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Accumulations

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METHODS BREIF SERIES **1.06**

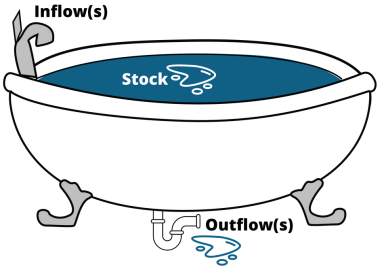
There are several features of complex systems that make creating change in K-12 education difficult, including: delays between the intervention and outcome, unexpected or confusing responses to interventions, and differences in how individuals and groups experience the same systems. The concept of "accumulation" provides important insight into how misperceptions, delays, and counter-intuitive system responses occur in education change efforts. Stock [BE1] and Flow Diagrams are visual tools to identify and visually describe key accumulations in the systems and facilitate conversations to understand systems better.

The purpose of this brief is to describe how the concept of accumulation can help us understand system behavior and to introduce how stock and flow diagrams can be used to help us model problems and find solutions in K-12 education.

+ WHAT DO WE MEAN BY ACCUMULATION?

Accumulation is one of the core concepts of system dynamics. An accumulation is something that builds up or drains over time, like a bathtub. So, let's use Donella Meadows' example of the bathtub[1]. If you want the stock of water to increase, you add water from the faucet. If you want it to decrease, you remove water through the drain. The rate at which you add water from the faucet matters. If you had a gushing faucet and a clogged drain, of course, the water in the tub would rise. If you unplug the drain to allow a bit of a trickle out but the faucet is still gushing, the water in the tub continues to increase.

You've started to solve the problem by opening the drain, but the overall behavior of the system still continues, just at a slower rate than before. If you turn off the faucet, the water in the stock will not magically go away. The only way to decrease the level of the tub is to have water flowing out of the drain faster than the water coming in. These inflows and outflows help explain the behavior of accumulations in human and environmental systems as well.



Specific contributions for each author are as follows:
a: conceptualizing; b: writing; c: providing feedback; d: revising

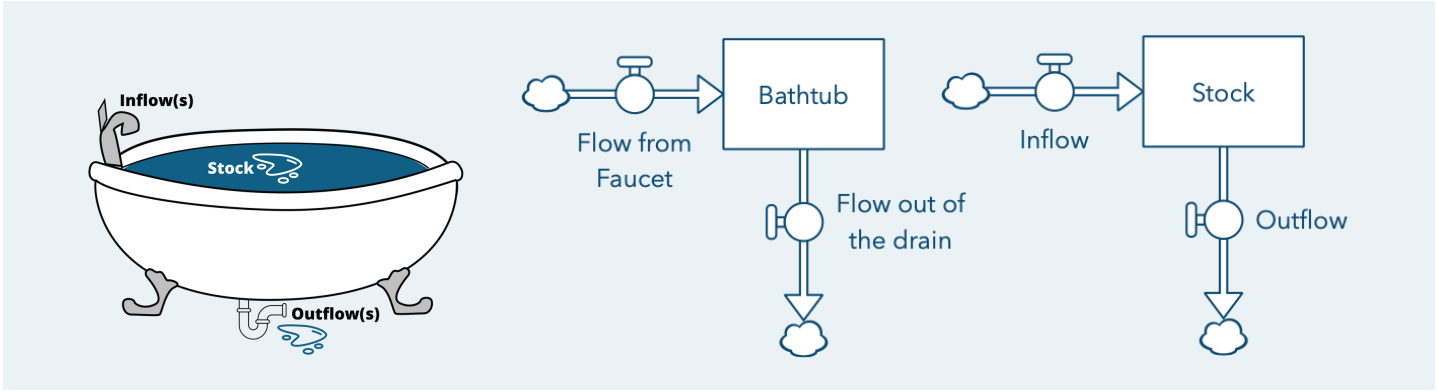
+ WHAT ARE EXAMPLES OF ACCUMULATION?

We all have real-life experience with accumulations, whether we realize it or not. Accumulations can be tangible – or easy to see and touch - such as trash in the trash can, students enrolled in a school, or parents on a waitlist for mental health services. Accumulations can also be intangible – or hard to see or touch but nevertheless real – such as traumatic experiences of a child or a family's trust in a school district. For example, when it is time to pay your rent or mortgage, you want to have enough money accumulated in your bank account! When your dirty clothes accumulate too much, you do laundry. Or maybe you are a person who does laundry every week to prevent an accumulation of dirty clothing.

