change over time of more than one element, identifying specific patterns and trends. Select specific time frames or *y*-axis values to highlight particular changes, patterns, or trends. **Transfer*:** Evaluate the validity of conclusions drawn about changes within two or more systems (*for example: it may not be valid to stress the similarities of a fictional character to a*

			operates in a similar manner (*for example: a fictional character's perseverance over time compared to that of an historic figure*).	*historical figure, because we don't know what historical figures are thinking; however, in some cases, diary or journal entries may reveal important truths*).
INTERDEPENDENCIES  Causal loops  **Stock-flow maps and computer models**  Connection circles	**Identification and Explanation:** Defines *feedback loop*, *reinforcing*, *balancing*, *stock*, and *causality*. Shows causal relationships as one-way, e.g., cause → effect (for example: increasing songbird populations lead to higher hawk populations[1]). **Representation:** Represents connections between the key elements of a system (*for example: uses a connection circle*). **Transfer*:** Generalizes the key elements of a system with interdependent relationships (*for example: "This system has two groups that depend on each other" or "In this system, one element reinforces another element, but balances a third"*). Identifies common elements of causal relationships in two situations. See possible student misconceptions following the rubric.	**Identification and Explanation:** Identifies and explains a single cause-and-effect loop. Distinguishes whether a loop represents a reinforcing or balancing process, or a causal relationship without feedback (*for example: as predator numbers increase, prey population decreases, which leads to decreased predator numbers…which is a balancing loop; as the number of trains in North America increased, bison populations decreased – however, changes in bison populations do not affect the number of trains…so it is a one-way causal relationship without feedback*). **Representation:** Represents a circular causal relationship between two elements of a system (*for example: uses a stock-flow map or causal loop diagram*). **Transfer*:** Applies conclusions about interdependencies in one situation to a situation of a similar type (*for example: the*	**Identification and Explanation:** Identifies and explains causality in a system of multiple connected loops. Explains the behavior over time of any stock in the system in relation to another stock (*for example: hawk, songbird, and insect populations are linked in two connected loops. See below.[2]) a reinforcing process*). **Representation:** Represents causality in a system of multiple connected loops (*for example: uses a stock-flow map or causal loop diagram*). Identifies when causality can best be represented with a stock-flow map or causal loop diagram (*for example, the interdependence between population and births can best be represented with a stock-flow map*. Represents loops that account for complex behavior beyond basic reinforcing or balancing behaviors (*for example:*	**Identification and Explanation:** Explain causal relationships and behaviors that are significant, but not obvious (*for example: the timing of a population boom in songbirds that coincides with a particular stage in the life cycle of its insect prey -- when it is dormant or pupating*). Explain loops that account for complex behavior beyond basic reinforcing or balancing behaviors (*for example: archetypes such as fixes that fail, limits to growth, or which include thresholds, time delays, etc.*). **Representation:** Create the most concise representation possible of a system, aggregating (generalizing) detailed information to represent the whole-system perspective on an issue or process. Represent causal relationships and behaviors that are significant, but not obvious. **Transfer*:** Evaluate the validity of conclusions drawn about two or more systems (*for example: it*

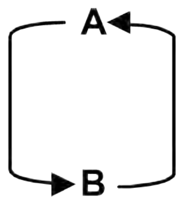
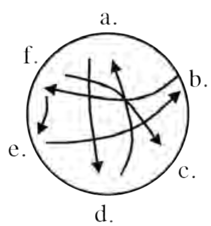
		increase in prey populations in response to plant increase in an ecosystem parallels the increase in bacterial growth in response to an increase in organic matter).	*archetypes such as thresholds, limits to growth, etc.*). **Transfer*:** Applies conclusions about key interdependencies in one situation to a situation of another type (*for example: the increase in prey populations in response to plant increase in an ecosystem parallels the increase of investors in a market when money is made more freely available - through interest rates, etc.*).	*may be overly simplistic to compare prey populations to investors, because investors are able to discover and communicate information about the environment which allows them to respond as a group differently than prey species).*
CONSEQUENCES  Causal loops  **Stock-flow maps and computer models**	**Identification and Explanation:** Defines *short-term consequences* and *long-term consequences*, *intended consequences*, and *unintended consequences*. Identifies at least one consequence for an action. **Representation:** Lists results occurring from actions. **Transfer*:** Generalizes the key elements of a situation involving actions and consequences (*for example: "This situation involves an individual who breaks rules" or "In this situation, a solution fixes the problem, but creates problems in other areas"*).	**Identification and Explanation:** Identifies and explains short-term and/or long-term intended consequences of a particular action. **Representation:** Identifies short-term and/or long-term consequences of a particular action on a provided causal loop diagram. **Transfer*:** Applies conclusions about consequences in one situation to a situation of a similar type (*for example: consequences of two different wars*).	**Identification and Explanation:** Identifies and explains short- and long-term intended and unintended consequences that have emerged as a result of actions (*for example: Explains a case in which "the most obvious solution" made a situation worse in the long term*). **Representation:** Represents short- and long-term intended consequences through a causal loop diagram, stock/flow diagram, computer model/simulation, and/or kinesthetic activity. **Transfer*:** Applies conclusions about key consequences in one situation to a situation of another type (*for example: the effects of an antibiotic on bacteria, the effects of criticizing*	**Identification and Explanation:** Predict and explain potential unintended consequences of an action (*for example: how a proposed solution could potentially backfire*). **Representation:** Show the short- and long-term intended and unintended consequences of actions within a complex system using a systems archetype (*for example: using a Fixes That Fail archetype to represent the slavery compromises prior to the Civil War).* **Transfer*:** Evaluate the validity of conclusions drawn about the consequences two or more systems (*for example: students could evaluate which conclusions are valid when comparing the*

 Iceberg	Identifies common elements of actions and consequences in two situations. See possible student misconceptions following the rubric.		*someone's incorrect statement on social media*).	*decline / disappearance of ancient civilizations*).
SYSTEM AS CAUSE  Iceberg  Ladder of inference	**Identification and Explanation:** Defines *mental model* and *structure of a system.* Identifies elements of a system (*for example: in a classroom, the students, the teacher, the lesson activities, the work, and the assessments*). **Representation:** Classifies given information as observable events, patterns of behavior, structures of the system, and mental models. **Transfer*:** Identifies two systems with similarities at the level of observable events, patterns of behavior, structures of the system, or mental models. See possible student misconceptions following the rubric.	**Identification and Explanation:** Identifies a system's observable events and patterns of behavior (*for example: observation - students performing well on a test; pattern of behavior - homework completion and earlier test results; underlying structures - lesson design and peer tutoring; and mental model - "all students can be successful with deliberate practice and feedback"*). **Representation:** Describes or visually represents observable events, patterns of behavior, structures of the system, and mental models. **Transfer*:** Compares and contrasts two systems at all the levels of observable events, patterns of behavior, structures of the system, or mental models (*for example: compare / contrast communism and capitalism*).	**Identification and Explanation:** Explains how a system's underlying structures and mental models create patterns of behavior over time and observable events (*for example: we can attribute improved student performance to underlying structures such as lesson design and peer tutoring, which emerge from the mental model that "all students can be successful with deliberate practice and feedback"*). **Representation:** Selects information and uses tools to represent a unified, coherent analysis of the structure of the system. **Transfer*:** Applies conclusions about the structure of a system to another system (*for example: what might happen if we applied the mental models underlying a communist system to a capitalist system?*).	**Identification and Explanation:** Explain the system "top-to-bottom and bottom-to-top" (i.e., from the event to the mental model level and from the mental model to the event level). Explain how the ladder of inference generates mental models. **Representation:** Create the most concise representation possible of a system, aggregating (generalizing) detailed information to represent the whole-system perspective on an issue or process. Represent a hypothetical or desired system in contrast to the current reality. **Transfer*:** Evaluate the validity of conclusions drawn about two or more systems (*for example: conclusions about improvements in capitalism drawn from communism may be difficult to*

				apply because the mental models contrast so much).
LEVERAGE ACTIONS  Causal loops   **Stock-flow maps and computer models**	**Identification and Explanation:** Defines "leverage action." Identifies desirable and undesirable effects of an action. **Representation:** Depicts cause and effect relationships within a system. **Transfer*:** Generalizes the key elements of a situation with multiple possible leverage actions (*for example: "This situation offers several ways a person could increase their savings" or "This system has several influential groups, each of which has its own needs and desires"*). See possible student misconceptions following the rubric.	**Identification and Explanation:** Identifies one or more potential high-leverage actions within a system. **Representation:** Labels one or more potential high-leverage actions within a system (*for example: identify all the places humans could intervene in the water cycle*). **Transfer*:** Compares and contrasts leverage action(s) in two or more systems (*for example: finding leverage actions that influence the passage of a law at the state level and at the federal level*).	**Identification and Explanation:** Explains how one or more potential high-leverage actions function within a system. **Representation:** Visually represents how one or more high-leverage actions function within a system (*for example: identifying ways humans could intervene in the water cycle to create feedback which would amplify/magnify leverage in the system).* **Transfer*:** Applies conclusions about leverage actions from one system to another (*for example: similarities between actions to stop a fire and actions to stop rumors from spreading*).	**Identification and Explanation:** Surface and test assumptions about potential leverage actions within a novel context, (*for example: in a real-world context, involving student-action committees, class projects, or community involvement; or in an academic context, predicting the impact of high-leverage actions in a short story using textual evidence*), or using a model (*for example: using STELLA software*). Propose innovative and logical ways to leverage change to the system. **Representation:** Create the most concise representation possible of a system, aggregating (generalizing) detailed information to represent the whole-system perspective on an issue or process. Combine representational methods to show the impact of leverage actions (*for example: including behavior-over-time*

