A Systems-Based Review of Demi's *One Grain of Rice*

By Linda Booth Sweeney

Book Title: One Grain of Rice: A Mathematical Folktale
Book author: Demi
Publisher: Scholastic Press: New York
Format: sophisticated picture book; fiction
Age range: 8 and up

Systems Thinking Concepts: reinforcing feedback, time delays, exponential growth

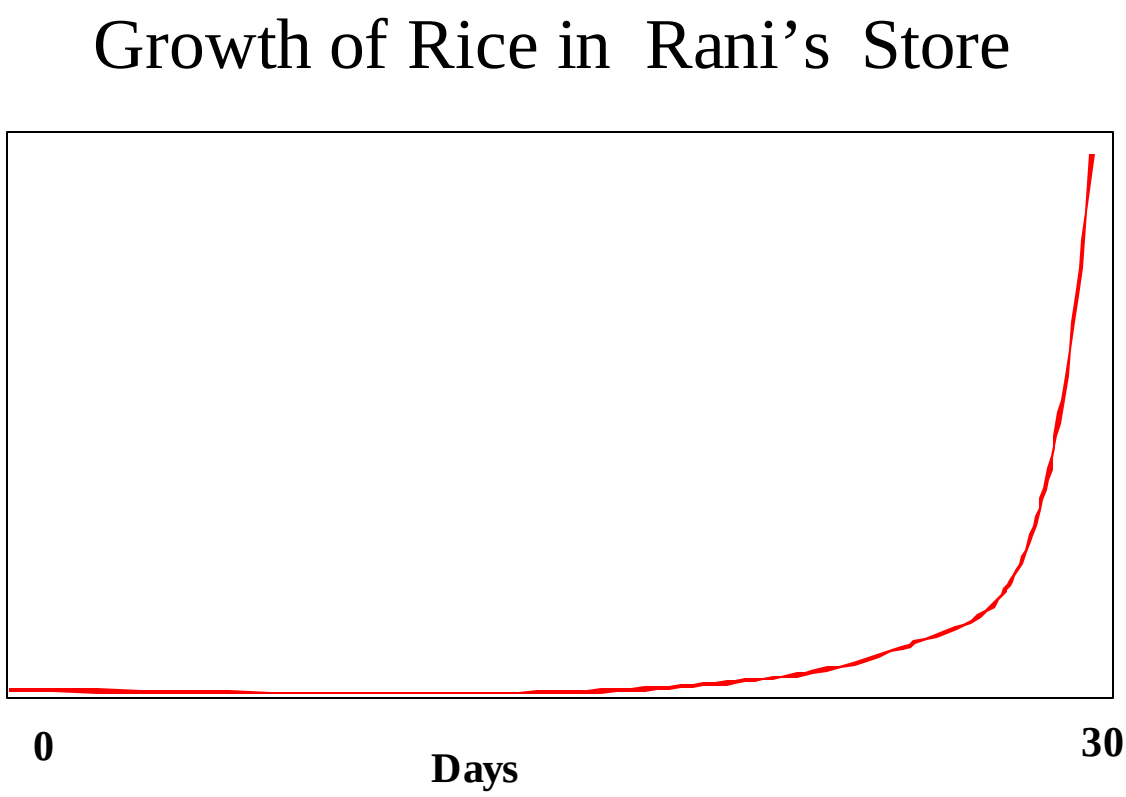
A Quick Look at the Story: In this wonderful teaching tale from India, a clever village girl outwits a powerful raja through her ability to recognize a basic pattern common to many systems. That pattern is exponential growth. At the beginning of the story, we are introduced to the raja as someone who believed he "was wise and fair, as a raja should be." Yet he requires villagers in his province to turn over almost all their rice for safe storage, leaving them only enough to get by. When a year of drought arrives, famine and hunger ensue. The villagers beg the raja to release some of the rice from the royal store but he refuses. As his people become more and more famished, the raja decides to have a feast for him and his court. As a parade of elephants returns from the royal storehouses loaded down with

sacks of rice, Rani, a clever village girl, walks behind them, collecting falling rice in her skirt. She is caught by the royal guards, but when they accuse her of stealing she tells them she is collecting the rice to return to the raja. The raja, striving to be wise and fair, decides to reward her for returning his rice. He tells Rani: "Ask me for anything and you shall have it."

To the raja's great surprise, Rani asks for just one grain of rice. When the raja says that is not enough of a reward, she acquiesces and asks that he give her one grain of rice on the first day. Then each day, for the following thirty days, he is to give her double the rice he gave her the day before. The raja considers this to be a modest request and readily agrees. By the end of the thirty days, Rani has more than a billion grains of rice and the raja has no more to give. The raja, having learned an important lesson both about math and about fairness, promises to only take as much rice as he needs from now on.