+ REPRESENTING ACCUMULATION WITH STOCK AND FLOW DIAGRAMS

Stocks and flows are a way of diagramming accumulations. A stock is just another word for an accumulation. A flow is an action that changes the level of a stock. Flows either build up a stock or deplete it.

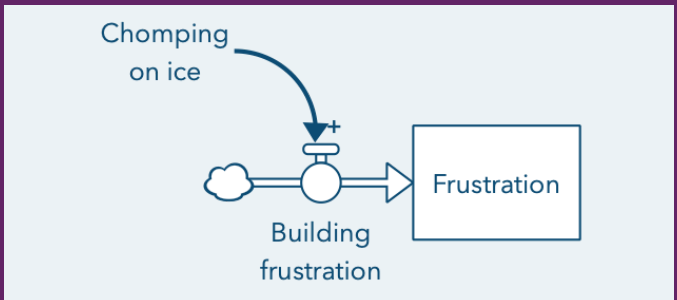
Figure 1: The Stock and Flows of a Bathtub



+ A STORY TO ILLUSTRATE STOCKS AND FLOWS IN OUR LIVE

Emma's biggest pet peeve is the sound of someone chewing ice---it just grates on her nerves. Lately during class, her classmate Bryan has been chewing on ice non-stop. Every time he takes a chomp, Emma's stock of frustration (like a bathtub) fills a little bit more.

Throughout the semester, Emma's stock of frustration becomes increasingly full, until she finally decides to talk to Bryan about it. He had no idea the ice-chewing bothered her and promised to do it less. Now he only chews on ice during class once every few weeks. The counterintuitive nature of accumulations can provide insight into what's going on here. Although Brian's ice-chewing slowed down, Emma's stock of frustration continued to rise. Going back to the bathtub example, even a slowly dripping faucet will eventually raise the level of the water—it will just take longer.



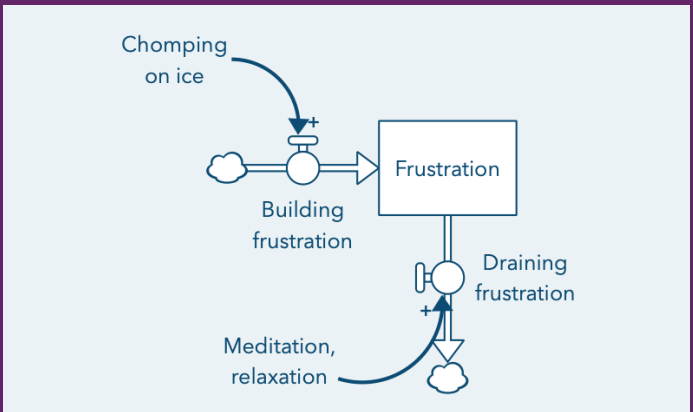
Key Point: Even if the rate of the inflow slows down, the level of the stock continues to rise.

One day, Bryan sits down for class with a big cup of ice and takes a first chomp, and Emma explodes! She yells and curses, and Bryan is confused – Emma asked him to slow down his chomping and he did, so why is she so ridiculously upset? Brian was confused about Emma's disproportionate response to his action. He just took one small crunch of ice and Emma blew up. This is an example of how accumulations can create non-linear effects. Emma's behavior was in response to the total level of frustration in her stock, which had been accumulating for an entire semester, while Brian thought that just one chomp didn't deserve such an outsized response.

Key Point: The system responds to the level in the stock, not to the rate of the inflow.

It can be easier for our minds to recognize inflows than outflows. For example, Emma talks to Brian to slow down her inflow of frustration. But her frustration may be rising for several reasons along with ice-chewing: the amount of homework she has to complete, the argument she had with her parents, etc. If the stock is continuing to fill with frustration, what can she do to drain the stock? Perhaps deep breathing helps her drain a small amount of frustration and prevent future explosions.

Key Point: It is important to identify and manage both inflows AND outflows.



+ WHY DOES THIS ACCUMULATION CONCEPT MATTER?