				graphs and feedback loops in an iceberg). Represent the outcomes of tested assumptions. Create a representation of the system that accommodates both short- and long-term impacts of leverage actions (*for example: incorporating time delays into stock/flow and/or causal loop diagrams*). **Transfer*:** Evaluate the validity of conclusions drawn about two or more systems (*for example: It might be valid to compare reduction of rumors and fire because both are best stopped by preventative measures).*
BIG PICTURE  Iceberg	**Identification and Explanation:** Defines *system, mental models.* Identifies and explains behaviors, goals, problems, and/or events as isolated details within a system. **Representation:** Lists issues, goals, problems, behaviors, and/or relationships among actors/parts within a system. **Transfer*:** Generalizes how the key elements of a system operate (*for example: "There is one person in control who makes many rules").*	**Identification and Explanation:** Identifies and explains behaviors, goals, problems, and/or relationships among distinct actors/parts within a system as a series of interrelated details. **Representation:** Creates a representation of individual interrelationships among parts of a system (*for example: a stock- flow map or causal loop showing how rabbit and coyote populations relate to one another - leaving out other factors, such*	**Identification and Explanation:** Explains behavior of the system as a whole: identifies and explains behaviors, goals, and/or problems within a system from a wide, "big picture" view, rather than focusing on details. Investigates and considers the perspectives/mental models underlying the system being considered. **Representation:** Creates a representation of the system's most important set of structures and relationships by taking a	**Identification and Explanation:** Explain or predict how the system as a whole may change or develop over time. Analyze the effect of redefining the limits of the system (*for example: considering the system of courts and laws as a smaller piece of a larger system of government; for example: how does a classroom community affect and respond to changes in a school-wide community?*). Analyze interactions among multiple systems (*for example: how do the economic, social, and*

 Reviewed by Waters Center for Systems Thinking Associates

 Causal loops  Connection circles	Identifies how common elements of a system operate in two situations. See possible student misconceptions following the rubric.	*as water, plant production, disease, other predators, etc.*). **Transfer*:** Applies conclusions about how one system operates to a system of a similar type (*for example: a marching band moving on a field and a military unit marching in a drill*).	whole-system perspective on an issue or process (*for example: a set of interconnected stock- flow maps demonstrating feedback or an iceberg model).* **Transfer*:** Applies conclusions about how one system operates to a system of another type (*for example: the behavior of a cell and the behavior of a factory*).	*religious systems of ancient cultures interact with one another?*). **Representation:** Create the most concise representation possible of a system, aggregating (generalizing) detailed information to represent the whole-system perspective on an issue or process. Create an alternate representation of the system by redefining the boundaries or agents of the system, or by including actors/parts not included in previous representations (*for example: redefining the coyote/rabbit predator/ prey relationship by adding the growth of plants or the interaction of weather and seasons*). **Transfer*:** Evaluate the validity of conclusions drawn about two or more systems (*for example: the comparison is valid because a cell, like a factory, only works when all the parts within it perform their own functions, and both are dependent on receiving materials from outside*).

SELF-REGULATION AND REFLECTION	**Reflection:** Identifies own strengths and weaknesses as a systems thinker. **Planning:** Sets personal goals for applying systems thinking habits and tools. **Mindset:** Explains the relationship between effort and success *(for example: "The harder I work at this, the better I'll be at it"; "I will work harder in this class from now on.")*. See possible student misconceptions following the rubric.	**Reflection:** Assesses application of the habits and tools of a systems thinker in response to feedback and/or established criteria. **Planning:** Sets goals for applying systems thinking. based on feedback and/or established criteria. **Mindset:** Demonstrates a desire to improve *(for example: employs more practice, sets goals for improvement, asks for help from others instead of giving up)*.	**Reflection:** Accurately reflects on the application of systems thinking habits and tools; uses reflection and/or feedback to revise thinking or to improve ideas. Questions and critiques own thinking process. Describes the learning that resulted from systems thinking. **Planning:** Seeks out, selects, and uses resources and strategies to achieve goals for improving the application of systems thinking habits and tools. **Mindset:** Demonstrates a growth mindset (the belief that he or she can get "smarter" at systems thinking through effective effort) in response to setbacks and challenges *(for example: persists on difficult tasks, takes risks in the learning process, accepts and uses feedback/criticism, is comfortable making mistakes, explains failure from a growth mindset perspective)*.	**Reflection:** Analyze patterns and trends in own thinking process. Evaluate the application of systems thinking habits and tools throughout the process. Seek out and act on feedback from peers, teacher, and experts to improve. **Planning:** Analyze patterns and prior performances to set new goals for applying systems thinking habits and tools; revise goals in response to ongoing reflection. **Mindset:** Proactively improve own areas of weakness by employing effective strategies to increase growth mindset (*for example: perseverance, taking risks, effective decision-making, actively seeking others' feedback, deliberate practice, finding and using external resources [skilled peers, other adult experts] to enrich and extend learning)*.

Possible Misconceptions: 6-8 Systems Thinking

The following chart lists possible misconceptions about **Systems Thinking**. Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

Students might exhibit the following misconception, belief, or perception that…		
Change Over Time	**Identification and Explanation**	• All change happens in the same way. • Once change is initiated, it will follow the same rate or trend over time. • Any action will result in immediate change.
	Representation	• Change-over-time graphs all take the same shape. • Actions (verbs) and things (nouns) are interchangeable as stocks and flows. • Reinforcing and balancing loops are value judgments (for example: reinforcing = good and balancing = bad).
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
Interdependencies	**Identification and Explanation**	• Two things are related because they happen at the same time. • Correlation equals causation.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

Possible Misconceptions: 6-8 Systems Thinking

The following chart lists possible misconceptions about **Systems Thinking**. Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

Students might exhibit the following misconception, belief, or perception that…		
Consequences	**Identification and Explanation**	• There are only intended consequences. • One type of consequence (short- or long-term, intended or unintended) is more important than another.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
System as Cause	**Identification and Explanation**	• My perception of a situation is accurate. • Events just "happen" for no reason or are caused by external factors. • My perspective, beliefs, and/or actions do not influence the system, situation, or behavior of others. • Implementing a structure or strategy once should lead to a change in events. • Once the patterns and/or observable events change, the structures are no longer needed to maintain the outcome.
	Representation	• All information about the system is of equal value. • We can fully understand a system by analyzing isolated parts. • Complicated or lengthy explanations or representations are inherently better.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

Possible Misconceptions: 6-8 Systems Thinking

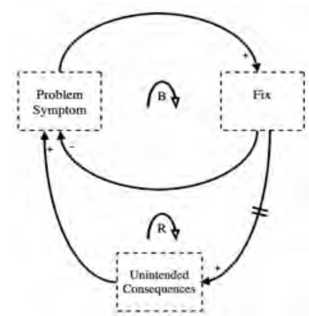
The following chart lists possible misconceptions about **Systems Thinking**. Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

<table>
<tr><th colspan="3">Students might exhibit the following misconception, belief, or perception that…</th></tr>
<tr><td rowspan="3">Leverage Actions</td><td>Identification and Explanation</td><td>• All leverage actions are equally impactful.
• Any action is a leverage point because it is part of the system.
• A leverage point must be large and obvious.
• A leverage action must come from an external source.</td></tr>
<tr><td>Representation</td><td>• Systems thinking tools are interchangeable in all situations.</td></tr>
<tr><td>Transfer</td><td>• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another.
• A generalization alone is a sufficient basis for transfer.</td></tr>
<tr><td rowspan="3">Big Picture</td><td>Identification and Explanation</td><td>• We cannot begin to explore the big picture until we fully understand all the details.
• The details don’t matter in relation to the big picture.
• A system only has one perspective, or only one perspective that matters.
• Big-picture understanding is static; once we identify it, it never changes.</td></tr>
<tr><td>Representation</td><td>• All elements of the system are of equal importance.
• Systems thinking tools are interchangeable in all situations.</td></tr>
<tr><td>Transfer</td><td>• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another.
• A generalization alone is a sufficient basis for transfer.</td></tr>
</table>

Possible Misconceptions: 6-8 Self-Regulation and Reflection

The following chart lists possible misconceptions about **Self-Regulation and Reflection.** Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

Students might exhibit the following misconception, belief, or perception that…		
Self-Regulation and Reflection	**Reflection**	• Reflection is all about what I think; other people's perspectives don't matter. • Only the teacher's perspective matters when it comes to identifying strengths and weaknesses. • I don't have any weaknesses. • I don't have any strengths. • All weaknesses affect my performance in the same way. • Reflection is a waste of time; I don't need to reflect to improve.
	Planning	• A goal is the same thing as a plan. • Any goal is a worthy goal. • Short-term goals aren't important. • I don't need a plan; if I set a goal, I will achieve it. • I should set goals in areas where I am already successful. • I should set the same goal over and over. • Someone else will give me resources and ideas about how to improve.
	Mindset	• Systems thinking is a talent and not a skill; I am as good at it as I'll ever be. • If I'm really good at something, I won't encounter any challenges. • If I experience a setback, I've failed. • Others' feedback can't help me. • Mistakes are bad; smart people don't make mistakes. • The safe route leads to guaranteed success.



Archetype: A multi-loop causal loop diagram that represents behavior commonly seen in complex systems. The archetypes are named - for example, "Fixes That Fail." In these systems, a problem is solved by some fix (a specific solution) that causes an immediate positive effect. Nonetheless, the "side effects" of this solution, after a time delay, make the problem worse.

