Systems Thinking: A 21st Century Skill

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In moments of reflection, many of us have probably turned our minds to the complicated system of interacting and interdependent parts that make up our world. Consider, for example, the complex interdependencies among parts of an ecosystem or a corporation and the interrelationships between these systems and the larger systems within which they exist. How can we, as educators, help our students to build the right skills — i.e., systems-thinking skills — to be able to make sense of global interconnectedness and to use their understandings to solve challenging problems now and in the future?

To understand the behavior of complex systems, we must understand not only the behavior of the parts, but also how they act together to form the behavior of the whole (Bar-Yam). It is not sufficient to study only the parts. The very reason for this study exists in the need to understand the system as a whole and its place in an even larger whole. Beyond understanding the structure of a system, a system thinker thinks critically and reasonably and is able to: (1) define a system’s existing behavior; (2) make this thinking visible to others; (3) create

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**Systems Thinking**

Building systems thinking skills helps learners to think critically and reason logically about problems. This is important because succeeding in today’s world requires that students understand problems and systems, breaking them down into parts, examining relationships among parts, and understanding the behavior of the parts to come up with informed decisions and appropriate solutions.
and use a model (or simulation) to explore a system’s dynamics; (4) identify and define a problem within
the system; (e) identify leverage points by which to improve the system’s functionality; and (5) use the
simulation to test the effects of different changes (possibly interventions) to the system. People who are
equipped with skills like these are able to contribute to solving complex problems and are highly valued by
society.

Many educators and policy makers are placing a strong emphasis on assisting students in developing and
improving their systems-thinking skills and associated problem-solving skills. Enhancing these skills will
help the students succeed in today’s complex world – one in which problems can no longer be passed on
to future generations.
**Research**

Systems thinking is a learner-centered approach, which is based on the notion that learning is primarily a construction rather than an assimilation process. Students who engage in systems thinking have to actively construct functional relations among relevant components either mentally or externally (Shute et al).

Why is systems thinking valuable? Systems thinking helps in designing and creating feasible solutions to complex problems. The field of systems thinking has generated a unique array of tools (e.g., causal loops, behavior over time graphs, stock and flow diagrams) to help us to (1) graphically depict our understanding of a system’s structure and behavior, helping us to think about it; (2) communicate with others about it; and (3) design high-leverage interventions for problematic system behavior (Pegasus Communications). Such activity requires deep engagement with content and a high degree of critical thinking both of which are valued by schools in preparing students for life in the 21st century.

Despite the value of systems thinking, a large body of research shows that even highly educated adults have poor systems-thinking skills (e.g. Sweeney and Sterman; Sterman). One of the reasons might be that systems thinking “does not develop ‘naturally’ . . . , but must be developed through formal education” (Sweeney and Sterman, *Thinking About Systems* 285). Thus, schools need to integrate systems concepts into their curriculum. Research shows that a well-designed curriculum that teaches systems-thinking skills (e.g., explaining relationships between parts and a whole, reading causal loop diagrams) enables students to learn analytic and synthesis skills previously taught primarily to graduate classes (Roberts).

In *National Science Education Standards*, the National Research Council identifies ‘systems’ as one of several important “unifying concepts . . . that need to be developed over an entire education . . . and [that] transcend disciplinary boundaries” (104). Taking up this idea in 1908, Inez Liftig, writes:

> A systems approach to science education is one of the powerful interdisciplinary ideas that AAAS [Advancing Science Serving Society] recommends be woven through science learning at all levels and in all content areas.
Understandings gained in learning about one system can be applied to make the learning of another more efficient. Having learned a systems approach in studying the human body, for example, students can apply their understandings about systems to make their learning more efficient when they encounter another system (e.g., the electoral system). If one adopts the view of the Earth as a 'single dynamic entity,' the possibilities for the application of systems thinking in the curriculum seem limitless.

“Incorporating a systems approach in . . . science teaching” says Lifrig, “and designing lessons with teachers in other curriculum areas will help produce . . . citizens who understand the interrelatedness between the natural physical, chemical, and biological systems they study and society's political, technological, and economic systems.”

