

MUSINGS ON SOCIAL STUDIES AND SYSTEM DYNAMICS II: Thinking Systemically

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In the last issue of the *CLExchange*, we suggested that the purpose of K-12 social studies, to develop active and engaged citizens able and willing to grapple with today's complex and challenging issues (National Council for the Social Studies), was supported by the mind- and tool-sets of system dynamics. We ended by suggesting that a three-sector concept map (Figure 1, below), focused on population, resources, and attitudes would help achieve two related goals:

- (1) To help *learn* about the critical dynamic interactions that drive the events and processes that comprise the social studies curriculum, and
- (2) To help *apply* the learning from these systemic relationships to leverage complex issues or problems.

In so doing, we enhance the potential for each student to become a "systems citizen," capable and willing "to make informed and reasoned decisions for the public good as citizens of a culturally diverse, democratic society in an interdependent world" (NCSS' "Vision of Powerful Teaching and Learning in the Social Studies," available at:

<http://www.socialstudies.org/positions/powerful/>).

INTRODUCTION TO PART II

This second article poses the question, "How can we effectively use system dynamics to build social studies curricula to meet those two goals?" These ideas have evolved over years of working with students, most recently with Rob Skiff within the middle- and high-school Social Science program of the Vermont Commons School. Use of the collective "we" is intentional; the two of us hope to illustrate here (and then continue in a third article) how WE, as a larger educational community, might use generic system dynamics concepts and tools to enhance social studies instruction. We'll then solicit from you, for a third article, examples of what you've done in the classroom and what you might be interested in doing to contribute to the CLE's collections and to bolster our collective capacity to assist social studies educators.

Where do we start? Any undertaking must begin with a fundamental appreciation for how students learn. A recent publication from the National Research Council, *How Students Learn: History, Mathematics, and Science in the Classroom* (The National Academies Press, 2005), identifies three overarching principles for maximizing student learning:

- (1) Preconceptions must be identified and challenged,
- (2) Knowledge must be organized conceptually, preferably with the processes and frameworks used by experts, and
- (3) Individuals must be able to independently translate concepts and/or insights between relevant areas (metacognition).

Operationally, our experience suggests that such efforts to support students in addressing meaningful real-world problems must be pursued steadily and iteratively in small steps that ultimately build that capacity.

This combination of principles and pragmatism meshes well with some of the ideas that were developed by Barry Richmond in *An Introduction to Systems Thinking* (2001) and which the two of us have further refined in our “Ladder of Engagement” sequence of learning (e.g.: http://www.clexchange.org/conference/cle_2004conference.htm). Building from Barry’s observation that “thinking” involves “*constructing* mental models, and then *simulating* them in order to draw conclusions and make decisions” (p.4), our Ladder involves sequencing our use of systems thinking tools to first “filter” (Barry’s term) and evaluate our *knowledge* (and preconceptions), then to “represent” the driving feedback dynamics to deepen and strengthen our operational *understanding*, and finally, to rigorously use “simulation” to devise and assess policies and strategies with which to *influence* these systems. By supporting students’ development of these thinking skills, deepened learning – challenging preconceptions, conceptually framing knowledge, and metacognitively applying those concepts to novel situations – should emerge.

But all of this sounds very abstract and unresponsive to our immediate classroom needs. In the remainder of this paper we’ll “model” for (and, ideally, with) you this process of engagement using the basic tools of system dynamics. If successful, this process will encourage “better questions,” deepen conceptual understanding, challenge preconceptions, and generate transferable insights of value to our present situation. The three-sector structure (Figure 1) developed in the first essay provides an organizing framework for addressing these “real world” problems. While we might begin to consider a given problem from a viewpoint within any one of those sectors, the truly interesting and challenging topics will typically require us, eventually, to draw together insights and perspectives from all three.

