Appendix D: Instructional Resources

Overview

In addition to handouts and resources included with individual lessons and within Appendix C, these are provided as general instructional resources for use within any of the lessons. Teachers may choose to differentiate or modify them for their own purposes.

Assessment Strategies for the Lessons

Educators hold a significant degree of personal choice regarding methods for assessing student growth and achievement. High expectations motivate students to work hard, ask good questions, and learn with open minds. Trust the students. They will use the tools and resources in creative, unpredictable ways.

Assessment for the lessons in *Now What?* may be divided into three categories:

- Content
- Systems Thinking Tools
- Systems Principles

Bringing the Lesson Home and *Bringing the Chapter Home*, the debriefing sections at the end of each lesson and chapter, provide teachers with questions to gauge student understanding in each area. Here are suggestions for further assessment.

Content

Each lesson plan suggests ways for students to document and share their work or participate in an activity or simulation. Teachers can observe and collect students' projects and watch them in interactive simulations and presentations to measure their achievement and effort to understand key environmental and sustainability concepts.

Be sure to evaluate students' growth and skills in different areas in order to give effective feedback. For example, some students will have difficulty speaking to an audience if they are inexperienced, nervous, or shy. Find other aspects of their work to praise and reinforce. Remember that learning is an iterative process.

Keep the following areas in mind while assessing student work:

- Quality of research
- Analysis of data and information that supports conclusions
- Use of a variety of sources
- Integration of systems tools
- Clarity of presentation or product
- Ability to work with teammates
- Effective graphic content and images

Systems Thinking Tools

The standards in Appendix D can be used as a checklist and will provide specific feedback to students. Teachers can adapt the standards to use with students at different levels of mastery to create rubrics that are continuum or level based.

Encourage students to address and improve their graphs, diagrams, and models based on feedback received in a similar way to revisions expected in other academic work.

Systems Principles

Whole class and group conversations based on student projects are essential to surfacing the big ideas that are the key to understanding the complexity of environmental systems. Those discussions allow ideas to be shared and explored and provide teachers with a sense of the collective level of learning. Combined with the debriefing questions at the end of each lesson and chapter, student reaction to their peers' projects is essential to "bringing the lesson home."

When individual reaction is desired for assessment, teachers can gather written responses to the debriefing questions and others that have arisen. Encourage students to ask their own questions, a vitally important skill when dealing with complex systems. Finding solutions will not be simple and clear-cut, and student opinions will reflect that uncertainty.

Bringing the Assessment Home

Understanding complex environmental systems is difficult. Discovering and implementing sustainable and just solutions to environmental problems is even harder. Students need to investigate content topics rigorously, applying systems tools and principles as they do their research and learning. Teachers should use formal and informal assessment methods to provide feedback, keeping in mind that overall evaluation of student growth and performance should be broadly based.

- Integrate all three areas: Content, Systems Tools, and Systems Principles
- Emphasize interconnections
- Encourage students to see the big picture
- Reinforce positive and specific strategies

Upcoming generations will inherit a world that requires changes in the way humans interact with our environment. Encouraging systems citizens while they study in school gives them a head start toward accepting and meeting that challenge.

Strategies for Presenting Student Work

When teams or individual students have conclusions to share, finding creative structures for presenting their work will motivate them to produce clear, high quality writing and graphic content. Effective communication should be a goal for every project, both when delivered "live" and when posted or published for audiences.

The following list can serve as a starting point of options:

- **Deliver an illustrated lecture** - Have students explain their research to another class. An elementary grade audience would require them to simplify concepts and diagrams. How about an audience of adults who are not professional scientists?
- **Draw cartoons** – Editorial cartoons are very effective and will appeal to many students who enjoy drawing and exercising their sense of humor. Because the prior knowledge among your students will vary, you need to make a teaching decision about presenting examples before they create their cartoons.
- **Prepare a slide show** – Presentations may include cartoons and graphics.
- **Create and perform a song, rap, or poem**
- **Write an explanation in their own words, integrating a stock/ flow model or other systems diagram** – Students can write persuasive essays, structuring them as "op-ed" pieces, or letters to the editor of newspapers and periodicals.
- P**repare and deliver a presentation to a town meeting** - Imagine your community needs to decide whether or not to use the resources of the local government to create and promote programs regarding environmental systems. Students can advocate for policies government should implement. For example, some cities and towns are moving toward renewable energy sources to power schools, municipal offices, and other public facilities. Explain why this is important.
- **Select an expert panel** – Choose students who have studied different aspects of a problem, including those with opposing conclusions. After brief statements, have them take questions from an audience of peers.
- **Build feedback into poster presentations** – Have students present their work on physical displays or digitally. Then encourage the audience of peers or guests to submit comments and questions after viewing the exhibits.
- **Publish a class magazine or newspaper** – Highlight student research and diagrams and disseminate online or print copies.

You can help other teachers by having your students share their projects. The CLE provides a website in which student examples are available for inspiration for other teachers. Consider having your students share work they have created (photograph and short description) to webmaster@clexchange.org with the subject line, "Now What: Student Projects."

Be sure you have students share according to school/district guidelines, indicating how the work should be credited, e.g., with name, school, or anonymously.

Handout: Strategies for Presenting Your Work

When you have conclusions to share, sometimes finding creative structures for presentations increases the impact of your ideas. Effective communication should be a goal for every project, both when delivered "live" and when posted or published for audiences.

Here are some options for sharing your work:

- **Deliver an illustrated lecture to a new audience** - Explain your research to another class. An elementary grade audience for example requires simpler concepts and diagrams. Or, address an audience of adults who are not professional scientists and use persuasive arguments.
- **Draw cartoons** – Editorial cartoons are entertaining and effective and can highlight your artistic ability and sense of humor.
- **Prepare a slide show** – Presentations may include cartoons among your graphics.
- **Create and perform a song, rap, or poem**
- **Write an explanation in your own words, integrating a stock/ flow model or other systems diagram** – Persuasive essays may take the form of "op-ed" pieces or letters to the editor of newspapers and periodicals.
- **Prepare and deliver a presentation to a real or simulated town meeting** - When your community needs to decide whether or not to use resources to create and promote programs regarding environmental systems, advocate for policies you believe government should implement. For example, some cities and towns are moving toward renewable energy sources to power schools, municipal offices, and other public facilities. Explain why this is important. If you don't have access to local government, simulate a meeting in your classroom.
- **Select an expert panel** – Team with other students who have studied different aspects of a problem, including those with opposing conclusions. After brief statements, take questions from an audience of peers.
- **Build feedback into poster presentations** – When you present your work on physical displays or digitally, encourage the audience to submit comments and questions.
- **Publish a class magazine or newspaper** – Highlight your research and diagrams and disseminate online or in print.

Consider sharing your final work (by sending a photograph and short description) to webmaster@clexchange.org with the subject line, "Now What: Student Projects."

Make sure to obtain permission from your teacher before sending and indicate how the work should be credited, e.g., with name, school, or anonymously.