Feedback: The interaction between two stocks that affect each other in turn.

- Balancing Feedback: "Effect of an action returned (fed back) to oppose the very action that caused it. Balancing feedback has a correcting or stabilizing effect on the system, and it reduces the difference (variance) between where the system is (the current status) and where it should be (the target value, or objective). For example, demand and supply in an economy work on each other to reach a stable (equilibrium) state through the feedback of information about price and availability. If supply is known to be greater than demand, price falls. Low price forces suppliers to pull out of the market, causing shortage that results in increase in price. High price attracts more supplies than there is demand ... and so on until a rough parity is achieved. Criticism can also be a balancing feedback if it results in the desired change in the recipient's behavior." (BusinessDictionary.com)

- Reinforcing Feedback: "Effect of an action, change, or decision returned to amplify or bolster what caused it. Reinforcing feedback drives a system increasingly faster in the direction it is already going whether away from its goal (called a vicious circle) or towards it (called a virtuous circle). It may destroy the system by pushing it beyond its limits unless the circle runs out of steam or is countered by a balancing feedback. A small ball of snow rolling downhill is an example of vicious circle. As its size continues to grow, it picks up ever-increasing amounts of snow. This process stops only when the giant ball of snow disintegrates under its own weight or runs out of slopes to roll down. Compound interest is an example of a virtuous circle. A praise or a reward can also be a reinforcing feedback if it results in the desired change in the recipient's behavior." (BusinessDictionary.com)

Flow: Rate of increase or decrease of a quantity that accumulates in a stock.

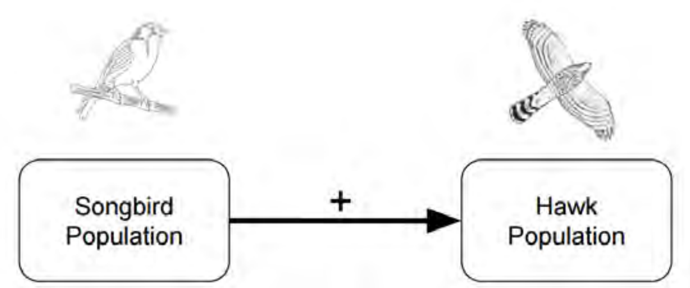
Limits: A definition of the boundaries and extent of the system, including which physical, environmental, structural, or temporal elements are relevant, and which aren't; systems may be nested within one another. Defining the limits of a system is a crucial part of the analysis of the system.

Stock: (Accumulation): A quantity that can be built up or depleted over time.

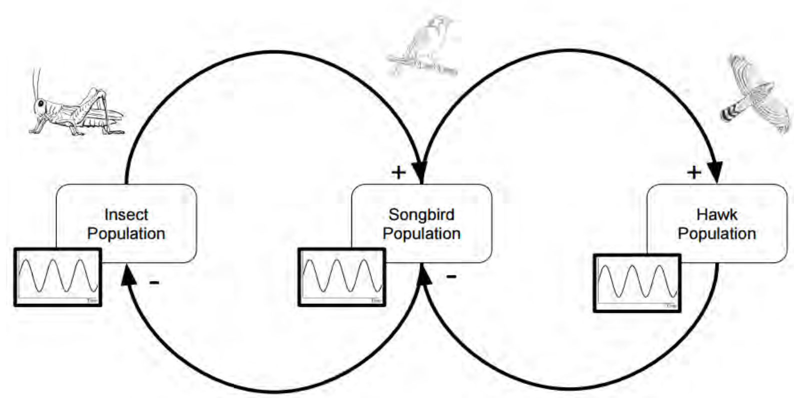
Time Delay: A gap in time between a cause and its effect within a system. Time delays may make systems hard to understand or predict.

Curricular Examples for Interdependencies: The following examples may give teachers an idea of how to use stock-flow maps:

Subject Area	Stock	Flow	Converters	Potential Feedback Relationships
Science	Songbird and Hawk Populations	• Songbirds born per year (increasing) • Songbirds dying per year (decreasing)	• Hawk predation • Number of fertile adult female songbirds	Hawk population (balancing feedback)

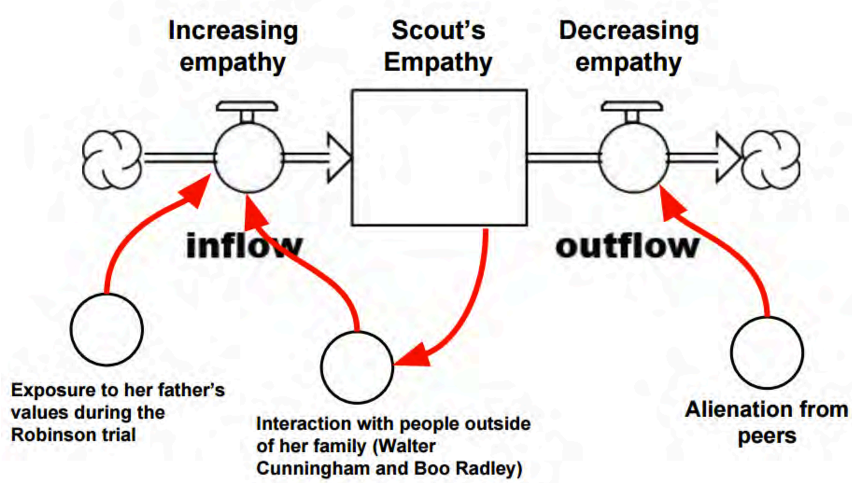


[1]*As songbird populations increase, hawk populations increase.*

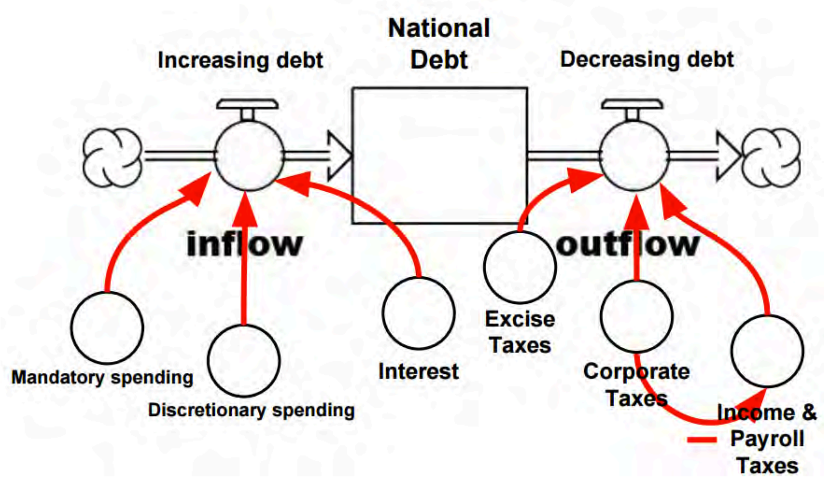


[2]*As hawks predate on songbird populations, songbird populations decrease, which allow insect populations to increase; this increase, however, has a balancing effect, allowing songbird populations to increase. Each population exists in a balancing relationship with the adjacent populations.*

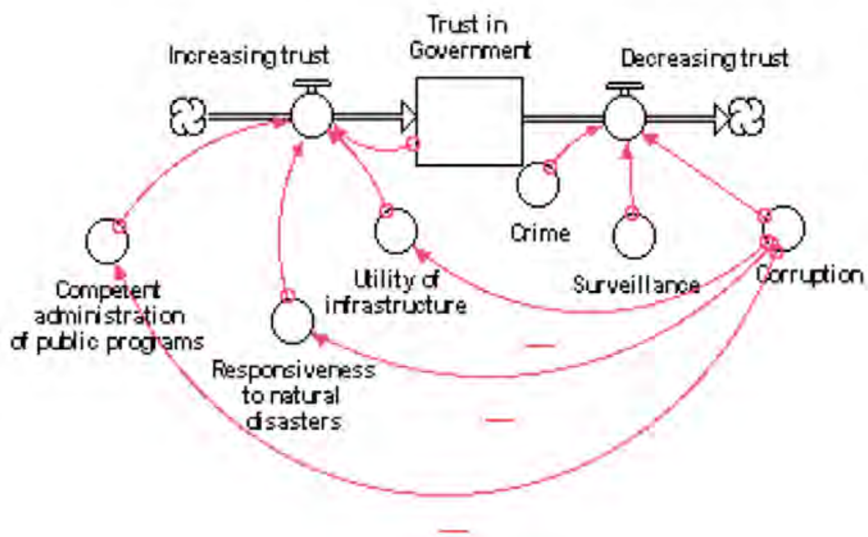
Subject Area	Stock	Flow	Converter(s)	Potential Feedback Relationships
English Language Arts	Scout Finch's level of empathy	• Increasing empathy • Decreasing empathy	• Exposure to her father's values during the Robinson trial • Interaction with people outside of her family (Walter Cunningham and Boo Radley)	Her empathy and the strength of her relationships with others (reinforcing feedback)



Subject Area	Stock	Flow	Converter(s)	Potential Feedback Relationships
Social Studies	National Debt	• Government spending (increasing debt) • Government revenue (decreasing debt)	• Kinds of Taxes • Mandatory spending: Social Security, Medicare, Medicaid, etc. • Discretionary spending: Military, Education, International Aid, Energy, etc.	• Federal Budget Surplus (reinforcing • Credit with other countries (balancing) • Corporate taxes reduce business expenditures on employees – reducing funds available through income/payroll taxes



Subject Area	Stock	Flow	Converter(s)	Potential Feedback Relationships
History	Trust in Government	• Increasing trust • Decreasing trust	• Scope of government surveillance • Competent administration of public programs	• Willingness to pay for public goods (reinforcing feedback) • Corruption erodes provision of services



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SYSTEMS THINKING RUBRIC
GRADES 9-12

CATALINA FOOTHILLS SCHOOL DISTRICT

TUCSON, ARIZONA

General Description and Suggestions for Use

The district's strategic plan, Envision21: Deep Learning, forms the basis for a focus on cross-disciplinary skills/proficiencies necessary for preparing our students well for a 21st century life that is increasingly complex and global. These skills, which are CFSD's "deep learning proficiencies" (DLPs) are represented as 5c + s = dlp. They are the 5Cs: (1) Citizenship, (2) Critical Thinking and Problem Solving, (3) Creativity and Innovation, (4) Communication, (5) Collaboration + S: Systems Thinking. CFSD developed a set of rubrics (K-2, 3-5, 6-8, and 9-12) for each DLP.