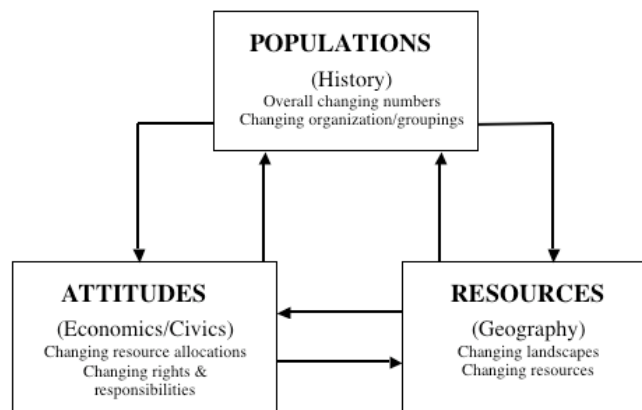


Figure 1. Interactions between three sectors inherent in dynamic social studies scenarios.

Let’s begin by recognizing a critically important system dynamics concept that also underlies the social studies: time or, more precisely, “change over time.” To appreciate this concept dictates that we jettison a static, “snapshot,” perspective of the world around us and begin to “think dynamically.” As Barry Richmond observed, we need to “push back” from discrete events “to see the patterns of which they are a part.” We need to view the events and conditions that comprise much of our current curricula as components of larger processes of change. That is a fundamental starting point for beginning to think more systemically about the causative

loops that extend back in time and whose effects ripple forward from the present. Nurturing this capacity for thinking systemically as a “habit of mind” then connects social studies and the tools of system dynamics in a common quest to build Systems Citizens.

Now permit us to challenge your comfort in working with causal relationships that unfold over a relatively long time line by focusing on a familiar historical episode. Recognizing that system dynamics is all about real-world problem-solving, we’ll frame the question as a problem: What exactly were the cause(s) and the effect(s) of the “Irish Potato Famine?” A common response might be:

The famine was a catastrophic event that occurred between 1846 and 1847, as a result of a potato blight that decimated the food supply. It led to many deaths (estimated at one million) and triggered at least as large an out-migration of Irish seeking new homes in other countries in its immediate aftermath.

Technically, that’s correct. But can we develop a richer story, one that provides hooks for looking at our current realities? We’ve started, almost intuitively, by focusing on people or, more precisely, on the Irish population that is comprised of discrete entities (people) the aggregate of which is subject to change over time. The “facts” of the scenario are straightforward: many people starved to death and then many more left Ireland in the next seven years. Subsequent, “better,” questions come to mind, however, after such a barebones description.

- How did the population become so susceptible to starvation (we’ve already hinted at the role of a specific resource, potatoes)?
- Does 1853 really mark the end of the Famine story?

To address these questions, consider a behavior-over-time graph (BOTG) of the Irish population (Figure 2). This focuses on the period between 1791 and 1901, roughly encompassing the half-centuries on either side of the famine, a very deliberately wider time period than our initial story (above) would have suggested. That BOTG shows that, prior to the 1846 Potato Famine, the Irish population grew rapidly (from 4.7 million in 1790 to almost 8.2 million fifty years later).

- What drove that growth?
- Did it make the Irish especially vulnerable to catastrophe such as the Famine?

Furthermore, when the potato crop failed, the resulting famine immediately generated nearly 1 million deaths (illustrated in the first steep drop) and an even greater number of emigrants in the following six years, the bulk of whom set sail for North America. Still, the BOTG shows the population did not rebound after 1854, as the food supply was stabilized and available data clearly show that births once again exceeded deaths, but continued to decline.

- What was happening? And why?

