Description and demonstration of a simulation learning environment for discovery learning about accumulations

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Abstract
This paper presents a web-based simulation learning environment (SLE) for facilitating discovery learning about accumulations that was designed to complement an Introduction to Environmental Science course at the college level. The primary learning objective is to develop the user's understanding of the relationship between inflows, outflows, and accumulations, as well as the effect of changes in inflow and outflow rates. Results from the use of this simulation in freshman Environmental Science classes are presented in another paper in these proceedings. Here we describe the approach taken in developing the SLE, the domain and discovery learning objectives, learning content, simulation interface, and learning support structures (scaffolding) and include a storyboard of the simulation. We also detail lessons learned in the development process.

Introduction
This paper presents a web-based simulation learning environment (SLE) for facilitating discovery learning about accumulations. The SLE was demonstrated in the poster session at the conference. Here we focus primarily on the principles we used to design the module and some of the key lessons we learned in the process of development. The purpose of this paper is to describe is to describe our experience for others who might want to develop similar tools. We describe the approach we took to design and develop the SLE, the domain and discovery learning objectives, lessons learned, and provide a detailed storyboard of the SLE in the Appendix.

The SLE was designed to complement a college-level Introduction to Environmental Science course. Although accumulations are central to understanding and managing the relationship between people and the environment (we generally want to increase or maintain levels of things we consider good, or valuable, and decrease the level of things we consider bad, or harmful), the basic principles that govern the dynamics of accumulations are poorly understood (e.g. Sterman and Booth Sweeney 2007, Cronin *et al.* 2009).

The primary objective of this SLE is to develop the user's understanding of the relationship between inflows, outflows, and accumulations, as well as the effect of changes in inflow and outflow rates. We use a scenario where sea beans accumulate on a hypothetical island to demonstrate the principles of accumulation. Sea beans, also

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known as “drift seeds,” are a large category of seeds that are transported on waterways from their source to someplace else where they can germinate. Coconuts are one example of drift seeds, but the seeds come in many sizes. In this simple scenario, sea beans wash in to shore and can be washed back out to sea.

The module is part of a series of simulation-based learning modules for teaching systems concepts underlying environmental science and management. The modules are set in the context of a generic small island. We are deliberately vague about the location of the island to leave open all possibilities for climate and other variations as needed for future modules. So far, we have developed a module on population and one exploring the dynamics of carbon accumulation in the atmosphere in addition to the one described here. While we incorporate as many real elements as possible, we also use creative license as necessary. This module is called *Island Dynamics: Accumulations*. The model was developed using the Forio Systems Simulate platform and hosted under their Basic subscription.

This module evolved from a simple simulation-based exercise on population. Over five semesters, the original exercise became several exercises focused on different objectives. The simulations have been used by over 750 students in the five semesters; 186 students have used the specific module we present here. Overall results of our assessments of student learning are discussed in Skaza and Stave (2010). We present results from the use of this particular simulation in freshman Environmental Science classes in another paper at this conference (Stave 2011).

This SLE is based on discovery learning principles and includes questions that facilitate discovery for the user. This version also provides assessment mechanisms for the instructor.

Approach: Example-based Discovery Learning

Discovery learning is the theoretical framework that underpins the SLE design. Sometimes known as inquiry learning, discovery learning is a pedagogical approach based on constructivist learning theory. In discovery learning, students engage in deeper learning through exploration, experimentation, and reflection (de Jong *et al.* 1998), a process that mimics scientific inquiry. In this case, the user forms a hypothesis by adjusting variable values in the simulation. Although it is possible for users simply to choose values randomly, the idea is to provide a platform that is engaging enough to encourage them to predict what might happen in a given scenario, test the outcome, and reflect on how the outcome compares to their prediction.

In this SLE, we ask users to predict how the accumulation will change given the conditions they choose, then have them run the simulation to test their hypothesis. The simulation allows them to revise their hypothesis based on the outcomes (choose new values), and test it again. Ideally, they repeat this process until they have tested several hypotheses and gathered enough information to interpret and analyze the data (fig. 1).

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This process allows students to develop (or redevelop) their own understandings about concepts and ideas (Mayer 2004, Zhang *et al.* 2004).

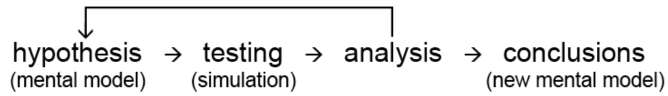

Figure 1. The SLE is underpinned by the scientific inquiry process.

One of the expected benefits of using simulations for discovery learning is increased intuitive understanding of complex concepts. Swaak *et al.* (2004) found that simulation users were able to answer predictive questions much faster than those who did not use a simulation. This quick anticipation of outcomes was used as an indicator of intuitive knowledge gains in discovery learning. A review by Reiser *et al*. (1998) found that because discovery learning promotes such increases in intuitive knowledge, it is more likely that knowledge will be remembered. This makes intuitive understanding useful and transferrable to other domains. Our design process was based on the assumption that the SLE will facilitate an increase in users' intuitive understanding of accumulations. Later modules in the series help transfer the knowledge from sea beans to other environmental issues, such as carbon in the atmosphere.

This module facilitates user discovery of the principles of accumulation by implicitly guiding the user through the scientific inquiry process. We ask users to articulate the results they expect when they choose values for in and outflow before they run the simulation, then compare the results to what they expected. In this way, we guide them to challenge their mental models through repeated experimentation. If the simulation does not produce the results users expect, they must alter their decisions to produce different results. The hope is that users discover the principles of accumulations as they begin to notice the patterns that emerge, and thus develop a more intuitive understanding inductively.

Learning Objectives

We designed the SLE around the following learning objectives:

1. *Domain objective: Improve understanding of accumulation dynamic*
   The primary learning objective for this simulation is to develop a better understanding of simple relationships between the inflows, outflows and accumulations and the effect of changing rates on the direction and size of change in the accumulation. These basic principles of accumulation are:
   - When the inflow is greater than the outflow, the accumulation increases.
   - When the inflow is less than the outflow, the accumulation decreases.
   - The speed at which the accumulation changes is related to the gap between the inflow and the outflow. When the gap is large, the accumulation changes rapidly; when the gap is small, the accumulation changes slowly.

Changing the rates partway through the simulation run illustrates other principles:

- For accumulations that are increasing:
  - To stop the increase and maintain a constant level, the inflow must become equal to the outflow.
  - To change the increase to a decrease, the inflow must become smaller than the outflow
  - To make the accumulation increase faster/slower**,** the difference between the inflow and outflow must become bigger/smaller
- For accumulations that are decreasing:
  - To stop the decrease and maintain a constant level, the inflow must become equal to the outflow.
  - To change the decrease to a increase, the inflow must become larger than the outflow
  - To make the accumulation decrease faster/slower**,** the difference between the inflow and outflow must become bigger/smaller

2. *Discovery objective: Improve discovery skills (formulate, test, and revise hypotheses, and interpret results)*
   In addition to facilitating the learning of systems concepts, the modules also facilitate the development of discovery learning skills. The main discovery learning objectives are for users to learn to generate questions and explore a simulation to test their hypotheses iteratively through the process of scientific inquiry.

Challenges and Design Considerations

We faced practical challenges of SLE design in the following three categories:

- Scaffolding domain knowledge and scientific inquiry
- Designing the interface
- Managing cognitive load

Scaffolding domain knowledge and scientific inquiry

De Jong and van Joolingen (1998) showed that many learners have difficulties with the inquiry tasks that facilitate discovery. They found that users without prior knowledge and experience in hypothesis generation, analysis, and experimental heuristics have greater difficulties with discovery learning. They argue users less experienced with the scientific process need to have tools that support inquiry tasks. Mayer (2004) argues that for discovery learning to be most effective, it needs to be carefully guided or scaffolded. In SLEs, learners need to have their attention directed to the most salient information. Learners need the freedom to explore and process information in the simulation to discover the underlying principles, but they also need guidance to ensure that useful knowledge is constructed along the way (Mayer 2004).