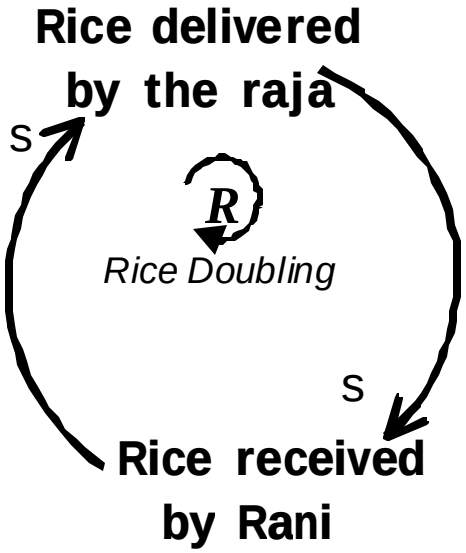
Teaching Tips: Rani understood a mathematical phenomenon that can often be difficult to grasp: doubling anything, in this case rice, always leads to exponential, rather than linear, growth. If we start out with 1, we then

double it and get 2, then 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048. We've jumped to a very large number in only 11 doublings. (There is a well laid out chart on the last page of the book that shows the amount of rice per day for thirty days.) One way to explore the dynamics of doubling with students is to first look at a behavior-over-time graph of the growth of Rani's rice store:



What is so striking about this graph? It shows why the raja could have so readily agreed to Rani's request. At first, it appears that doubling one grain of rice will yield at most enough for one bowl by the end of the month. As

the graph and the causal loop diagram below illustrate, positive feedback sets off a doubling pattern that starts slowly.



As he doles out the rice, no significant change in the amount of rice is noticeable, even as the number of rice grains double from 1 to 2 to 4 to 8 to 16 to 36 and so on. Then, although the underlying growth pattern hasn't changed at all, an explosion seems to occur. By the 30th doubling, Rani has actually accumulated over one billion grains of rice.

So why do most of us profoundly underestimate the effect of exponential growth as the raja did? One answer may be that much of the expansion and change in our daily lives is essentially linear in nature, therefore a great deal of our experience is with linear growth, not

exponential growth. Many of us rely on our experience with linear systems when we estimate the numbers or the behavior that will result from exponential expansion. A linear process occurs when driving the car; you add, for example, 50 miles per hour to the distance traveled. An exponential process would, for example, double the speed every hour. So, the larger the quantity of something (for example, number of grains of rice, amount of money in a bank account) the greater the *rate* of growth of that quantity. And then, as a result of this reinforcing process, we see an even greater *quantity* (of rice, people, money, etc.) in the future. These reinforcing loops lie at the heart of exponential growth we see around us everyday, e.g., compounding interest, population growth, rising productivity, and even arms races.[1]

You can use the following traditional French riddle as another way to illustrate the surprising nature of exponential growth:

Suppose a water lily is growing on a pond in your backyard. The lily plant doubles in size each day. If the lily were allowed to grow unchecked, it would completely cover the pond in 30 days, choking out all other forms of life in the water. For a long time, the plant

[1] This discussion is adapted from Booth Sweeney and Meadows (2001) *The Systems Thinking Playbook*, volume III.

seems small, so you decide not to worry about cutting it back until it covers half the pond. How much time will you have to avert disaster, once the lily crosses your threshold for action?

The answer is, "One day." The water lily will cover half the pond on the 29th day; on the 30th day, it doubles again and covers the entire pond. If you wait to act until the pond is half covered, you have only 24 hours before it chokes the life out of your pond.

Questions to Ask:

- What happens in the story of One Grain of Rice?
- How would you describe the nature of doubling to someone else?
- Where do we see the impact of doubling (leading to exponential growth) in real life? **(**Examples you can provide to stimulate thinking are: spread of rumors, accumulation of personal problems, and a bank account -- as interest accumulates and money is not spent.)

Partner Stories and Activities:

Stories: You can try contrasting Demi's *One Grain of Rice* with *Anno's Magic Seeds* (by Mitsumasa Anno) and *Tuck Everlasting* by Natalie Babbit. In *Tuck Everlasting* for example, a 10-year-old girl discovers a magic spring, which

turns out to be a fountain of youth. The story explores the lure and implications of the ultimate example of unlimited growth -- the ability to live forever.

Activities: Several exercises in *The Systems Thinking Playbook* also explore the dynamics of exponential growth. Paper Fold, for example (found in volume III), works well to give students, young and old, a way to experience exponential growth by folding a piece of paper, or a large sheet. Group Juggle (vol. II) is another good exercise to explore this dynamic.

References:

- For further discussion about exponential growth, see the article by John Sterman (1994) "Learning in and about complex systems." System Dynamics Review **10**(2-3), p. 291-330.
- For a discussion of how exponential growth is common to a variety of systems, see the Creative Learning Exchange website, particularly *SE1995-08: STin25WordsorLess.pdf* .