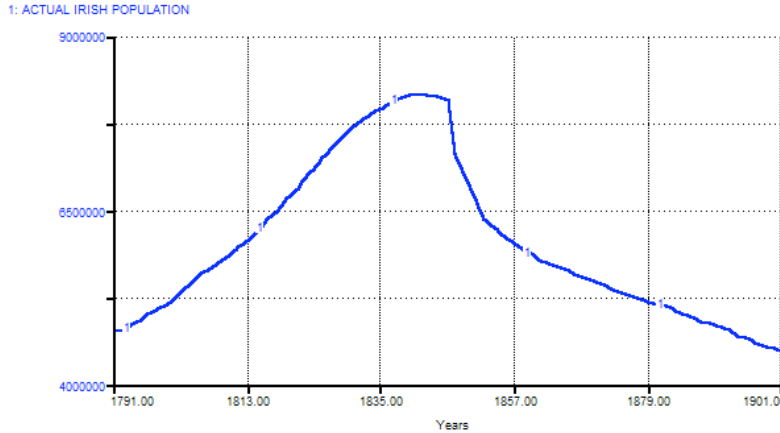


Figure 2. A Behavior-Over-Time Graph (BOTG) of the population of Ireland, 1791-1901

To understand what was driving these dynamics requires that we begin to think in terms of stocks, flows, and feedbacks, the basic “building blocks” of systems. As illustrated in the simple diagram on the top left of Figure 3, we start with a conceptual map that includes a single stock (Irish population) and two flows (births and deaths). The stock represents the actual “accumulation” of people present in “the system” at any moment in time. The flows, in turn, identify “rates” or activities that define how the stock changes over time: unlike stocks, flows involve dynamic processes that do not exist at a single moment in time, but rather unfold over time (Barry Richmond suggested in *An Introduction to Systems Thinking* that stocks may be thought of as the “nouns” in a system, and flows as “verbs.”). Thus, our stock/flow diagram reminds us of the critical distinction between an “accumulation” of people at any moment in time and the ongoing processes of births and deaths that continually “flow” in and out to alter the size of the stock

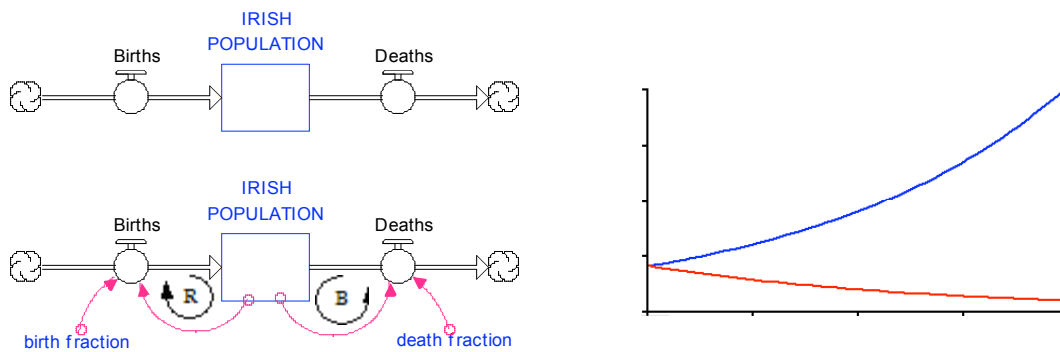


Figure 3. Stock/Flow Feedback Maps with projected behaviors over time that result from the structure of the bottom Stock/Flow Map.

But stocks and flows are only a part of the system: feedback loops comprise the other. In system dynamics, circular feedback involves one of two self-generating (or what system dynamicists call “endogenous”) structures, typically referred to as “reinforcing” and “balancing” loops. In the case of “reinforcing” feedback, a change in one factor will lead to a cycle (or causal loop) of activity that eventually leads to that same factor being pushed further in the original direction; in contrast, a “balancing” (or “counter-acting,” as it is sometimes

described) feedback loop will set into motion a sequence of events that ultimately leads the original factor being pulled back toward the position where it started.