These rubrics were developed using a backward design process to define and prioritize the desired outcomes for each DLP. They provide a common vocabulary and illustrate a continuum of performance. By design, the rubrics were not written to align to any specific subject area; they are intended to be contextualized within the academic content areas based on the performance area(s) being taught and assessed. In practice, this will mean that not every performance area in each of the rubrics will be necessary in every lesson, unit, or assessment.

The CFSD rubric for **Systems Thinking** was designed as a cross-disciplinary tool to support educators in teaching and assessing the performance areas associated with this proficiency:

- **Change Over Time**
- **Interdependencies**
- **Consequences**
- **System as Cause**
- **Leverage Actions**
- **Big Picture**
- **Self-Regulation and Reflection**

This tool is to be used primarily for formative instructional and assessment purposes; it is not intended to generate psychometrically valid, high stakes assessment data typically associated with state and national testing. CFSD provides a variety of tools and templates to support the integration of **Systems Thinking** into units, lessons, and assessments. When designing units, teachers are encouraged to create authentic assessment opportunities in which students can demonstrate mastery of content and the deep learning proficiencies at the same time.

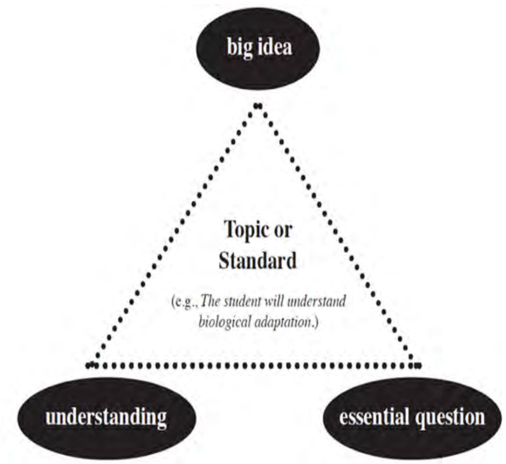
The approach to teaching the performance areas in each rubric may vary by subject area because the way in which they are applied may differ based on the field of study. Scientists, mathematicians, social scientists, engineers, artists, and musicians (for example), all collaborate, solve problems, and share their findings or work within their professional communities. However, the way in which they approach their work, the tools used for collaboration, and the format for communicating their findings may vary based on the profession. These discipline-specific expressions of the 5Cs + S may require some level of customization based on the subject area. Each rubric can also be used to provide students with an opportunity to self-assess the quality of their work in relation to the performance areas. Student-friendly language or "I can" statements can be used by students to monitor and self-assess their progress toward established goals for each performance area.

Transfer

CFSD educators prioritize understanding and transfer to ensure that learning extends beyond the school experience. This 2019 version of the DLP, **Systems Thinking**, includes long-term **transfer goals** that describe autonomous applications of student learning in college, career, and civic life. "Drill and direct instruction can develop discrete skills and facts into automaticity…but they cannot make us truly able. Understanding is about *transfer*, in other words. To be truly able requires the ability to transfer what we have learned to new and sometimes confusing settings. The ability to transfer our knowledge and skill effectively involves the capacity to take what we know and use it creatively, flexibly, fluently, in different settings or problems, on our own" (Wiggins and McTighe, 2011, p. 40).

Big Ideas

This 2019 version of the DLP, **Systems Thinking,** includes a set of Understandings and Essential Questions (UEQs) developed by an interdisciplinary team of K-12 teachers and administrators with guidance from Jay McTighe, author of *Understanding by Design*. These big ideas will guide teachers toward the thoughtful design of assessments, units, and lessons that will facilitate transfer of deep learning. "Because big ideas are the basis of unified and effective understanding, they provide a way to set curriculum and instructional priorities…they illuminate experience; they are the linchpin of transfer…" (Wiggins and McTighe, 2011, p.71). "Understandings are the specific insights, inferences, or conclusions about the big idea you want your students to leave with" (Wiggins and McTighe, 2011, p. 80). "Essential questions make our unit plans more likely to yield focused and thoughtful learning and learners" (McTighe, 2017; McTighe & Wiggins, 2013, p. 17). The figure on the right represents the interrelationship among big ideas, understandings, and essential questions.



The **DLP Understandings** are written for K-12 because they express lasting, transferable goals for student learning. Understandings are meant to be revisited over time and across contexts. The continuity of working toward the same goals will help students deepen their understanding from Kindergarten to 12th grade. Understandings are primarily planning tools for teachers, although teachers may choose to share them with their students, if appropriate. Communicating an Understanding does not give away "the answer," since simply stating an Understanding is not the same as truly grasping its meaning.

The **Essential Questions** are teaching and learning tools that help students unpack the Understandings. They support inquiry and engagement with deep learning and therefore may vary in complexity across grade levels.

Systems Thinking Transfer Goals and UEQs

Transfer Goals	
Students will be able to independently use their learning to. . . • Employ the habits of a systems thinker to better understand situations, make effective decisions, and plan for the future.	
Understandings	**Essential Questions**
Students will understand that. . .	**Students will keep considering. . .**
• A system is comprised of interrelated and interdependent parts which serve a specific purpose; changing one part of a system affects other parts.	• What is a system? • How do elements of a system affect each other? • How do the elements fit into the system as a whole? • Why are things the way they are? • What are the causal relationships within a system?
• Systems thinking enables us to look at problems and situations in new ways, which can lead to new solutions and insights.	• How can we use systems thinking to effect change, make predictions, and/or solve problems? • How can we maintain balance between the “big picture” and important details?
• Systems thinkers use specific habits, tools, and vocabulary to represent, describe, and analyze systems and solve problems.	• What makes an effective systems thinker? • How can we use the habits of a systems thinker to help us understand and analyze a system? • How can we come to understand and improve a system? • Which tool(s) will be most effective in analyzing the relationships within the system?
• Systems thinkers observe and connect information in order to understand systems.	• What makes an effective systems thinker? • What are the causal relationships within a system? • How can we maintain balance between the “big picture” and important details?

• A system's structure drives its behavior.	• How do structures drive behavior? • Why are things the way they are?
• Examining a system from different perspectives helps us identify various mental models and better understand the system.	• How do mental models affect our thoughts and actions? • Why are things the way they are?
• Recognizing patterns of change enables prediction and guides planning for the future.	• What has changed and why? • How can analyzing patterns help us predict or plan for the future? • What patterns or trends have emerged over time? • How does understanding of one system transfer to understanding of another system?
• Actions can have short-term, long-term, and/or unintended consequences; we can strategically choose leverage actions that produce or increase desired results.	• What are the causal relationships within a system? • What are the systemic effects of actions in a system? • How does determining possible short-term, long-term, and/or unintended consequences help us make decisions? • How do we determine where a small change might have a long-lasting, desired effect?

Self-Regulation and Reflection Transfer Goals and UEQs

Transfer Goals	
Students will be able to independently use their learning to. . . • Improve performance and persevere through challenges by applying deliberate effort, appropriate strategies, and flexible thinking.	
Understandings	**Essential Questions**
Students will understand that. . .	**Students will keep considering. . .**
1. Effective learners set goals, regularly monitor their thinking, seek feedback, self-assess, and make needed adjustments.	• How am I doing? How do I know? What are my next steps? • What is the most effective way to monitor my progress? • How do I know which feedback will help me improve my work? • How can I get useful feedback? • How do I prioritize my work? • How can I maintain focus on areas of influence rather than on factors I cannot influence?
2. We can always improve our performance through deliberate effort and use of strategies.	• How can I keep getting better at systems thinking?

The deep learning proficiencies (5c+ s) are highly interconnected. For example, productive collaboration is contingent upon effective communication. Efficient and effective problem solving often requires collaboration skills. Divergent and convergent thinking, which are traits of Creativity and Innovation, are directly related to critical thinking. Our students will need to use a combination of proficiencies to solve problems in new contexts beyond the classroom. Therefore, it is important to be clear about which proficiency and/or performance area(s) are the focus for student learning, and then to assist students in understanding the connections between them and how they are mutually supportive.

<u>What does Score 1.0 – Score 4.0 mean in the rubrics?</u>

The rubrics are intended to support student progress toward mastering the deep learning proficiencies (DLPs). Four levels of performance are articulated in each rubric: Score 1.0 (Novice), Score 2.0 (Basic), Score 3.0 (Proficient), and Score 4.0 (Advanced). The descriptions follow a growth model to support students in developing their skills in each performance area. Scores 1.0 (Novice) and 2.0 (Basic) describe positive steps that students might take toward achieving Score 3.0 (Proficient) or Score 4.0 (Advanced) performance.