Finding the right amount of support is a balancing act. Structuring the SLE to facilitate discovery learning must be complemented, but not overpowered by support structures. For example, Veermans *et al.* (2000) found that with appropriate feedback information

SLE users spend more time experimenting, thereby gaining intuitive knowledge in the process, Swaak *et al.* (2004) argues that offering too much support can negate the discovery process entirely and becomes simply prescriptive.

We found three categories of learning support scaffolds described by Zhang *et al.* (2004) useful in understanding, planning, and designing support structures for this SLE. Zhang et al. describe these categories as experimental, interpretive, and reflective support.

Experimental support involves scaffolding a user's inquiry skills, particularly relating to predictions and comparisons. In this module, we prompted users to make predictions about how their decisions would affect the accumulation of sea beans. Short answer boxes were provided on the simulation interface screen to give users the space to write a response. Following the simulation run, users were again asked a short answer question, this time prompting them to compare the results with their predictions.

Interpretive support provides background information that facilitates a user's understanding of the problem (Zhang *et al.* 2004). In this SLE, we provide background information about sea beans and how they accumulate on the shore in the form of instructional text and graphics. Explanation pages feature text and line graphs describing the trends of inflows, outflows, and accumulations of interest in the simulation. This content serves to reinforce how to understand the graphs as well as familiarizes users with the interface. Debrief pages at the conclusion of the SLE describe to learners the principles of accumulation. This gives them a final means to check their new knowledge against the intended learning objectives.

Reflective support structures include ways to help users make observations, record data and draw conclusions (Zhang *et al.* 2004). Quintana *et al.* (2004) found that providing a way for users to record and observe data is beneficial in discovery learning as it reduces the amount of information a user needs to keep in short term memory. We provide data tables of a user's simulation runs and ask them to answer analysis questions, drawing conclusions about patterns observed in the data.

Another straightforward way to structure SLEs is through the use of "assignments." De Jong *et al.* (1998) outline several examples of assignments that range from free exploration to achieving specific goals. In our case, we include specific challenges for users. They are asked to get levels of sea beans to accumulate within an acceptable range given different starting conditions. These kinds of goal-seeking activities help users focus their hypotheses more efficiently (de Jong *et al.* 1998).

Another type of support scaffolding we used is the concept of gradual-increase-in-complexity. As Yasacaran (2009) argues, users understand complex concepts better when they progress from simpler to more complex concepts over time. The SLE comprises two parts that reflect an increase in complexity within the simulation model. In part one, the values users choose are flows that remain static during simulation run time. In part two, users choose two sets of values for flows that change during the simulation run time. This is designed to build a user's understanding of the principles of accumulation incrementally.

Designing the interface
The design and functionality of the interface is another important factor that influences the effectiveness of an SLE. Liang and Sedig (2009) describe the importance of choosing the right structure and navigation type based on the content and pedagogical strategy. In our case, we chose a linear structure where users progressively move from one section of the activity to the next (background, simulation, reflection, debrief). Users may access these sections from a menu page, but are not able to freely move between pages. The navigation is set up to lead users through the SLE so that they progress through increasingly complex lessons.

We created visual hierarchies within the interface layout by creating regions on the page where a specific feature or activity would always be displayed. There are areas for text and for output graphics. Activity panels contain decision-making features (e.g., slider bars) and action features (e.g., buttons to run and reset the simulation). Illustrations and photos accompany and enhance the text. We also color-code important elements. For example, the systems inflow, "sea beans added," is always represented in the same color, whether it as a trend line on a graph or textually in a description of the system. This consistent treatment helps users become familiar with the SLE interface, its content and features.

The simulation interface itself has three components: simulation controls, graphical outputs, and reflective support (described on the previous page). The simulation controls include the slider bars representing the inflow and outflow levers of the sea bean accumulation model. Users set values on the slider bars and run the simulation for one year. Navigational buttons for running and resetting the simulation, and moving on to the next page are also part of the controls.

We use multiple representations in the simulation interface to show the results of simulation runs. Rieber *et al.* (2004) point out that by representing information in more than one form—visually or verbally—learning outcomes can be enhanced. The representations in this SLE take the form of line graphs, bar graphs, and graphical images. Users may focus on or more representation to understand the results of their flow decisions. Providing multiple modes of encoding information in memory not only aids in knowledge retention but also accommodates users with different learning styles (Lindgren and Schwartz 2009).

Managing cognitive load
Another challenge to creating effective SLEs is the management of cognitive load. This is not so much a separate challenge, but one that has design implications for both scaffolding and interface. Cognitive load refers to the amount of short term, or working memory available for thinking and learning (Kirschner 2000). In an SLE, demands on

cognitive load come not just from the way a user is guided through the discovery process, but also how they interact with the SLE. Since working memory can only manage up to seven items at a given time, and only two or three simultaneously (Kirschner 2000), all demands on cognitive load should be accounted for when designing SLEs.

The three types of cognitive load, as described in a review of cognitive load theory by Vogel-Walcut *et al.* (2010) are intrinsic, germane, and extraneous cognitive load. Intrinsic cognitive load comes from the learning content (i.e., accumulation of sea beans) and is reduced through scaffolding. Germane cognitive load is related to the use of discovery skills (e.g., making predictions, analyzing results). Extraneous cognitive load is anything that is unrelated to learning (e.g., navigation). Both germane and extraneous cognitive load can be reduced though good instructional and interface design. To promote effective discovery learning in the SLE it is important to maximize the intrinsic cognitive load while minimizing the extraneous cognitive load.

Development Process

We took six months to develop the SLE to this stage. Design and development was an iterative process that involved several rounds of user testing and SLE revisions. The SLE presented here was used for a paired experiment with 188 students in an Introduction to Environmental Science course in Spring 2011.

Our design and development process was conducted in roughly the following stages:

1. Determined learning objectives. We made the learning objectives explicit at the start of the process and continuously referred back to them (see page 3). All decisions in the SLE development must support ultimately support the learning objectives.
2. Determined page flow and navigation. We determined how the users would interact with the SLE by creating storyboards that included navigation elements and rough content sketches for the introduction, simulation, reflection, and debrief pages. We considered how both the control (non-simulation) and treatment (simulation) groups would differ. Then we generated the necessary text and graphics.
3. Developed simulation model. The operational model was created in Vensim and then imported into Forio Simulate.
4. Developed reflective support. This included the predictive and reflective questions.
5. Built pages in software. The operational pages were constructed including text, graphics, and interface for both simulation group and control group.
6. User testing conducted. Several rounds of user testing and feedback sessions were conducted where information about the usability of the interface and the clarity of the learning objectives was gathered.
7. Refined content, support structures, and interface based on user feedback.
8. Tested and published current iteration.

9. Conducted paired experiment with the SLE.
10. Analyzed results and user feedback.

Lessons Learned

The development of this SLE was an iterative process that involved several rounds of user testing. In early stages of development, we had individuals and small groups use the simulation and give us written and/or verbal feedback while we observed their use. We also collected user feedback on the final version of the SLE after students used it for their assignment. We gave students an extra-credit opportunity in which they either completed a packet with screenshots detailing their feedback, or participated in a one-on-one live session where feedback was exchanged with a facilitator. Users were asked their thoughts on the layout, navigation and usability of the SLE, the learning content (text, graphs, and graphics), learning support questions, as well as their general thoughts. They were asked which features were and were not helpful and what elements their eye was drawn to first to last. In the live sessions this information was gathered verbally. Users were encouraged to think aloud as they moved through the SLE. All user feedback provided valuable information that helped identify what aspects of the SLE needed to be refined or in some cases, redesigned.