[Note: For a more detailed explanation, download “Tips for Using System Dynamics Tools” at <http://www.clexchange.org/ftp/documents/Implementation/IM2003-12TipsUsingSDTools.pdf>]

Both feedbacks are present in our Irish population model as illustrated in the bottom stock/flow map in Figure 3. Both “Births” and “Deaths” flows are parts of a larger integrated “system” incorporating dynamic feedback loops, one reinforcing and the other balancing. In both cases, the size of the population stock is an essential factor affecting those flows. In addition, each of the flows is influenced by the fraction of the population that gives birth or dies each year; those fractions are also included in the lower stock/flow map of Figure 3. These two feedbacks, if operating with constant birth and death fractions, generate one of two behaviors (illustrated in the BOTG on the right side of Figure 3): exponential growth or “goal-seeking” decay. Both behaviors are readily observable, historically or currently, at local, regional, national, and global levels (note, for instance, what is actually happening to some European populations that are falling).

Typically, we talk about annual “birth” and “death” fractions (or rates) within populations as so many (births/deaths) per thousand individuals in the population, that is, during each year some fraction of the population gives birth and some fraction dies. In cases where births outnumber deaths, we would expect to see a pattern of exponential growth because the positive loop is dominant; where deaths outnumber births, exponential decline because the negative or balancing loop is dominant.

Let’s do more than simply hypothesize how these loops work. Let’s actually convert this stock/flow feedback map into a very simple running computer model and incorporate historical Irish data to test our mental model of population change over time by simulating a portion of the Irish past. We know from research undertaken using available records that there were, in the half century prior to the famine, an annual average of 41 births per 1000 individuals but only 29 deaths.

How accurate is our model in tracking change over time? Figure 4 captures the powerful process of a half-century of net exponential growth prior to the Famine, comparing the actual census data (line 1) with the projection of a simple model (line 2) utilizing constant birth and death fractions equal to the 50-year average values. While, at one level, the cultural “norms” (family size) defining the “birth fraction” were largely unchanging over the half-century, the continual growth in the number of women having children fueled this accelerating growth.

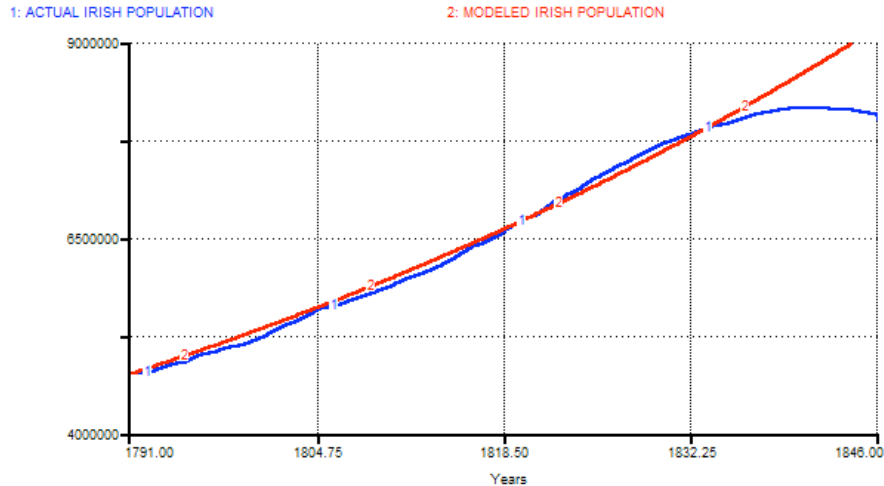


Figure 4. A Behavior Over Time Graph plotting the actual Irish population (Line 1) vs modeled output (Line 2).

The modeled population seems to track the population size reasonably well for more than 40 years into the model run, until close to the 1830s. For the next 10 years, however, our projection fails to track the reality: while the model continues to project exponential growth (to more than 9.2 million). The real population grows much slower, and indeed, appears to show a stagnant or even slightly declining trajectory. What can we learn through those discrepancies?