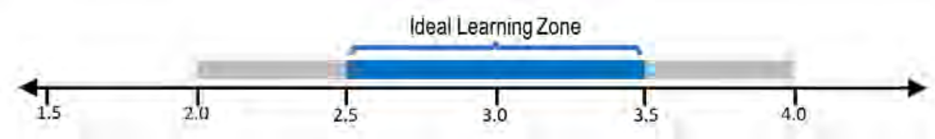
When using the rubrics to plan for instruction and assessment, teachers need to consider the knowledge and skills described in the Score 2.0 column (Basic) to be embedded in the Score 3.0 (Proficient) and 4.0 (Advanced) performance. The Novice level (Score 1.0) indicates that the student does not yet demonstrate the basic skills within the performance area, but that he/she exhibits related readiness skills that are a stepping-stone to a higher level of proficiency. Descriptions at the Novice level also include likely misconceptions that the student might exhibit.

The descriptive rubrics are designed to illustrate students' depth of knowledge/skill at various levels in order to facilitate the instructional and assessment process for all learners. At some performance levels, the indicators may remain the same. However, the material under study is more or less depending on the grade level band (for example: the complexity of the material at grades 6-8 differs from that of grades 3-5 or 9-12).

The following descriptions explain the four levels on the rubric:

- Score 1.0 (Novice): Describes student performance that demonstrates readiness skills and/or misconceptions and requires significant support.
- Score 2.0 (Basic): Describes student performance that is below proficient, but that demonstrates mastery of basic skills/knowledge, such as terms and details, definitions, basic inferences, and processes.
- Score 3.0 (Proficient): Describes student performance that is proficient – the targeted expectations for each performance area of the DLP.
- Score 4.0 (Advanced): Describes an exemplary performance that exceeds proficiency.

The image below represents the ideal learning zone for students as 2.5 – 3.5.



Glossary

Long-term consequences: Intended or unintended consequences that have longer lasting effects and that are harder to anticipate.

Short-term consequences: Short-term or immediate effects that are often easier to identify or predict. Many humans make decisions just based on short-term consequences.

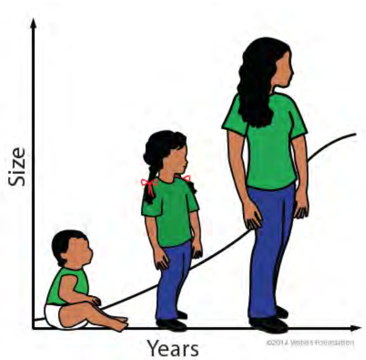
*Transfer: Before a student can successfully transfer, he/she must first master the other skills within each performance area.

Sources

The following sources directly influenced the revision of CFSD's rubrics:

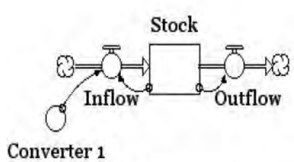
- Catalina Foothills School District. (2011, 2014, 2016, 2018). Rubrics for 21st century skills and rubrics for deep learning proficiencies. Tucson, Arizona
- Waters Center for Systems Thinking, https://waterscenterst.org/

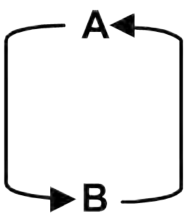
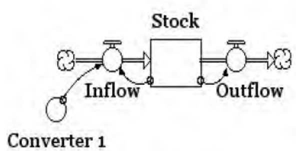
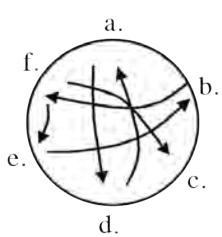
A **system** is a collection of elements that interact with each other over time to function as a whole (Waters Center for Systems Thinking, 2018). A **systems thinker** is anyone who uses the **Habits of a Systems Thinker** (see end of document) in combination with the concepts and visual tools of systems thinking to increase understanding of systems and how they influence both short- and long-term consequences. Many systems thinking concepts are embedded either explicitly or implicitly within the Habits of a Systems Thinker. The CFSD Systems Thinking rubrics include the concepts of Change Over Time, Interdependencies, Consequences, System-as-Cause, Leverage Actions, and Big Picture. Systems thinking provides students with a more effective way to interpret the complexities of the world in which they live—a world that is increasingly dynamic, global, and complex.

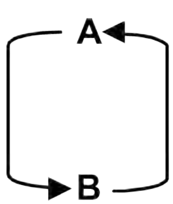
Change Over Time, page 8	**Consequences, page 10**	**Leverage Actions, page 12**
		
Interdependencies, page 9	**System-as-Cause, page 11**	**Big Picture, page 14**
		

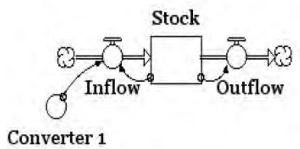
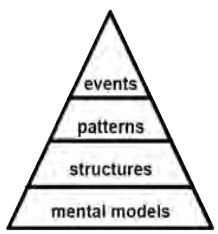
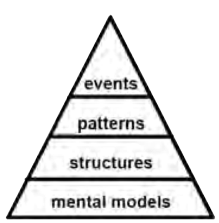
 Reviewed by Waters Center for Systems Thinking Associates

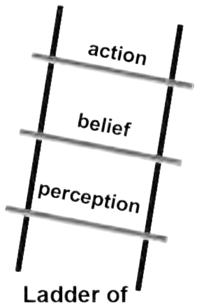
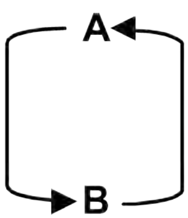
SYSTEMS THINKING

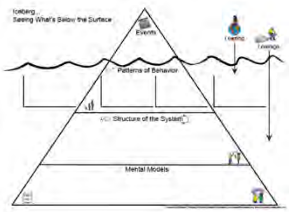
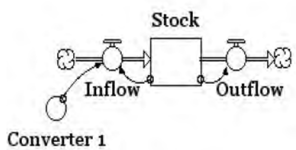
DLP Performance Area	1.0 (Novice) The student may exhibit the following readiness skills for Score 2.0:	2.0 (Basic) When presented with a grade-appropriate task, the student:	3.0 (Proficient) In addition to Score 2.0, the student:	4.0 (Advanced) In addition to Score 3.0, the student may:
CHANGE OVER TIME  **Behavior-over-time graphs**  **Stock-flow maps**	**Identification and Explanation:** Defines *accumulation*, *rate of change*, *element*, *trend*, and *pattern*. Describes a change that occurs over time. Lists and orders events. **Representation:** Charts a change over time, given a graph with pre-defined *x* and *y* axes. **Transfer*:** Generalizes the key elements of a situation involving change over time (*for example: "This situation involves a person whose actions are influenced by her environment."* or *"This situation is characterized by a steady increase followed by a sudden drop and a slow recovery"*). Identifies common elements of two situations involving change over time.	**Identification and Explanation:** Describes general trends in change over time. Identifies elements of the system that change over time. **Representation:** Constructs a behavior-over-time graph to chart a general change over time, including defining a time frame (x axis) and a scale for changes in an accumulation (*y* axis) (*for example: line graph showing a general trend*). **Transfer*:** Applies conclusions about change over time in one situation to a situation of a similar type (*for example: perseverance over time for two characters in different texts*).	**Identification and Explanation:** Describes the nature of specific trends in changes over time (*for example: a gradual increase, a sudden drop, a stepwise increase, an increase approaching a limit*). Analyzes why elements of a system change over time. **Representation:** Constructs a detailed behavior-over-time graph (*for example: depicts transitions, annotates with evidence supporting claims, etc.*) to chart specific changes over time (including specific changes in rate, relationship between general trend, and transition points). Constructs a stock-flow map to analyze why elements of a system change over time (*for example: includes individual behavior-over-time graphs within stocks to show behavior of the system over time*). **Transfer*:** Applies understanding of an identified	**Identification and Explanation:** Identify and explain overarching patterns in change over time. Analyze the relationship between two or more elements that change over time. **Representation:** Create the most concise representation possible of a change over time, aggregating (generalizing) detailed information to represent the wider perspective on an issue or process. Represent change over time of more than one element, identifying specific patterns and trends. Select specific time frames or *y*-axis values to highlight particular changes, patterns, or trends. **Transfer*:** Evaluate the validity of conclusions drawn about changes within two or more systems (*for example: it may not be valid to stress the similarities*