Overall, we received mixed feedback on the functionality of navigating through the SLE. Some users found the navigation intuitive and self-explanatory, while other users struggled to understand the tasks expected of them. Some understood how to use the inflow and outflow slider bars, but others manipulated the sliders haphazardly without an apparent understanding of the purpose. One user reported taking several minutes to figure out how to start, despite the availability of the tutorial. Any time a user is left wondering what they are supposed to do on a given page, we can conclude that the navigation has failed. Ultimately, a user that doesn't know what to do will not be able to discover any of the intended lessons.

We revised the navigation and the simulation interface over several iterations. Each one required us to redesign the user experience and the overall navigation of the learning environment. In our first iteration for this package, we prompted users to explicitly enter the relationship between inflow and outflow variables (e.g., inflow ">" outflow, inflow "=" outflow). We expected that drawing the student's attention to the most germane information would help them notice patterns. This was intended to scaffold the user's understanding of the relationships between inflows and outflows, but rather became an impediment to achieving the learning objective. The extra navigation steps caused users to spend too much time on a relatively minor aspect of the simulation. While highlighting the relationships between inflows and outflows was important to the learning objectives, this method did not seem to help users.

With each revision, we allowed students to more freely explore the exercise, and required fewer repeated steps. In later versions (as the one presented here), we decided to scaffold reflection about what users observed rather than directing them to focus on specific information. We used discovery questions to prompt users' reflection about their mental models about accumulations. Feedback from users on these questions was mixed, however. Many stated that they liked being prompted to think about the problem in such a way. Others found the questions tedious and did not understand their purpose. A few reported they thought the reflective questions would have a correct answer, and expected to be informed whether they got it right or wrong. What these users may not realize is that there is a distinction between questions that are meant to scaffold their discovery and evaluative questions for a grade. We should make it clear to users that scaffolding questions are meant to encourage more reflection, not test them on their knowledge.

Several users responded positively to being able to compare their reflection responses to the accumulation principles. This allowed them to confirm their new knowledge against the learning objectives. Veermans *et al.* (2000) found that providing this kind of feedback information was beneficial to discovery learners. We will provide more feedback of this kind to help users check their understanding in future iterations. Users will check their understanding of accumulations and receive feedback about their answers. Once confronted with an incorrect answer, we can give users the option of going back to try the simulation again. For those who answer correctly, we confirm that they are "on the right track."

The simulation interface screen needs to be refined to make comparisons to previous trials easier. While each simulation run includes before and after information, comparing information between runs is not as straightforward, nor as graphically rich. The current iteration has users making comparisons "across screens," no doubt more demanding on cognitive load than a side-by-side comparison would be. As Zhang *et al*. (2004) note, facilitating the comparison of data between runs supports users as they form hypotheses and make predictions.

Many users reported that there was too much explanatory text in the SLE. Because of the large amount of background information at the start of the SLE, they were unsure about what information was most important. Many users reported or were observed only skimming the content, while others skipped it all together. This confirms findings by Reiber *et al*. (2004) that too much expository information up front can lead to cognitive overload and diminished interest.

This does not require that content be eliminated entirely. Instead the content can be reorganized or edited to a form that is more useful. For example, Hulshof and de Jong (2006) used tips offered on a "just-in-time" basis to provide the most immediately germane information. Some of our content should be edited and used as supplemental information tips in future iterations. Adding help buttons associated with specific content or interface elements would give users the option to access the information when it is most relevant. Tips such as these are less taxing on cognitive load than upfront instruction (Hulshof and de Jong, 2006). Allowing this information to be optional does not disrupt users who may be less inclined to dig deeper into the content.

User feedback also indicated that the tutorial should be more useful. We originally designed the tutorial to be optional, as we felt some would not be interested in using it. This was confirmed in the live user feedback sessions. Some found the tutorial tedious and didn't want extra support. Ironically, many who did not use the tutorial were confused about what to do when they got to the simulation. We will need to further refine the tutorial by making it easier to understand, faster to access, and also make it more directly related to the immediate task. Merging the tutorial with the simulation screen could help make a more useful tool for those who need added support.

Response to the design elements in the SLE was neutral. Some found the images and graphics engaging and helpful. Most reported that color-coding was particularly useful. Consistent colors for inflows, outflows and accumulations allow users to quickly identify compare these important simulation components.

As expected, finding the optimal amount of learning support to help users process and understand the learning objectives still proves challenging. Some users reported feeling that the activities were at times confusing or repetitious. Too much repetition without understanding the purpose can make users lose interest in the activity. Again, we found that anything that does not immediately support discovery or achievement of the learning objectives could be taxing on cognitive load and therefore result in an SLE that is not as effective as it could be.

In summary, we learned much through the iterative development process of building and designing this SLE. User testing and feedback helped us understand how people interact and use the SLE. Consequently, we have identified several key lessons that will inform the further development of this SLE. Our next steps in revising this SLE will focus on the following:

1. Minimizing the cognitive load of using the interface. We will streamline the navigation to allow users to more easily and freely explore the simulation. Too many steps reduce interest and learning outcomes. We will also redesign the navigation buttons themselves using icons and accompanying text to clarify the action of each button.
2. Creating a better balance instruction and simulation time. Too much expository information up front can lead to cognitive overload and diminished interest. We will edit the content and embed relevant information in the simulation interface. Users will have on-demand access to information when they need it most. This allows users to begin exploring the simulation sooner.
3. Providing the appropriate amount feedback to help people learn. Redesigning the simulation interface to include comparisons to the problem trend, or previous runs will streamline the interface and give users more tools to explore the domain. We will also add ways for users to confirm their new knowledge against the learning objectives. We will give users an opportunity to check their understanding between simulation levels by asking them multiple-choice questions relating to the learning objectives. Users will receive feedback on their

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answers and will then decide whether they want to use the simulation to explore the problem further or move on.

This SLE will continue to be refined to maximize its discovery learning benefits. We will examine the effectiveness of our design and test the expected learning gains in future paired experiments.