Ideally, our stock/flow feedback map can help us understand these dynamics. The BOTG displays a classic S-shaped growth pattern, with growth beginning to slow as early as the early 1820's. System dynamicists would recognize this as “shifting dominance” in the system, where the stabilizing feedback exercised by the death side of the system became progressively more important, relative to the reinforcing feedback of births. If we're beginning to engage in “three-sector thinking,” we can seek the cause of that shift in one of the other sectors. Since our evidence suggests no major change in Irish attitudes relative to family size (that would affect the birth fraction) or migration (more on this shortly) in that period, we are left with the probability of a growing death fraction, likely driven by the resource sector. Whether due to limits on available land or diminishing productivity, we can reasonably hypothesize that the Irish population had run up against the land's “carrying capacity.” That suggests that, as the population approached that carrying capacity, food (especially for the less well-off fraction of the population) was reduced and the death fraction increased. We can incorporate that idea into our feedback thinking, operationalize it in our model, and use it to simulate a more accurate and insightful picture of what was happening (Figure 5).

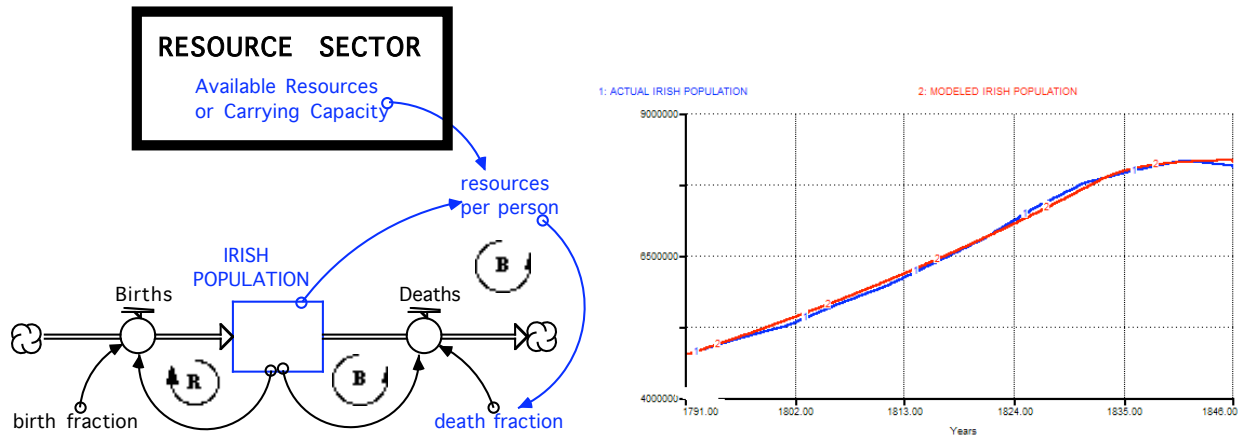


Figure 5. A revised S/F Feedback Map incorporating the concept of a resource-based “carrying capacity” (left) and the resultant Behavior Over Time Graph (right).

With “causes” now clearer in terms of long-term developments and the shorter-term problems presenting themselves prior to the famine itself (this pattern of declining population growth, incidentally, was also true in the events leading up to the Black Death in the 1340s – an “early warning signal,” as it were), we can move our focus to the famine’s “effects.”

We’ll begin by taking the model developed in Figure 3 and running it out to 1901 with the following modifications: we’ll incorporate the deaths of 800,000 people between 1846 and 1847 and we’ll further add the powerful wave of about 1.4 million émigrés between 1847 and 1853 [Note that we selected these particular numbers to match the two-staged population fall that actually occurred].

The output from that model (Figure 6 Line 2), however, does not accurately track what happened over the half-century beginning in 1854. That model projects that, even with the reduced birth fraction observed after the famine, the Irish population should have rebounded by 1901 to a population approaching 8 million.