The Research in Practice

Familiar with the benefits of systems thinking in fostering the kind of deep thinking in which we want our students to engage, educators have been working to incorporate systems thinking into the curriculum, aligning systems-thinking concepts and tools with state standards (Sweeney and Sterman, *Bathtub Dynamics*). Some states even include standards – like those listed here – that directly address systems thinking. They provide students opportunities to learn *about* systems thinking.

- “Students know that any system may be thought of as containing *subsystems* and as being a *subsystem* of a larger *system*” (6-8 SYSA). To fulfill this standard students are asked to “identify subsystems and a larger encompassing system (e.g., the heart is a system that is made up of tissues and cells, and is part of a larger circulatory system)” (OSPI).
- To fulfill the ‘Application of Science’ standard (SC.S.4.3) in West Virginia, students are asked to “identify how the parts of a system interact; recognize and use models as representations of real things; [and] observe and identify patterns of change, consistency or regularity within the environment” (WV Department of Education).
To provide opportunities for their students to learn through systems thinking, teachers are also approaching core content from a systems perspective. It is clear, for example, how a systems approach may be used in addressing content standards like these:

- “Students know that certain structures and behaviors enable plants and animals to respond to changes in their environment (4-5 LS1C)” (OSPI).
- “Evaluate the impact of various forms of government on people in the past or present (1.2.3)” (OSPI).
- “Find probabilities of compound events using organized lists, tables, tree diagrams, and simulation (7.SP)” (Common Core Standards Initiative).

By integrating learning about systems with core content, a teacher is able to address two learning objectives at once. A middle school science teacher, seeking to cover standards related to human physiology, for example, may use the opportunity to also help students understand systems, sub-systems and suprasystems. Perhaps when covering ecosystems she may ask her students to monitor the growth of plants in an aquarium for a month, requiring that students use this information to build a mathematical model to help them predict how much the plant will grow the next month.

Similarly in social studies, a teacher might ask his students to explore the role of women in literature identifying patterns of past behavior, in order to inform predictions regarding future behavior – or perhaps he will ask students to explore the impact of a crisis in one country on the economy of countries tied to it via trading relationships. In mathematics, a middle school teacher might have her students examine the flows into and out of an account (or stock) to help them to understand the factors that contribute to the profitability of a business, or she may have them use a model to test the impact of a variety of variables on that profitability. In each of these examples, systems thinking is not something that is taught in addition to existing content, rather content learning is approached from a systems perspective – one that leads to real understanding and that makes learning more efficient and transferable.

To demonstrate further how systems-thinking skills and content learning may be taught hand in hand, let us examine a more detailed example. When teaching the concept of homeostasis, a high school teacher may have students create a feedback diagram – a visual representation that tells the story of how regulation is achieved in the body. Perhaps students will model the control of breathing rate by the
medulla oblongata to maintain the necessary homeostasis of blood gases \((O_2\text{ and } CO_2)\) or the mechanism of osmoregulation that maintains the right amount of water and salt in the blood. In order to be able to create this diagram, students must engage with the content and truly understand the negative feedback mechanism that results in the balancing of the system. Such a task is best approached by first providing students with opportunities to read feedback loop diagrams.

Using other systems-thinking tool – a mathematical model – students might further explore regulatory mechanisms. They might, for example, be asked to construct a simple model of the homeostasis of blood sugar levels. A formula can be created that allows students to predict how blood glucose levels might change over time due to the effects of the regulatory hormones insulin or glucagon. By changing the initial variables (e.g., the starting sugar level, the set point, and the correction factor), students can ‘try out’ different scenarios, running as many trials as necessary to see how this homeostatic mechanism works under different conditions. If students are asked to identify a problem with the existing behavior of the system and propose a solution, they can ‘plug’ the changes into the model and observe the effect. As Pegasus Communication points out, the process is rather like taking a ‘test – flight’ of a solution – risk-free! Here is what they say about the value of the process:

When you . . . build a model you define the variables (things that change over time) that are important in the problem you’re trying to address. You then clarify your assumptions about how those variables affect one another, and assign mathematical equations to reflect those relationships. Once you’ve assigned these equations, you can plug in various changes, run the simulation, and see what outcome your changes might generate . . . this forces you and your team to think carefully about the problem at hand. And by working through your problem with that kind of

### Reasoning

While solving problems, students demonstrate logical thinking by critically analyzing and evaluating information. Through their critical thinking process, they synthesize information, form inferences and logical conclusions, and apply inductive and/or deductive reasoning appropriately to solve the problem at hand.
Collaboration while working on complex activities or problems make students feel that they are responsible for one another’s learning. As they learn from each other, they feel that they are an integral part of the project and their group. They also share responsibility for the development and quality of the group output.