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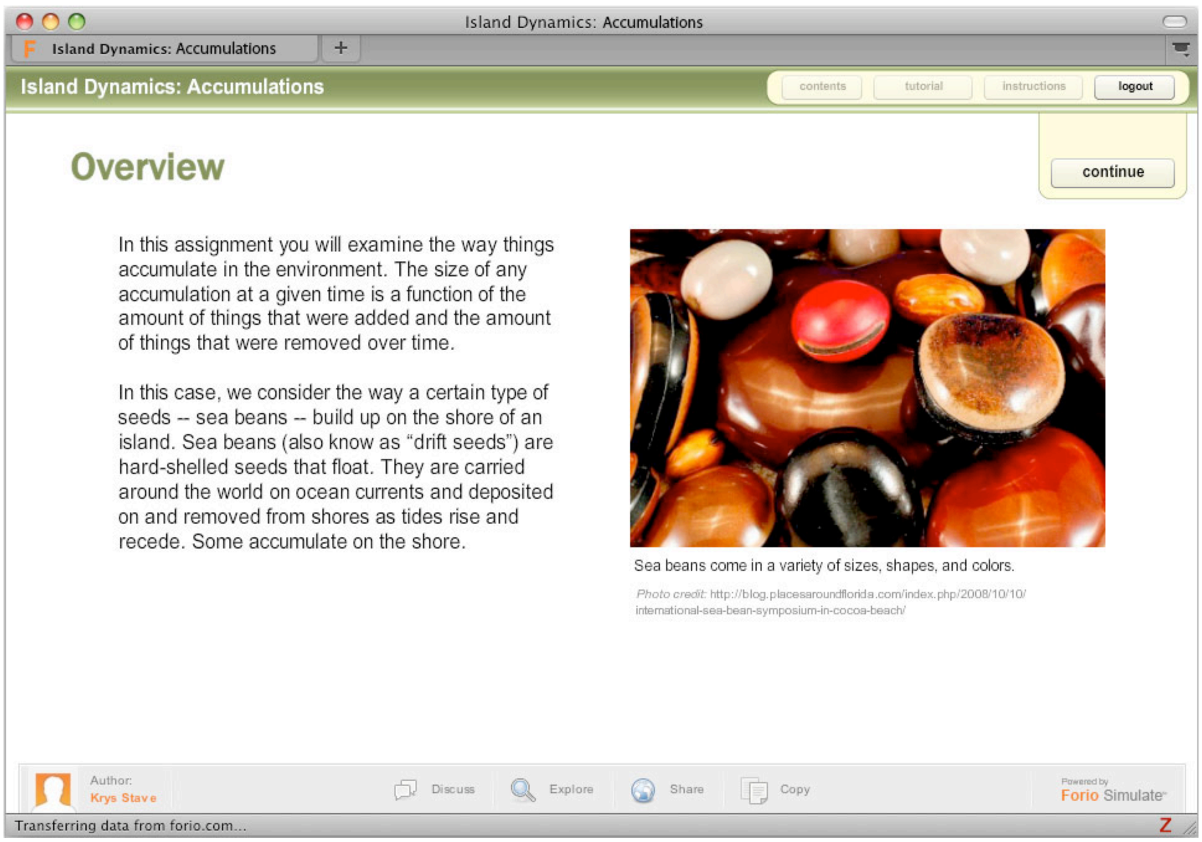
APPENDIX

The Simulation Storyboard

In this module, we use the movement of sea beans (a large category including seeds from a variety of species that drift on waterways, including ocean currents), to examine simple accumulation concepts. The accumulation of sea beans on the island depends only on addition and removal from the sea. There is only one inflow — sea beans washing in to shore — and one outflow — sea beans washing out to sea. There is no feedback from the accumulation to the flows. The length of the simulation period is one year and the interval is one day.

We start with an overview:



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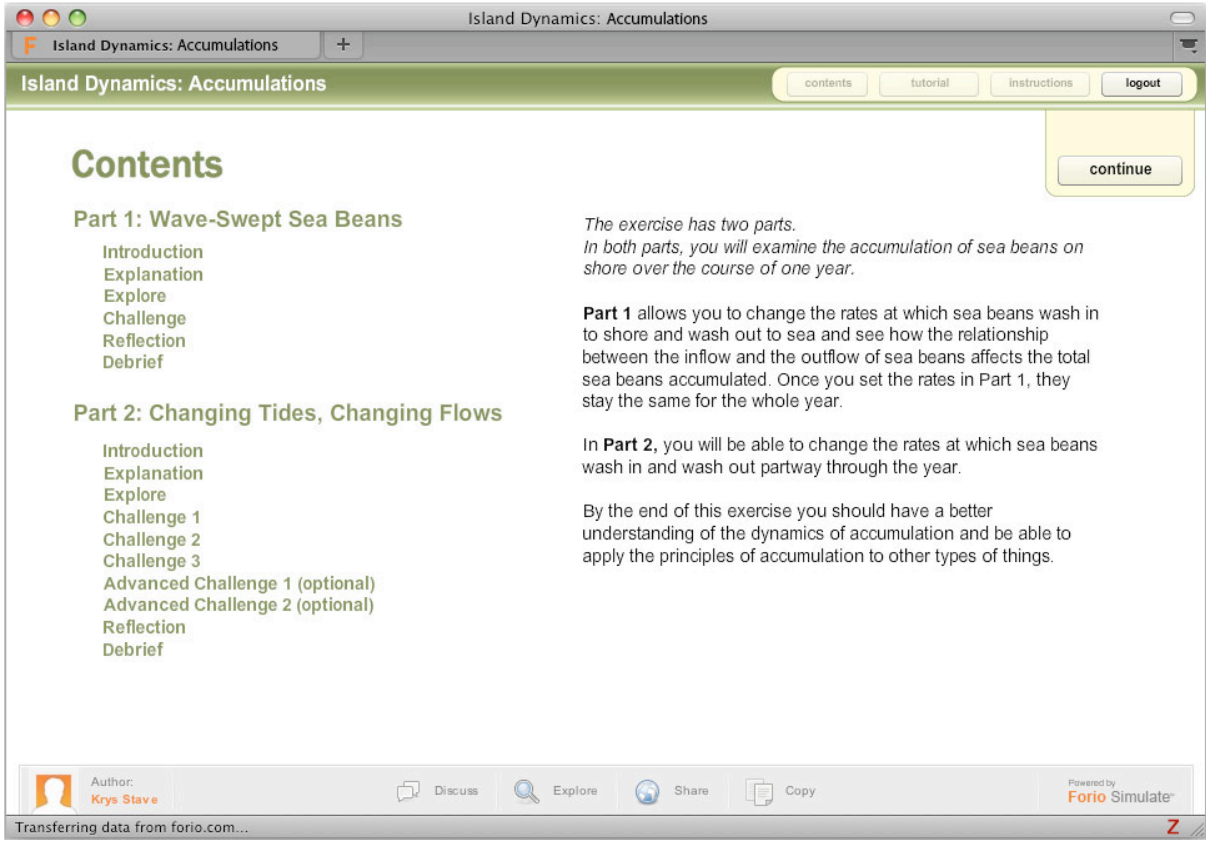

There are two parts to the exercise. The first is very simple, exploring the relationship between flows and accumulation when the flows remain constant over the course of the year. In the second part, we allow users to change the rates four months into the simulation. That is, the rates are constant for the first 4 months, they change linearly to the new rates between four and six months, then stay constant at the new rates for the last six months. In both parts, we start with an explanation of the basic concepts, illustrated with static graphs, then allow users to explore the simulation on their own, then present them with challenges to prompt them to explore more. Prompts for prediction and reflection are included throughout the simulation. Finally, we repeat the main concepts in the debrief section.