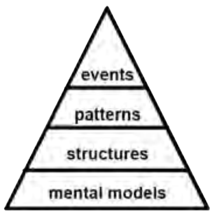
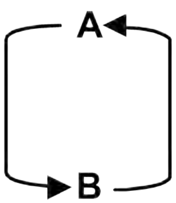
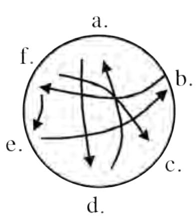
	See possible student misconceptions following the rubric.		change over time to analyze a situation of a different type that operates in a similar manner (*for example: a fictional character's perseverance over time compared to that of an historic figure*).	*of a fictional character to a historical figure, because we never have access to historical characters' thoughts; however, in some cases, diary or journal entries may reveal valid similarities*).
INTERDEPENDENCIES  **Causal loops**  **Stock-flow maps and computer models**  **Connection circles**	**Identification and Explanation:** Defines *feedback loop*, *reinforcing*, *balancing*, *stock*, and *causality*. Shows causal relationships as one-way, e.g., cause → effect (for example: increasing songbird populations lead to higher hawk populations[1]). **Representation:** Represents connections between the key elements of a system (*for example: uses a connection circle*). **Transfer*:** Generalizes the key elements of a system with interdependent relationships (*for example: "This situation involves two interdependent, symbiotic species" or "This situation is marked by a reinforcing loop and a balancing loop with one common actor"*).	**Identification and Explanation:** Identifies and explains a single cause-and-effect loop. Distinguishes whether a loop represents a reinforcing or balancing process, or a causal relationship without feedback (*for example: as predator numbers increase, prey population decreases, which leads to decreased predator numbers…which is a balancing loop; as the number of trains in North America increased, bison populations decreased – however, changes in bison populations do not affect the number of trains…so it is a one-way causal relationship without feedback*). **Representation:** Represents a circular causal relationship between two elements of a system (*for example: uses a stock-flow map or causal loop diagram*).	**Identification and Explanation:** Identifies and explains causality in a system of multiple connected loops. Explains the behavior over time of any stock in the system in relation to another stock (*for example: hawk, songbird, and insect populations are linked in two connected loops. See below.*[2]) **Representation:** Represents causality in a system of multiple connected loops (*for example: uses a stock-flow map or causal loop diagram*). Identifies when causality can best be represented with a stock-flow map or causal loop diagram (*for example, the interdependence between population and births can best be represented with a stock-flow map*). Represents loops that account for complex behavior beyond	**Identification and Explanation:** Explain causal relationships and behaviors that are significant, but not obvious (*for example: the timing of a population boom in songbirds that coincides with a particular stage in the life cycle of its insect prey -- when it is dormant or pupating*). Explain loops that account for complex behavior beyond basic reinforcing or balancing behaviors (*for example: archetypes such as fixes that fail, limits to growth, or which include thresholds, time delays, etc.*). **Representation:** Create the most concise representation possible of a system, aggregating (generalizing) detailed information to represent the whole-system perspective on an issue or process.

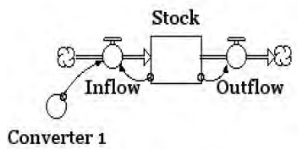
	Identifies common elements of causal relationships in two situations. See possible student misconceptions following the rubric.	**Transfer*:** Applies conclusions about interdependencies in one situation to a situation of a similar type (*for example: the increase in prey populations in response to plant increase in an ecosystem parallels the increase in bacterial growth in response to an increase in organic matter).*	basic reinforcing or balancing behaviors *(for example: archetypes such as thresholds, limits to growth, etc.*). **Transfer*:** Applies conclusions about key interdependencies in one situation to a situation of another type (*for example: the increase in prey populations in response to plant increase in an ecosystem parallels the increase of investors in a market when money is made more freely available - through interest rates, etc.*).	Represent causal relationships and behaviors that are significant, but not obvious. Represent loops that account for complex behavior beyond basic reinforcing or balancing behaviors *(for example: archetypes such as thresholds, limits to growth, etc.*). **Transfer*:** Evaluate the validity of conclusions drawn about two or more systems (*for example: it may be overly simplistic to compare prey populations to investors, because investors are able to discover and communicate information about the environment which allows them to respond as a group differently than prey species).*
CONSEQUENCES  Causal loops	**Identification and Explanation:** Defines *short-term consequences* and *long-term consequences*, *intended consequences*, and *unintended consequences.* Identifies at least one consequence for an action. **Representation:** Lists results occurring from actions. **Transfer*:** Generalizes the key elements of a situation	**Identification and Explanation:** Identifies and explains short-term and/or long-term intended consequences of a particular action. **Representation:** Identifies short-term and/or long-term consequences of a particular action on a provided causal loop diagram. **Transfer*:** Applies conclusions about consequences in one	**Identification and Explanation:** Identifies and explains short- and long-term intended and unintended consequences that have emerged as a result of actions (*for example: Explains a case in which "the most obvious solution" made a situation worse in the long term*). **Representation:** Represents short- and long-term intended consequences through a causal	**Identification and Explanation:** Predict and explain potential unintended consequences of an action *(for example: how a proposed solution could potentially backfire*). **Representation:** Create the most concise representation possible of a system, aggregating (generalizing) detailed information to represent the whole-system

 **Stock-flow maps and computer models**  Iceberg	involving actions and consequences (*for example: "This situation involves an individual who chose not to comply with the regulations of a governing body." or "This situation is marked by an unintended consequence that happens after a significant delay"*). Identifies common elements of actions and consequences in two situations. See possible student misconceptions following the rubric.	situation to a situation of a similar type (*for example: consequences of two different wars*).	loop diagram, stock-flow map, computer model/simulation, and/or kinesthetic activity. **Transfer*:** Applies conclusions about key consequences in one situation to a situation of another type (*for example: the effects of an antibiotic on bacteria, the effects of anti-terrorism efforts on terrorist actions*).	perspective on an issue or process. Combine representational methods to show the short- and long-term intended and unintended consequences of actions within a system (*for example: crafting a computer model / simulation; integrating behavior-over-time graphs and feedback loops; using an iceberg to combine representations into a coherent display).* **Transfer*:** Evaluate the validity of conclusions drawn about the consequences of two or more systems (*for example: students could evaluate which conclusions are valid when comparing revolutions in the United States, France, and Colombia*).
SYSTEM AS CAUSE  Iceberg	**Identification and Explanation:** Defines *mental model* and *structure of a system.* Identifies elements of a system (*for example: in a classroom, the students, the teacher, the lesson activities, the work, and the assessments*). **Representation:** Classifies given information as observable events, patterns of behavior,	**Identification and Explanation:** Identifies a system's underlying structures, mental models, and patterns of behavior (*for example: observation - students performing well on a test; pattern of behavior-homework completion and earlier test results; underlying structures - lesson design and peer tutoring; and mental model - "all students*	**Identification and Explanation:** Explains how a system's underlying structures, mental models, and patterns of behavior create behaviors over time, and observable events (*for example: we can attribute improved student performance to underlying structures such as lesson design and peer tutoring, which emerge from the mental model that "all students can be*	**Identification and Explanation:** Explain the system "top-to-bottom and bottom-to-top" (i.e., from the event to the mental model level and from the mental model to the event level). Explain how the ladder of inference generates mental models.

 Ladder of inference	structures of the system, and mental models. **Transfer*:** Identifies two systems with similarities at the level of observable events, patterns of behavior, structures of the system, or mental models. See possible student misconceptions following the rubric.	*can be successful with deliberate practice and feedback"*). **Representation:** Describes or visually represents observable events, patterns of behavior, structures of the system, and mental models. **Transfer*:** Compares and contrasts two systems at all the levels of observable events, patterns of behavior, structures of the system, or mental models (*for example: compare/ contrast subsistence farming to modern industrial agriculture*).	*successful with deliberate practice and feedback"*). **Representation:** Selects information and uses tools to represent a unified, coherent analysis of the structure of the system. **Transfer*:** Applies conclusions about the structure of a system to another system (*for example: what might happen if we applied the mental models underlying a communal farming community to modern industrial agriculture?*).	**Representation:** Create the most concise representation possible of a system, aggregating (generalizing) detailed information to represent the whole-system perspective on an issue or process. Represent a hypothetical or desired system in contrast to the current reality. **Transfer*:** Evaluate the validity of conclusions drawn about two or more systems (*for example: conclusions about improvements in subsistence farming drawn from industrialized systems may not be valid because the climate/soil in industrialized countries supports different crops).*
LEVERAGE ACTIONS  Causal loops	**Identification and Explanation:** Defines "leverage action." Identifies desirable and undesirable effects of an action. **Representation:** Depicts cause and effect relationships within a system. **Transfer*:** Generalizes the key elements of a situation with multiple possible leverage actions (*for example: "This*	**Identification and Explanation:** Identifies one or more potential high-leverage actions within a system. **Representation:** Labels one or more potential high-leverage actions within a system (*for example: identifying all the places humans could intervene in the water cycle*). **Transfer*:** Compares and contrasts leverage action(s) in	**Identification and Explanation:** Explains how one or more potential high-leverage actions function within a system. **Representation:** Visually represents how one or more high-leverage actions function within a system (*for example: identifying ways humans could intervene in the water cycle to create feedback which would*	**Identification and Explanation:** Surface and test assumptions about potential leverage actions within a novel context, (*for example: in a real-world context, involving student-action committees, class projects, or community involvement; or in an academic context, predicting the impact of high-leverage actions in a short story using textual*