By acknowledging accumulation, we are forced to acknowledge the impact of history on where we are now. For example:

- We can teach a math lesson today to prepare a student for tomorrow's test. But the number of math concepts the student has accumulated from the past three years will have a far greater impact than the time spent studying today.
- When meeting a new parent for a parent-teacher conference, it can be easy to assume that are coming to you with a blank slate – an empty tub. But that parent might have had years or generations of distrust that has built over time, and you are meeting that parent as an accumulation of their history, not just the short interaction of that moment.
- When managing school mental health services, it does not tell you much to know that three students signed up for therapy today. It matters a lot more to know that those three students joined a group of 20 students that have accumulated on a waiting list for therapy. The system will react to the accumulation, not only the input.

By asking questions about inflows *and* outflows, we can identify different ways of problem-solving:

- For example, let's say your school has a shortage of experienced teachers. You can put a lot of time and money into hiring teachers in order to increase the inflow of teachers into the school. However, if you ignore the outflow of "Teachers leaving", you won't solve the problem – you will just speed up how quickly teachers are moving through the system. You can slow down the outflow of "Teachers Leaving" by investigating what is causing teachers to leave and addressing those causes.

+ CONSIDERATIONS WHEN APPLYING THE CONCEPT OF ACCUMULATIONS

- Using intuition alone can lead to incorrect assumptions about accumulations. Accumulations occur naturally in the world around us but understanding them is not always intuitive. Studies show that even students with strong mathematical training make persistent mistakes understanding even simple dynamic systems that include accumulations.[2] Understanding dynamic systems gets even harder once you add feedback loops and time delays. Visual stock and flow diagrams and mathematical models of accumulations can help you think more clearly and challenge your intuition.
- Accurately quantifying stocks and flows for intangible variables or situations can be difficult. Though it can be done, there is often less certainty relative to models of tangible and measurable variables.
- Accumulations and stock and flow diagrams can be harder for some people to conceptualize than causal loop diagrams. As with all system dynamics and group model building work, jargon and academic language can create a barrier to entry and an expert/novice dynamic that fails to recognize the value of people's lived experiences and understanding of problems.
- Stock and flow diagrams can lead to the illusion of accuracy. These diagrams may look formal and mathematical, but it is important to remember that the quality of output of a model depends on the mental models, stories, and experiences of the people who informed it!

+ GETTING STARTED

See accumulations around you:

- Explore: about your home, your family, your classroom, or your community: what are some accumulations you see? What are accumulations you can't see but know are there?
- Consider: What are the inflows to that accumulation? What are the outflows?
- Reflect: How is the current level of this stock (bathtub) the product of the whole history of inflows and outflows?

Practice Diagramming:

- Draw: a stock and flow diagram of a problem or dynamic you see in your work, either individually or with your team.
- Brainstorm: What are the multiple ways to intervene suggested by this diagram? How might you intervene on the inflow OR the outflow? How could you create new inflows? New outflows?
- Reflect: How does this framing change or refine how you think about the problem?

Share Out:

- Share: Show your stock and flow diagram to other stakeholders in the system, what would they change?
- Reflect: How do you see this concept fitting into your eaching/facilitation/management/leadership?

+ ACKNOWLEDGEMENTS

- Emma's story of ice chomping is used by Ellis Ballard of the SSDL to illustrate concepts of accumulation. He adapted this story from a version presented by Peter Hovmand as part of teaching system dynamic course work at the Brown School focused on frustration with social service providers.

+ SUGGESTED CITATION

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+ SOURCES

1. Meadows, D. H. (2008). Thinking in systems: A primer. Hartford, VT: Chelsea Green Publishing.
2. Cronin, M. A., Gonzalez, C., & Sterman, J. D. (2009). Why don't well-educated adults understand accumulation? A challenge to researchers, educators, and citizens. Organizational Behavior and Human Decision Processes, 108(1), 116–130. https://doi.org/10.1016/j.obhdp.2008.03.003

+ ABOUT THE SERIES

Social System Design Lab Methods Briefs are short, digestible notes on applications of system dynamics and systems thinking in community settings. They are meant to capture and share out our current thinking on core ideas.

"Series 1: Systems Thinking Foundations" focuses on introducing core concepts of systems thinking and system dynamics as they relate to issues of educational equity. This series draws from community-based modeling work with educators and students over the last ten years. Other briefs in this series include:

- Systems Thinking Iceberg | **1.01**
- Characteristics of Complex Problems | **1.02**
- Mental Models | **1.03**
- Framing Dynamic Problems | **1.04**
- Understanding Systems from a Feedback Perspective | **1.05**
- System Archetypes in K-12 Education | **1.07**

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