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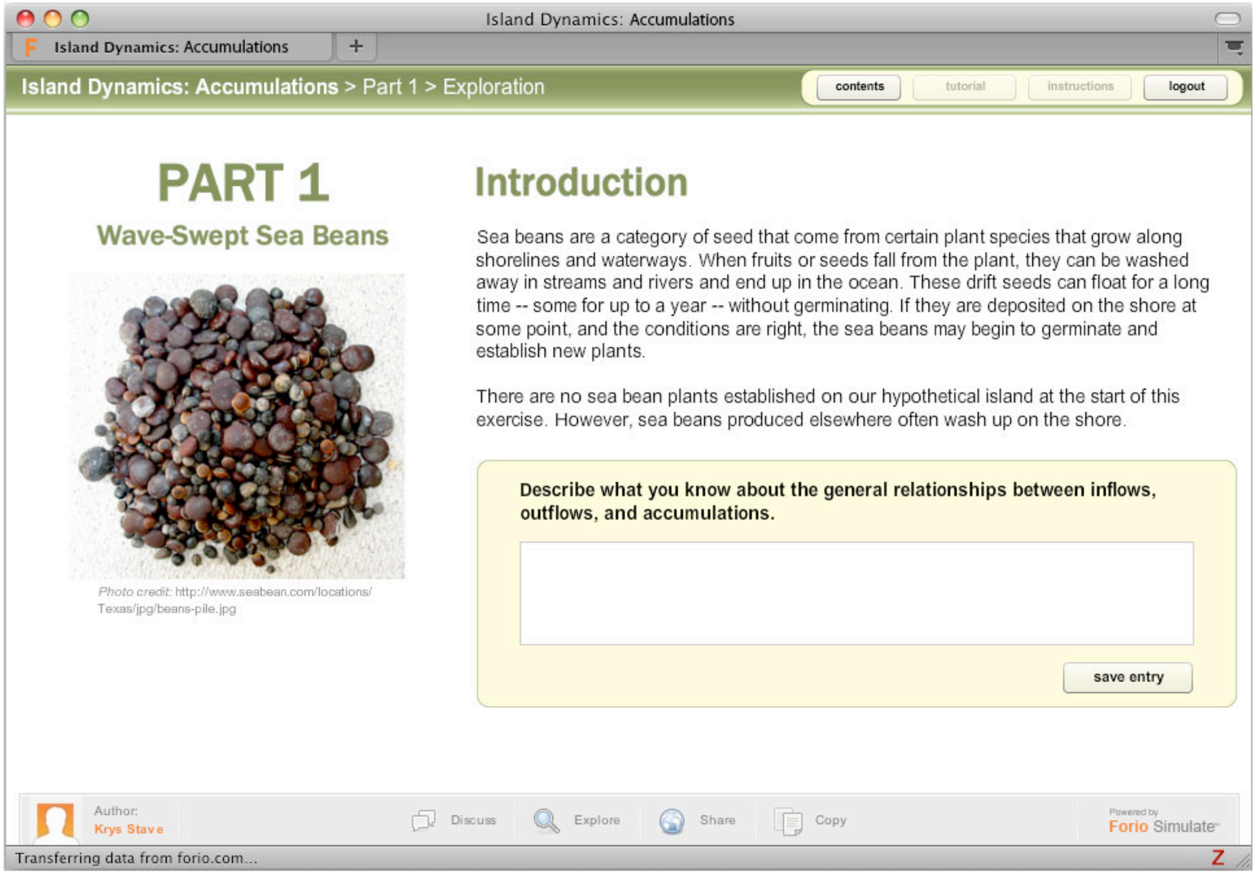
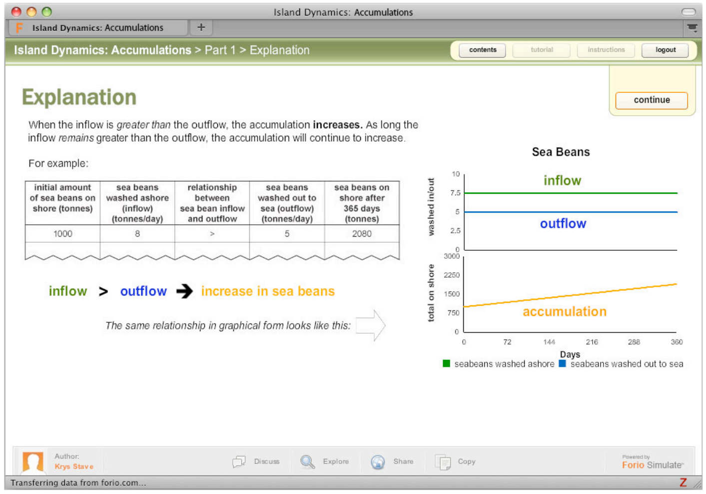


Part 1: Wave-Swept Sea Beans

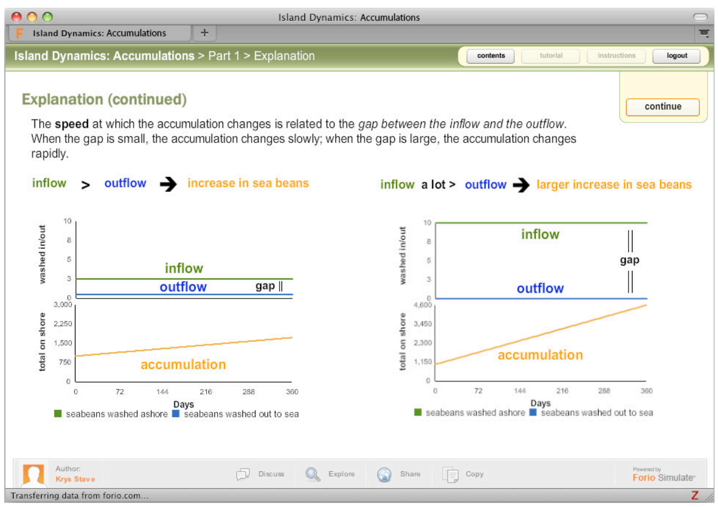
After an introduction to sea beans and their penchant for travel, we ask users to tell us what they know about accumulations. Forio's Basic level subscription allows data like this to be collected.

The next three screens provide the equivalent of a simple lecture on accumulations. Users can page through these screens at their own pace. They also introduce users to the graphs they will see on the simulation page.

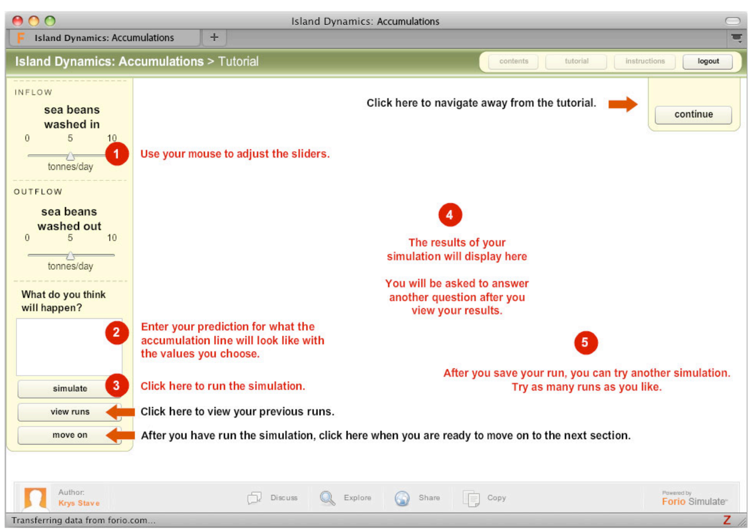
After the explanation, users can go directly to the simulation or see a tutorial page that takes them through the sequence of steps in the simulation and identifies the navigation buttons.



Explanation



Explanation



Tutorial

Proceedings of the 29th International Conference of the System Dynamics Society. Washington, DC, July 24-28, 2011. Available at: http://www.systemdynamics.org/conferences/2011/proceed/index.htm