Problem-solving activities such as the ones described in this paper, enhance students’ systems-thinking skills and promote deeper understanding of academic content. The infusion of technology into this mix, expedites routine tasks and increases students’ potential for deep learning. Technology provides visualization tools (e.g., graphing and diagramming tools) that help students interact with systems information in order to construct knowledge. These tools are especially valuable in helping students to represent systems or system behavior (e.g., change over time) as a first step in developing conceptual understanding about them. Technology further equips students with the computational power necessary for them to develop working models of systems. As we have seen from the previous examples, models allow students to examine and explore systems so that they may come to understand the interdependencies of their parts, their inputs and outputs, and the effects of interventions on the system as a whole. Such tools put students in control of their own content learning, effectively allowing ‘hands-on’ investigation of systems from within the classroom. As Stephen Wilmarth observed: “We cannot expect to ‘think the same’ about teaching when the act of teaching is shifting dramatically as a result of technology tools and access to information” (Wilmarth qtd. in Jacobs 2).

Finally, collaborative classroom environments assist in building systems-thinking skills. In general, finding feasible solutions to solve complex problems is better achieved when people work collaboratively because they bring to the task a broader spectrum of skills, knowledge, and perspectives than an individual. When students work together they enhance their systems-thinking skills by listening to and reflecting on one another’s ideas. They share their visions and information and provide feedback for one another. They also help one another to become active constructors of knowledge and skills (e.g.,
problem-solving and teamwork skills), rather than passive observers or listeners. Having students collaborate when working on systems thinking activities helps them to develop different, innovative, and advanced ways of thinking about and understanding complex situations.

**Conclusion**

The innovations and changes that have occurred in the world in the last two decades have created for teachers an urgency to provide for students opportunities to acquire ‘21st century skills.’ Rather than being new, these skills (which include systems thinking) are ‘newly important’ in developing the critical thinking, logical reasoning, and creativity necessary to solve complex problems at school, at work, and in everyday life (Rotherham and Willingham). Research shows, for example, that enhancement of systems-thinking skills leads to effectiveness in decision making when one is faced with complex problems (Maani and Maharaj); and as Richmond points out, “system dynamics and systems thinking hold great promise as approaches for augmenting our solution-generation capacity” (113). As such, they may well provide the most powerful way for teachers to tangibly prepare students for the unknown future of which Trilling and Fadel speak.

If we are sincere about preparing students for a new future, we should no longer require that they memorize facts and repeat them on demand; rather we should provide them with opportunities to interact with content, think critically about it, and use it to create new information. “Preparation for future work situations,” says Wagner, “requires teaching learners ‘to use their minds well’ rather than testing them reductively” (8). Systems’ thinking provides the tools necessary to enable students to do just that.

To turn the tide in education that is leaving students “ill-prepared to tackle real-world, complex problems [we must change our course]. . . We cannot directly adjust the wind (the future), but we can adjust the sails (competencies). To do so effectively, we need to have a good sense of bearings – where we are, and where we are heading. (Shute et al. 283)

Equipping students with systems-thinking tools that they can apply in many different contexts is one way in which we can address the need to prepare our students for the realities of their future. By helping
them to develop systems-thinking skills, we are equipping them with effective strategies to interpret the world around them – strategies that may help them gain confidence in managing their lives and the many problematic situations that they may encounter.
About Edvation

Edvation empowers educators with tools and resources to support the successful integration of technology and 21st Century skills development into standards-based curriculum and classroom practice. Providing curriculum, assessment, professional development and training solutions, Edvation is focused on the meaningful integration of technology to enhance learning and support systemic school improvement processes.

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