  **Stock-flow maps and computer models**	*situation offers several ways a manufacturer could lower a price." OR "This situation is marked by several influential groups, each of which has its own needs and desires."*). See possible student misconceptions following the rubric.	two or more systems (*for example: finding leverage actions that influence the passage of a law at the state level and at the federal level*).	*amplify/magnify leverage in the system).* **Transfer*:** Applies conclusions about leverage actions from one system to another (*for example: using a medical model to curtail epidemic infection rates in order to reduce the spread of violence in the youth of a community, as described by Gary Slutkin, in his TED Talk, "Let's Treat Violence Like a Contagious Disease"*).	*evidence*), or using a model (*for example: using STELLA software*). **Representation:** Create the most concise representation possible of a system, aggregating (generalizing) detailed information to represent the whole-system perspective on an issue or process. Combine representational methods to show the impact of leverage actions (*for example: including behavior-over-time graphs and feedback loops in an iceberg).* Represent the outcomes of tested assumptions. Create a representation of the system that accommodates both short- and long-term impacts of leverage actions (*for example: incorporating time delays into stock-flow maps and/or causal loop diagrams*). **Transfer*:** Evaluate the validity of conclusions drawn about two or more systems (*for example: although gang violence and microbial infection might not seem similar, statistics of 'contagion' -- how one infected victim causes 3 more to fall sick,*

				or one victim of violence results in 3 more revenge victims -- show remarkable congruence, therefore the generalization is valid).
BIG PICTURE  Iceberg  Causal loops  Connection circles	**Identification and Explanation:** Defines *system, mental models.* Identifies and explains behaviors, goals, problems, and/or events as isolated details within a system. **Representation:** Lists issues, goals, problems, behaviors, and/or relationships among actors/parts within a system. **Transfer*:** Generalizes the key elements of how a system operates (*for example: "This system is characterized by the centralized control of a variety of separate entities, which do not communicate with one another, but draw from the same resources").* Identifies common elements of how a system operates in two situations. See possible student misconceptions following the rubric.	**Identification and Explanation:** Identifies and explains behaviors, goals, problems, and/or relationships among distinct actors/parts within a system as a series of interrelated details. **Representation:** Creates a representation of individual interrelationships among parts of a system (*for example: a stock- flow map or causal loop showing how rabbit and coyote populations relate to one another - leaving out other factors, such as water, plant production, disease, other predators, etc.*). **Transfer*:** Applies conclusions about how one system operates to a system of a similar type (*for example: a marching band moving on a field and a military unit marching in a drill*).	**Identification and Explanation:** Explains behavior of the system as a whole: identifies and explains behaviors, goals, and/or problems within a system from a wide, "big picture" view, rather than focusing on details. Investigates and considers the perspectives/mental models underlying the system being considered. **Representation:** Creates a representation of the system's most important set of structures and relationships by taking a whole-system perspective on an issue or process (*for example: a 2 or 3-stock stock-flow map or an iceberg model showing how rabbit, coyote, plant, climate, etc. relate to one another).* **Transfer*:** Applies conclusions about how one system operates to a system of another type (*for example: the behavior of a cell and the behavior of a factory*).	**Identification and Explanation:** Explain or predict how the system as a whole may change or develop over time. Analyze the effect of redefining the limits of the system (*for example: considering the system of public education as a smaller piece of a larger system of government; for example*). Analyze interactions among multiple systems (*for example: how does the system of public education interact with the labor market, or patterns of immigration?*). Propose innovative and logical ways to change the system. **Representation:** Create the most concise representation possible of a system, aggregating (generalizing) detailed information to represent the whole-system perspective on an issue or process.

 **Stock-flow maps and computer models**				Create an alternate representation of the system by redefining the boundaries or agents of the system, or by including actors/parts not included in previous representations (*for example: redefining the coyote/rabbit predator/ prey relationship in terms of energy transfer between trophic levels, rather than as interactions among individual organisms*). **Transfer*:** Evaluate the validity of conclusions drawn about two or more systems (*for example: the comparison is valid because a cell, like a factory, only works when all the parts within it perform their own functions, and both are dependent on receiving materials from outside*).
SELF-REGULATION AND REFLECTION	**Reflection:** Identifies own strengths and weaknesses as a systems thinker. **Planning:** Sets personal goals for applying systems thinking habits and tools. **Mindset:** Explains the relationship between effort and success (*for example: "The harder I work at this, the better I'll be at*	**Reflection:** Assesses application of the habits and tools of a systems thinker in response to feedback and/or established criteria. **Planning:** Sets goals for applying systems thinking based on feedback and/or established criteria.	**Reflection:** Accurately reflects on the application of systems thinking habits and tools; uses reflection and/or feedback to revise thinking or to improve ideas. Questions and critiques own thinking process. Describes the learning that resulted from systems thinking.	**Reflection:** Analyze patterns and trends in own thinking process. Evaluate the application of systems thinking habits and tools throughout the process. Seek out and act on feedback from peers, teacher, and experts to improve. **Planning:** Analyze patterns and prior performances to set new

	it"; "I will work harder in this class from now on."). See possible student misconceptions following the rubric.	**Mindset:** Demonstrates a desire to improve *(for example: employs more practice, sets goals for improvement, asks for help from others instead of giving up).*	**Planning:** Seeks out, selects, and uses resources and strategies to achieve goals for improving the application of systems thinking habits and tools. **Mindset:** Demonstrates a growth mindset (the belief that he or she can get "smarter" at systems thinking through effective effort) in response to setbacks and challenges *(for example: persists on difficult tasks, takes risks in the learning process, accepts and uses feedback/criticism, is comfortable making mistakes, explains failure from a growth mindset perspective).*	goals for applying systems thinking habits and tools; revise goals in response to ongoing reflection. **Mindset:** Proactively improve own areas of weakness by employing effective strategies to increase growth mindset (*for example: perseverance, taking risks, effective decision-making, actively seeking others' feedback, deliberate practice, finding and using external resources [skilled peers, other adult experts] to enrich and extend learning).*

Possible Misconceptions: 9-12 Systems Thinking

The following chart lists possible misconceptions about **Systems Thinking**. Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

Students might exhibit the following misconception, belief, or perception that…		
Change Over Time	**Identification and Explanation**	• All change happens in the same way. • Once change is initiated, it will follow the same rate or trend over time.
	Representation	• Change-over-time graphs all take the same shape. • Actions (verbs) and things (nouns) are interchangeable as stocks and flows. • Reinforcing and balancing loops are value judgments (for example: reinforcing = good and balancing = bad).
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
Interdependencies	**Identification and Explanation**	• Two things are related because they happen at the same time. • Correlation equals causation.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

Possible Misconceptions: 9-12 Systems Thinking

The following chart lists possible misconceptions about **Systems Thinking**. Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

Students might exhibit the following misconception, belief, or perception that…		
Consequences	**Identification and Explanation**	• There are only intended consequences. • One type of consequence (short- or long-term, intended or unintended) is more important than another. • Any action will result in immediate change.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
System as Cause	**Identification and Explanation**	• My perception of a situation is accurate. • Events just "happen" for no reason or are caused by external factors. • My perspective, beliefs, and/or actions do not influence the system, situation, or behavior of others. • Implementing a structure or strategy once should lead to a change in events. • Once the patterns and/or observable events change, the structures are no longer needed to maintain the outcome.
	Representation	• All information about the system is of equal value. • We can fully understand a system by analyzing isolated parts. • Complicated or lengthy explanations or representations are inherently better.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

Possible Misconceptions: 9-12 Systems Thinking

The following chart lists possible misconceptions about **Systems Thinking**. Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

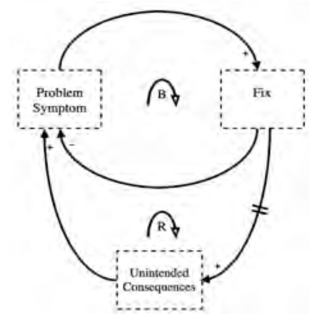
Students might exhibit the following misconception, belief, or perception that…		
Leverage Actions	**Identification and Explanation**	• All leverage actions are equally impactful. • Any action is a leverage point because it is part of the system. • A leverage point must be large and obvious. • A leverage action must come from an external source.
	Representation	• Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.
Big Picture	**Identification and Explanation**	• We cannot begin to explore the big picture until we fully understand all the details. • The details don't matter in relation to the big picture. • A system only has one perspective, or only one perspective that matters. • Big-picture understanding is static; once we identify it, it never changes.
	Representation	• All elements of the system are of equal importance. • Systems thinking tools are interchangeable in all situations.
	Transfer	• All situations are unique; therefore, analysis of one cannot be applied to the analysis of another. • A generalization alone is a sufficient basis for transfer.

Possible Misconceptions: 9-12 Self-Regulation and Reflection

The following chart lists possible misconceptions about **Self-Regulation and Reflection.** Understanding student misconceptions can help teachers develop lessons that proactively address these barriers to deep learning and transfer.

Students might exhibit the following misconception, belief, or perception that…		
Self-Regulation and Reflection	**Reflection**	• Reflection is all about what I think; other people's perspectives don't matter. • Only the teacher's perspective matters when it comes to identifying strengths and weaknesses. • I don't have any weaknesses. • I don't have any strengths. • All weaknesses affect my performance in the same way. • Reflection is a waste of time; I don't need to reflect to improve.
	Planning	• A goal is the same thing as a plan. • Any goal is a worthy goal. • Short-term goals aren't important. • I don't need a plan; if I set a goal, I will achieve it. • I should set goals in areas where I am already successful. • I should set the same goal over and over. • Someone else will give me resources and ideas about how to improve.
	Mindset	• Systems thinking is a talent and not a skill; I am as good at it as I'll ever be. • If I'm really good at something, I won't encounter any challenges. • If I experience a setback, I've failed. • Others' feedback can't help me. • Mistakes are bad; smart people don't make mistakes. • The safe route leads to guaranteed success.

Archetype: A multi-loop causal loop diagram that represents behavior commonly seen in complex systems. The archetypes are named - for example, "Fixes That Fail." In these systems, a problem is solved by some fix (a specific solution) that causes an immediate positive effect. Nonetheless, the "side effects" of this solution, after a time delay, make the problem worse.



Feedback: The interaction between two stocks that affect each other in turn.