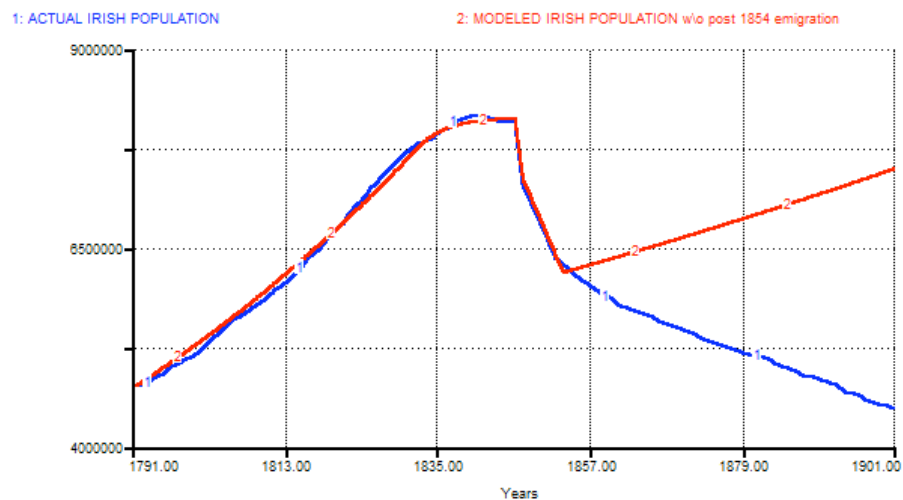


Figure 6. Behavior Over Time Graph of the actual (Line 1) versus modeled (Line 2) Irish population

What really happened? Clearly population decline continued to exceed growth. If births exceeded deaths, then the only explanation is that Ireland continued to experience significant emigration, long after the immediate effects of the famine had passed. Indeed, if we dig into the historical data, we find clear indications that folks continued to leave their homeland for decades after conditions returned to “normal.” So emigration clearly persisted throughout the next half century. Figure 7 illustrates the modeled time line when we recognize the need for such continued emigration.

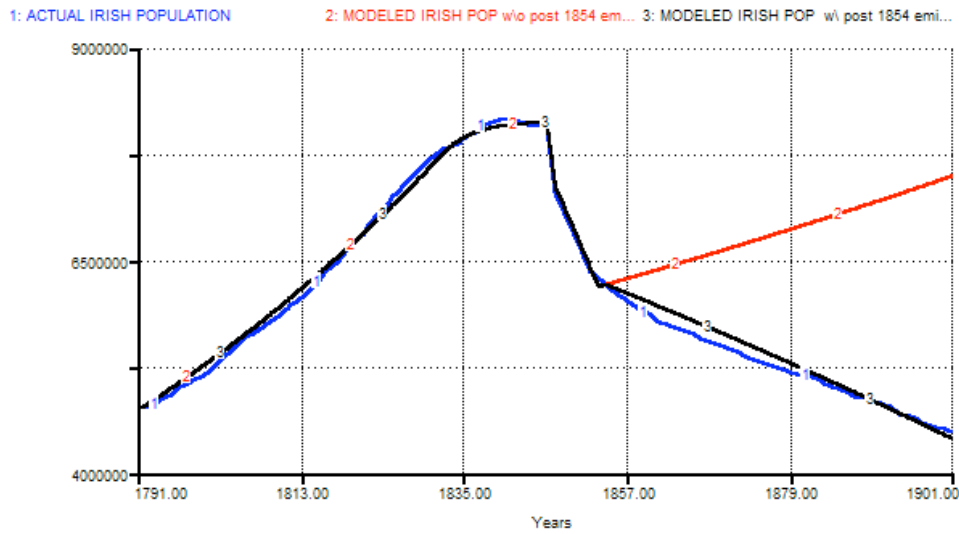


Figure 7. Behavior Over Time Graphs of the Irish Population. Lines 1 and 2 are the same as those presented in Figure 6. Line 3 is the modeled population with an annual emigration of 60,000 per year after 1854.