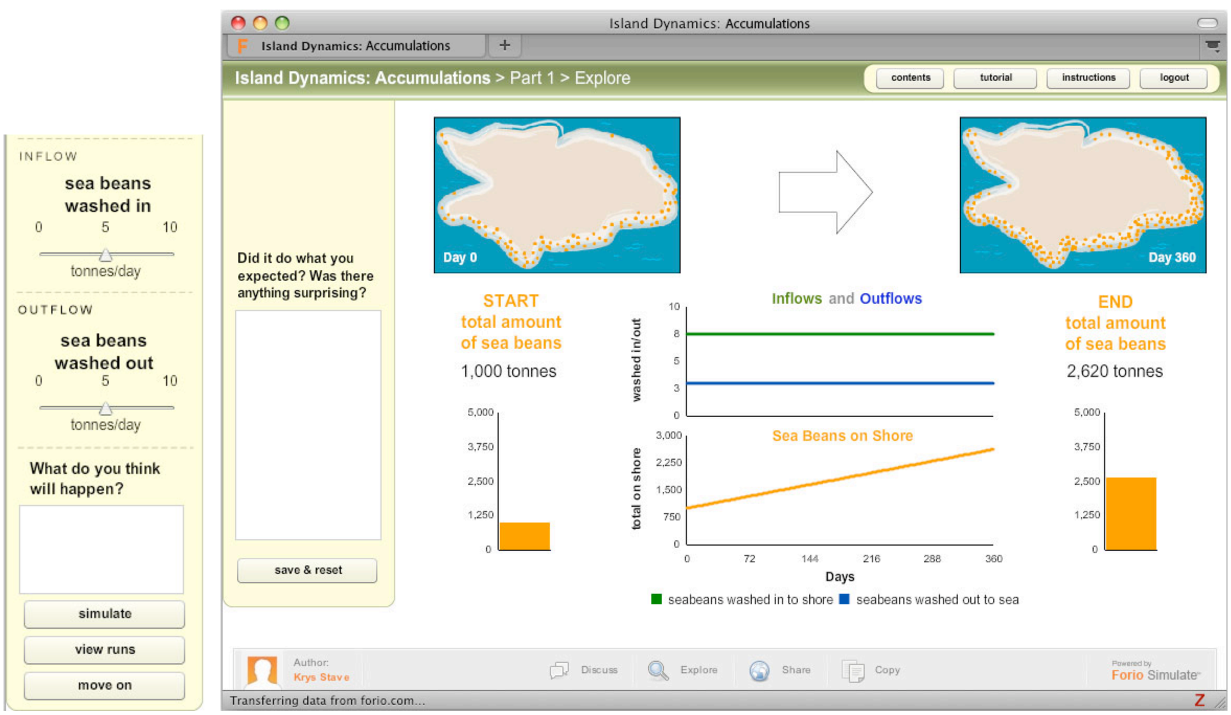
Simulation Interface

To run the simulation, users first set initial inflow and outflow rates using slider bars (formulate hypothesis). We ask them to predict what will happen to the total accumulation of sea beans on the shore with those flow rates.

Once they have made their decisions and click “simulate” (test hypothesis), the results display in multiple ways.

- Graphical feedback includes:
  - Before and after image with colored dots to indicate how the number and density of sea beans on the shores have changed over time.
  - Line graphs that illustrate the trend over time
  - Before and after animated bar graphs that compare accumulations at the start and end of the simulation.
- Numerical feedback reveals how the number of sea beans has changed over the course of the year.

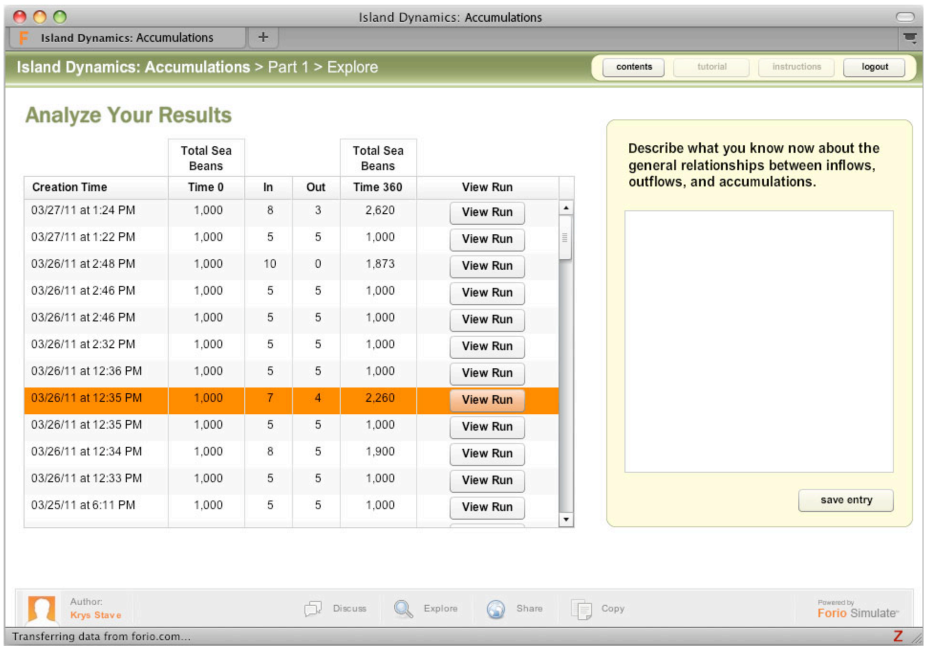
We ask them to note what happened after the run, and comment on what they saw. Users can choose to rerun the simulation with new values, revising their hypotheses in the process. After the first run, users can also view a table of runs that give the input and output values for each run, and allows them to see the graph again.



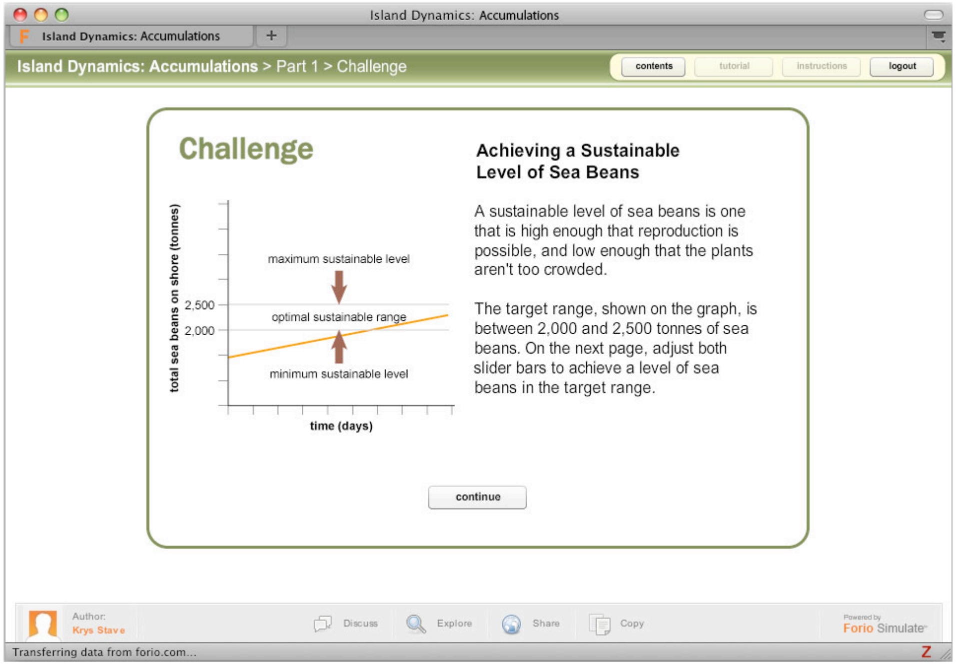
Proceedings of the 29th International Conference of the System Dynamics Society. Washington, DC, July 24-28, 2011. Available at: http://www.systemdynamics.org/conferences/2011/proceed/index.htm

Analysis and Challenges

After the user moves on from the simulation screen, they are asked again to describe what they know about the relationship between flows and accumulations. They can see all their runs. This prompts them to interpret and reflect on their observations.