- Balancing Feedback: "Effect of an action returned (fed back) to oppose the very action that caused it. Balancing - feedback has a correcting or stabilizing effect on the system, and it reduces the difference (variance) between where the system is (the current status) and where it should be (the target value, or objective). For example, demand and supply in an economy work on each other to reach a stable (equilibrium) state through the feedback of information about price and availability. If supply is known to be greater than demand, price falls. Low price forces suppliers to pull out of the market, causing shortage that results in increase in price. High price attracts more supplies than there is demand ... and so on until a rough parity is achieved. Criticism can also be a balancing feedback if it results in the desired change in the recipient's behavior." (BusinessDictionary.com)

- Reinforcing Feedback: "Effect of an action, change, or decision returned to amplify or bolster what caused it. Reinforcing feedback drives a system increasingly faster in the direction it is already going whether away from its goal (called a vicious circle) or towards it (called a virtuous circle). It may destroy the system by pushing it beyond its limits unless the circle runs out of steam or is countered by a balancing feedback. A small ball of snow rolling downhill is an example of vicious circle. As its size continues to grow, it picks up ever-increasing amounts of snow. This process stops only when the giant ball of snow disintegrates under its own weight or runs out of slopes to roll down. Compound interest is an example of a virtuous circle. A praise or a reward can also be a reinforcing feedback if it results in the desired change in the recipient's behavior." (BusinessDictionary.com)

Flow: Rate of increase or decrease of a quantity that accumulates in a stock.

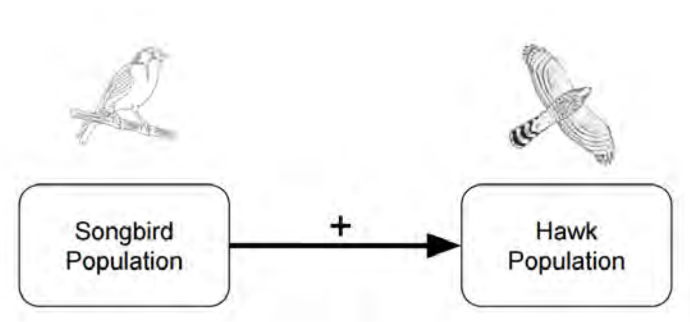
Limits: A definition of the boundaries and extent of the system, including which physical, environmental, structural, or temporal elements are relevant, and which aren't; systems may be nested within one another. Defining the limits of a system is a crucial part of the analysis of the system.

Stock: (Accumulation): A quantity that can be built up or depleted over time.

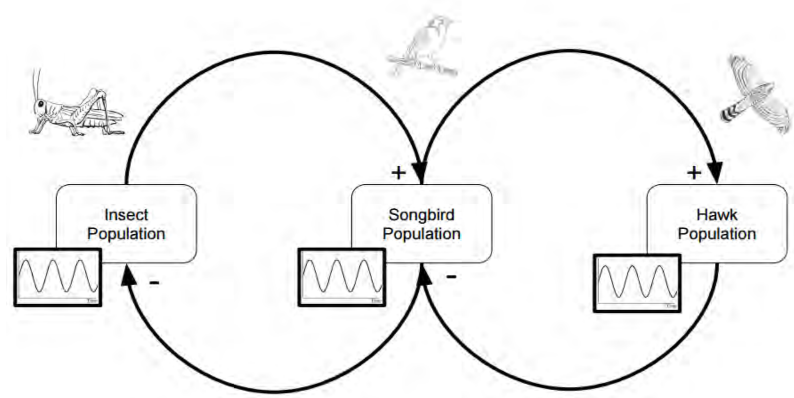
Time Delay: A gap in time between a cause and its effect within a system. Time delays may make systems hard to understand or predict.

Curricular Examples for Interdependencies: The following examples may give teachers an idea of how to use stock-flow maps:

Subject Area	Stock	Flow	Converters	Potential Feedback Relationships
Science	Songbird and Hawk Populations	• Songbirds born per year (increasing) • Songbirds dying per year (decreasing)	• Hawk predation • Number of fertile adult female songbirds	Hawk population (balancing feedback)

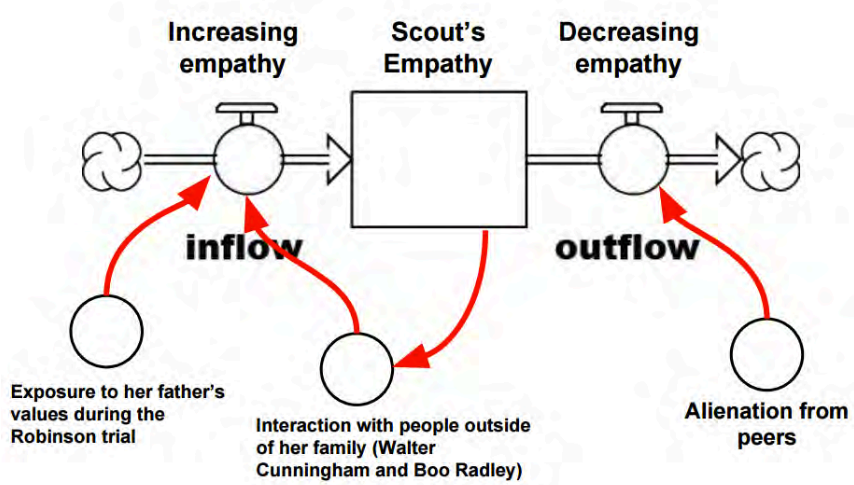


[1]*As songbird populations increase, hawk populations increase.*

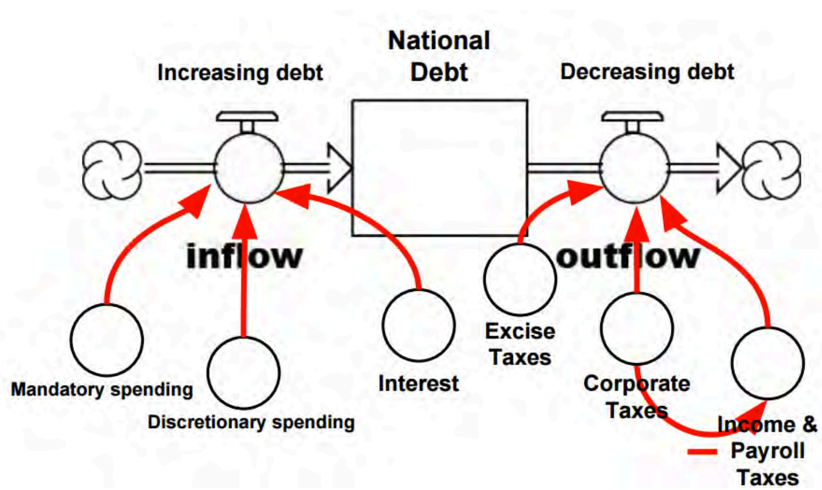


[2]*As hawks predate on songbird populations, songbird populations decrease, which allow insect populations to increase; this increase, however, has a balancing effect, allowing songbird populations to increase. Each population exists in a balancing relationship with the adjacent populations.*

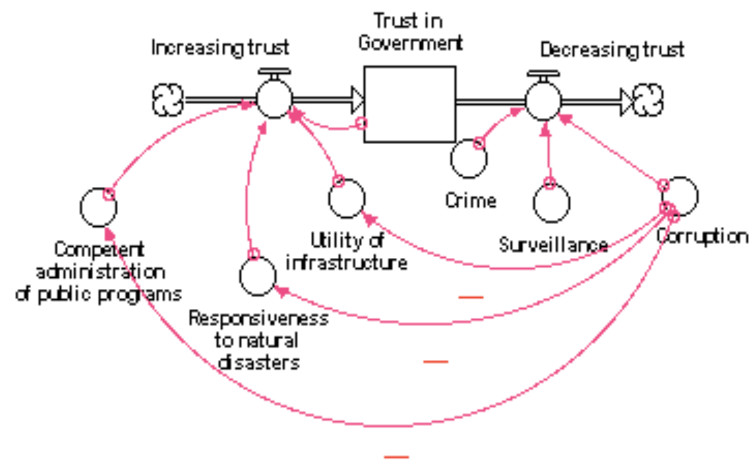
Subject Area	Stock	Flow	Converter(s)	Potential Feedback Relationships
English Language Arts	Scout Finch's level of empathy	• Increasing empathy • Decreasing empathy	• Exposure to her father's values during the Robinson trial • Interaction with people outside of her family (Walter Cunningham and Boo Radley)	Her empathy and the strength of her relationships with others (reinforcing feedback)



Subject Area	Stock	Flow	Converter(s)	Potential Feedback Relationships
Social Studies	National Debt	• Government spending (increasing debt) • Government revenue (decreasing debt)	• Kinds of Taxes • Mandatory spending: Social Security, Medicare, Medicaid, etc. • Discretionary spending: Military, Education, International Aid, Energy, etc.	• Federal Budget Surplus (reinforcing • Credit with other countries (balancing) • Corporate taxes reduce business expenditures on employees – reducing funds available through income/payroll taxes



Subject Area	Stock	Flow	Converter(s)	Potential Feedback Relationships
History	Trust in Government	• Increasing trust • Decreasing trust	• Scope of government surveillance • Competent administration of public programs	• Willingness to pay for public goods (reinforcing feedback) • Corruption erodes provision of services




Seeks to understand the big picture
Observes how elements within systems change over time, generating patterns and trends
Size
Years
Recognizes that a system's structure generates its behavior
Identifies the circular nature of complex cause and effect relationships
Makes meaningful connections within and between systems
Changes perspectives to increase understanding
Surfaces and tests assumptions
Sugar
Vitamins
Super Star Cereal
Habits of a Systems Thinker
Considers an issue fully and resists the urge to come to a quick conclusion
Considers how mental models affect current reality and the future
Uses understanding of system structure to identify possible leverage actions
Considers short-term, long-term and unintended consequences of actions
BANK
Donut Shop
Pays attention to accumulations and their rates of change
Recognizes the impact of time delays when exploring cause and effect relationships
Checks results and changes actions if needed: "successive approximation"
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