[Note: Emigration is added as an exogenous (defined from outside the model) variable in order to run this version of the model and to show the implication of such emigration. One of the next steps of building a running model would be to develop emigration as an endogenous (defined by factors internal to the model) variable.]

But why did people continue to leave Ireland so long after the immediate crisis had subsided? Here, let us suggest that we contemplate the third and final sector of “the system”: attitudes. And, in the spirit of generating “better questions,” let me suggest two very powerful attitudes that probably were functioning during that half-century. The first, we’ll call “memory.” Traumatic events, we know, can often leave long-term “scars.” To the extent that people remained in Ireland who could tell powerful stories, particularly to younger generations, the image of despair and misery could readily invoke concern or fears that inspired emigration. Essentially, the numbers in the Irish population with first-hand memories combined with the strength of their memories continued to ‘push’ the Irish from their homeland.

A second attitude, not altogether unrelated, involved emigrants writing back to relatives and neighbors, advising them of “streets paved with gold” and greater opportunities to be found elsewhere, not least because the earlier emigrants provide resources and support for new arrivals. Here the idea of “expectations” of a life better than that currently available in Ireland would act as a ‘pull’ to new destinations. This idea of “relative attractiveness” has been powerfully developed by system dynamicists in a variety of contexts.

Each of these hypothesized attitudes can be precisely modeled, if questions such as ‘push’ vs ‘pull’ dominance were of interest and were necessary to move the conversation (and the learning) along. These are not particularly easy tasks, however, and often much of the benefit of such modeling can, in this context, be obtained through the conceptual and conversational exploration of the ideas. We would argue that those conversations will be more focused and objective if the underlying stock/flow logic is kept clearly in mind.

So, to sum up: what have we learned? Population dynamics are frequently central in shaping long-term patterns of events and they are often wonderful starting points for exploring such patterns. They are not the “whole” story, however, but act together with resources and attitudes to drive the social dynamics. Here, for instance, we can ascribe the rapid pre-Famine population growth to a combination of resources (the availability of a relatively new and plentiful food resource, the potato) and attitudes that saw high value in children as an important source of farm labor (we could have attached the Attitude Sector to the birth fraction, if we had cared to, but it seemed an undue complexity for that stage of the story, so it slid by. Potatoes provided sustenance, allowing larger numbers and higher densities to live on the same land. The Famine illustrated in the harshest terms, however, the vulnerability of a population pushing its carrying capacity and dependent on a single resource. But, at the other end of the time-line, what of the long-term migration, seemingly lost from the record and from many accounts of the Famine? The answer here also rests with attitudes, memory on the one hand and ‘relative attractiveness,’ driven by prior emigrants, on the other. Only recently has the population rebounded to roughly 6 million inhabitants.

How does this inform the way we think about current events?

- Is population growth putting any of us at risk to overshoot available critical resources?
- Do we depend on single, potentially vulnerable, sources of any critical resources?
- Do fears, hopes, or desires drive our resource use?
- If history is to be truly valuable, it should inform the present. Does it?

Concluding Thoughts

In this piece we’ve tried to “model” an illustration for how we might use the tools of system dynamics and a framework of “three-sector thinking” to develop social studies curricula that challenge our students’ knowledge of familiar events, stimulate them to think more dynamically and systemically about causes and effects underlying real world issues, and plant an interest and motivation for them to apply those tools and the insights in addressing the current challenges that face them.

Have we generated any reactions?

- Do you have particular pieces of curricula that address social studies standards and incorporate system dynamics tools that you’d be willing to share in our third and final newsletter piece?
- Equally useful, do you have a particular “problem” or “problems” for which you’d like to see system dynamics-based curricula developed?

The title for the next piece is “Where do we go from here?” We hope it will be a collaborative piece that helps guide us to contemplate new and better ways to make a difference in the future. Send us (jpotash@clexchange.org or jheinbokel@clexchange.org) your thoughts, please!