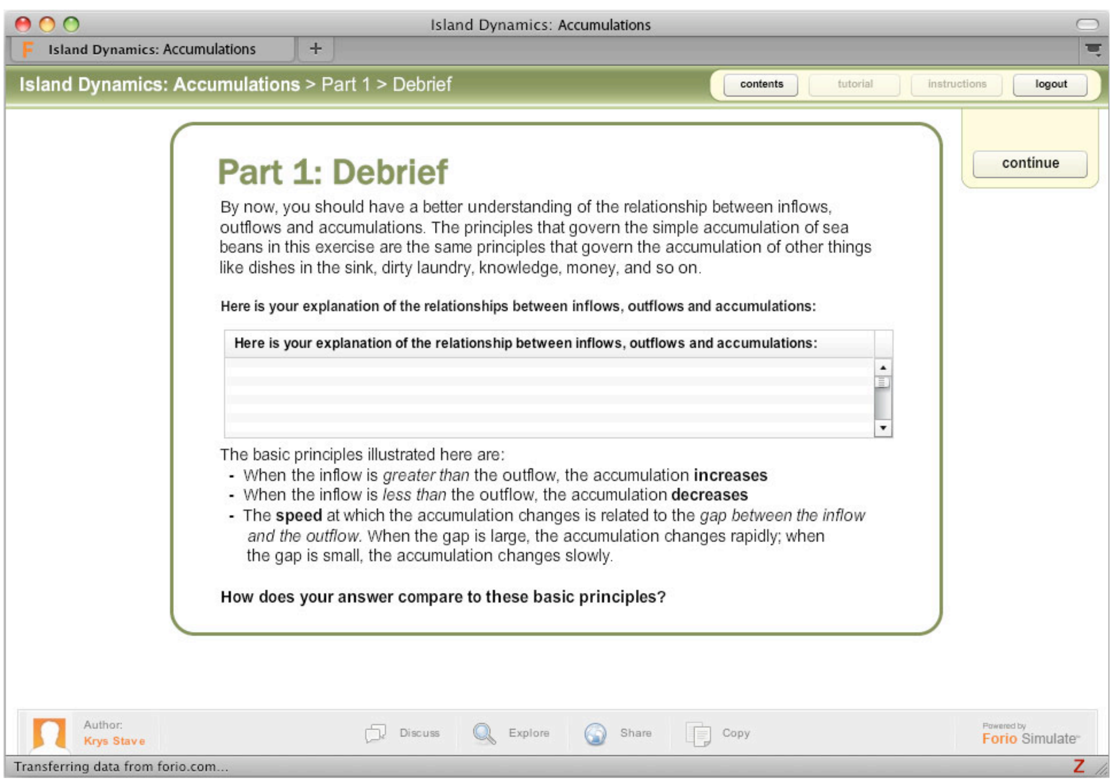


For a challenge in part 1, they are asked to achieve a level of accumulation in a target range. Part 2 gives them several challenges, asking them to achieve a target with a specific pattern of behavior.



Debrief

On the debrief page, we reflect their answers back to them, and provide the statement of principles again. They can then either go back to re-read the Part 1 explanation pages, re-run the Part 1 simulation, or go on to Part 2.

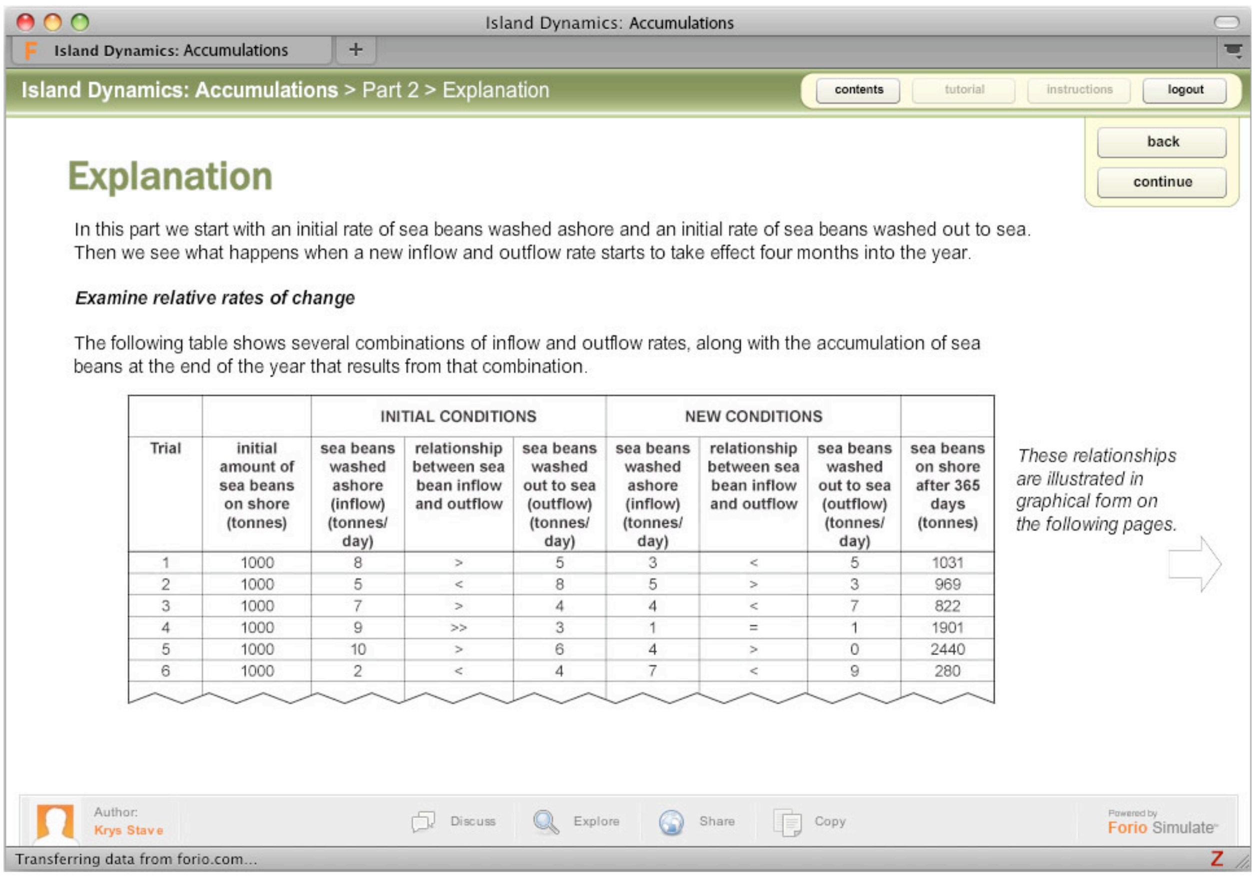


Part 2: Changing Tides, Changing Flows

Part 2 follows the same structure as Part 1, but allows the user to change rates. The scenario states:

> Imagine that four months into the year (at 120 days) the tides change. This could happen as a result of seasonal change, major weather patterns like El Nino, or climate change. When the tides change, the rates at which sea beans wash ashore and are washed back out to sea also change. It takes about 60 days for the tides to change completely to the new rates.

This is followed by a similar static explanation of the principles, again illustrated by tables and graphs.



		INITIAL CONDITIONS			NEW CONDITIONS			
Trial	initial amount of sea beans on shore (tonnes)	sea beans washed ashore (inflow) (tonnes/ day)	relationship between sea bean inflow and outflow	sea beans washed out to sea (outflow) (tonnes/ day)	sea beans washed ashore (inflow) (tonnes/ day)	relationship between sea bean inflow and outflow	sea beans washed out to sea (outflow) (tonnes/ day)	sea beans on shore after 365 days (tonnes)
1	1000	8	>	5	3	<	5	1031
2	1000	5	<	8	5	>	3	969
3	1000	7	>	4	4	<	7	822
4	1000	9	>>	3	1	=	1	1901
5	1000	10	>	6	4	>	0	2440
6	1000	2	<	4	7	<	9	280

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Trial 2:
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Accumulation decreases then increases
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total on shore
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Krys Stave
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Inflow rate decreases
Outflow rate increases
by the same amount
Accumulation increases then decreases
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seabeans washed in to shore
seabeans washed out to sea
Trial 4:
Inflow rate decreases steeply
Outflow rate also decreases,
but less steeply
Accumulation increases then remains the same
washed in/out
total on shore
Days
seabeans washed ashore
seabeans washed out to sea
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Trial 5:
Inflow rate decreases considerably
Outflow rate remains below inflow rate
Accumulation increases at a steady rate
washed in/out
total on shore
Days
seabeans washed ashore
seabeans washed out to sea
Trial 6:
Inflow rate increases considerably
Outflow rate remains above inflow rate
Accumulation decreases at a steady rate
washed in/out
total on shore
Days
seabeans washed ashore
seabeans washed out to sea
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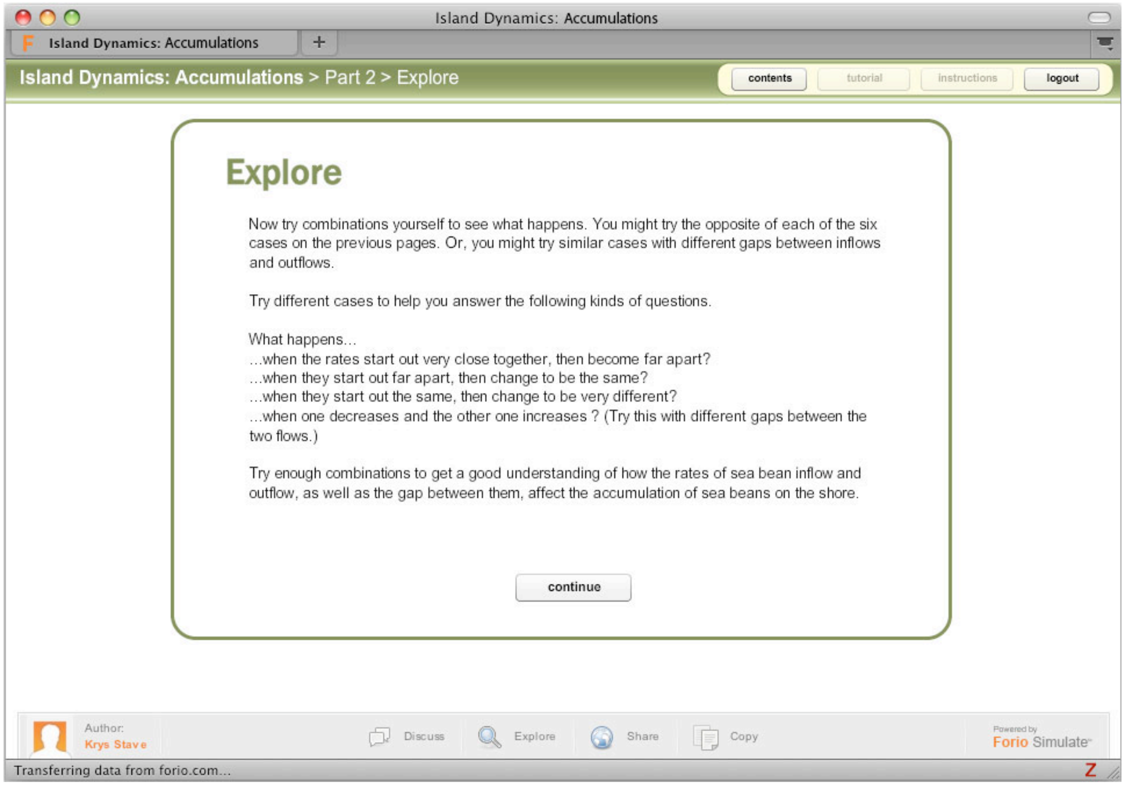
Simulation

The simulation pages are the same as in Part 1, except there are four sliders for the two sets of rates: initial and new inflows and outflows. They are introduced with this screen:



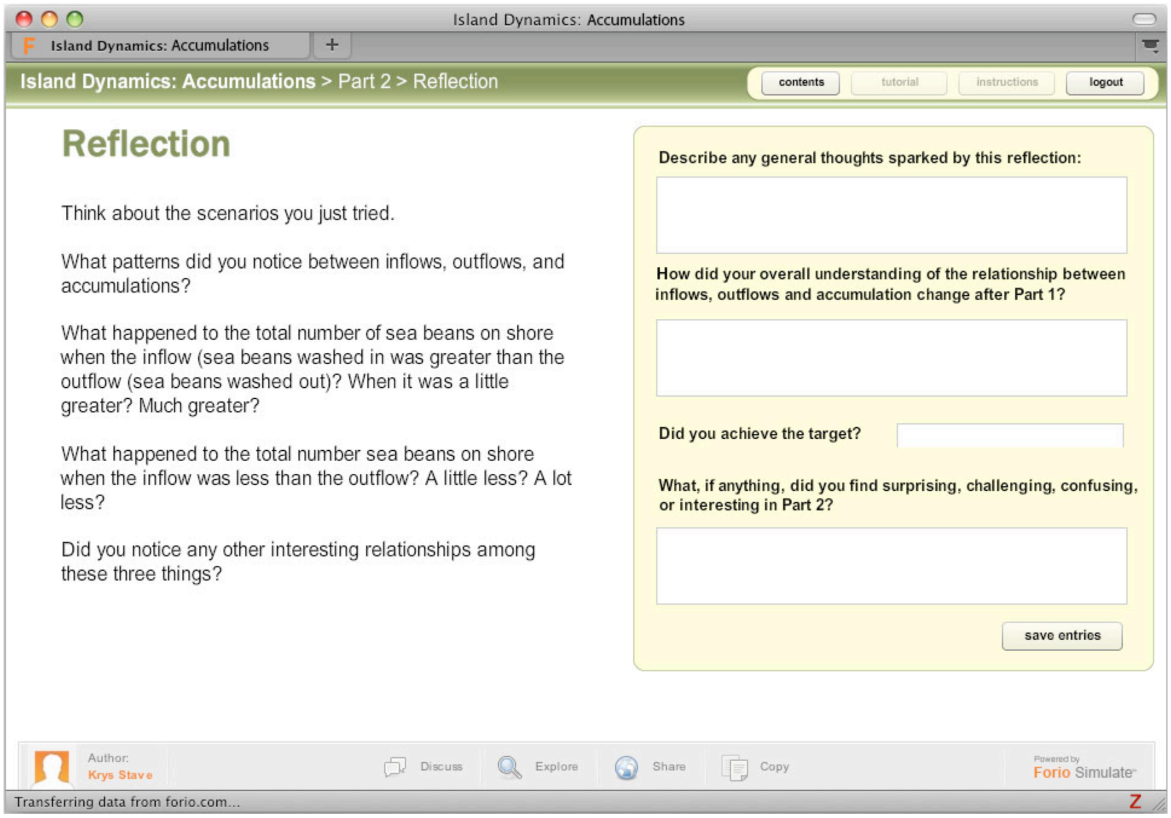
Challenges

There are five challenges in Part 2:

1. Achieve an accumulation in the target range of 2,000 – 2,500 tonnes.
2. Achieve the target range with a pattern that first increases, then decreases.
3. Achieve the target range with a pattern that first increases quickly, then increases more slowly.
4. Achieve the target range with a pattern that first decreases, then increases.
5. Achieve an accumulation in the range 500 – 750 tonnes with a pattern that first decreases quickly, then decreases more slowly.

Reflection

After the user moves on from the simulations, we ask them to reflect on the experience.



Part 2 concludes with a Debrief section that summarizes the principles presented in the explanation pages, and again allows the user to return to Part 1 or Part 2.