Systems Thinking/System Dynamics Project Standards

See next page for system dynamics model standards

BOTGs	Feedback Loops
o The x-axis represents time. o The y-axis represents the variable being investigated. o The graph is a line graph. o All variables are quantities that can increase or decrease with time. o Scales are clearly labeled and related to the behavior. They can be numeric or descriptive. o The line accurately shows the behavior described. o The scale is long enough to show the pattern of behavior. o When possible, the graph shows lines for more than one related variable. o The graph focuses attention on the pattern of behavior rather than only on specific events. o Variables are carefully chosen. o The graph leads to questions about the dynamics of the system and possible causes of the behavior. o The written project summary includes an explanation of what the graph shows.	o Each arrow shows a causal relationship between two variables. o Does not use "more" or "less" o Arrows show smooth causal links through the diagram with a minimum of crossing lines. o All variables are nouns, quantities that can increase or decrease over time. o Variables are carefully chosen and are significant. o Variables combined when appropriate o All polarities (+/- or s/o) are labeled. o Connections are based on evidence, data, or reasonable hypotheses. o The diagram includes feedback loops. Positive (reinforcing) and negative (balancing) feedback loops are labeled. o Delays are indicated. o A brief description tracing the feedback loops is included in the written project summary.
Stock/Flow Diagrams	**Iceberg Models**
o Significant stocks in the system are identified. o Stocks are expressed as nouns, or noun phrases. o Stocks are accumulations that go up and down over time. o Stocks are changed only by flows. o Flows have accurate titles. o Converters show the relationships among elements of the model. o Converters clearly show the influence behavior of the flows. o The diagram shows causality (feedback) within the system. o Positive and negative feedback loops are labeled. o The diagram has smooth connections and limited crossing lines. o The diagram provides insight into the possible causes of the behavior in question. o The diagram is "operational"; graphs are generated which simulate behaviors. o The written explanation of the structure of the system is clear and shows understanding and insight.	o *Events* are identified clearly. o *Patterns* shows variables that change over time. o Iceberg shows at least three levels. o *Patterns* cited are significant and help to describe the problem. o *Structures* are identified that cause patterns of behavior. o *Structures* represented by feedback loops or S/F diagrams o Counterintuitive and/or unintended outcomes are described. o Delays between iceberg levels are noted. o *Mental models* are linked to appropriate sections in the diagram. o Explanation highlights possible leverage points that could change the behaviors. o A short written description of the diagram and significant insights is included.

System Dynamics Models

Conceptualization

- The model has a clear purpose stated in behavioral terms.
- The question is about something that changes over time.
- The question involves feedback – the cause of the behavior is endogenous to the system.
- The question has a manageable focus – the boundaries of the system are clear and reasonable.
- System dynamics tools can provide useful insight into the problem.
- The problem is framed in a reference behavior mode – an initial behavior over time sketch of the behavior pattern in question. (See BOTGs)
- The initial mental model is briefly described. These are assumptions about how the system works and what is causing the behavior in question. Key elements of the system and their interrelationships are hypothesized.

Reflection throughout the Project:

- Is your mental model changing?
- Do your findings surprise you?
- Where are you encountering difficulty?
- Where can you get the help or information you need?
- Are things still missing from your model? How could it be improved?

Model Construction

Diagram(See S/F standards)

The Equations (The Assumptions)

- Equations mathematically describe causal relationships.
- All variables are named and represent real-world entities; they can be soft or hard.
- Units are listed for each variable and balance in each equation and throughout the model.
- All equations are simple and clear, briefly documented in simple terms.
- Complex equations are broken into simpler converters for clarity.
- Equations are arithmetic. Non-linear relationships are expressed as graphic functions.
- Graphic functions accurately capture complex non-linear relationships; curves are smooth.
- All parameters (constants) have reasonable real-world values.
- Switches are used judiciously.

Simulation Mechanics

- The solution interval (DT) is 1/3 or less of the smallest time constant to produce a smooth curve.
- The length of simulation is chosen to show the complete pattern of behavior.

The Structure

- The model starts with a simple structure and builds in complexity. The development sequence is shown if the model is complex.

Model Analysis

- The model accurately captures the behavior in question, usually requiring an iterative process of comparing the output to real-world values, identifying structures or parameters that need refinement, and simulating repeatedly.
- The behavior of all model variables is examined for reasonableness.
- The model is tested under extreme conditions.
- Leverage points are identified by determining which parameters have the greatest and least impact.
- Important causal loops are identified.
- Causes of the behavior are traced back through the loops.
- A causal loop diagram may be used to explain the feedback loops. (See CLDs.)
- Graphs are used to show and interpret the behavior under varying conditions.
- Supporting graphs show the behavior of all-important related variables.
- Scales are appropriate for ease of interpretation.

Completing the Project

- The presentation clearly communicates what was learned about the system. It is appropriate to the audience.
- All elements of the project are clearly and accurately labeled.
- Visual tools (graphs, pictures, tables, etc.) are used to support the presentation.
- The display is neat and aesthetically pleasing.
- The project is used to examine assumptions about different policies. The model is used to think about "what-ifs" and make decisions.
- If the project could not answer the question (which is OK too), there is an explanation of what was learned in the process.
- A brief written summary accompanies the display. It includes a description of the project and reflections.

Reflection on learning

- Did your project remind you of another similar system?
- How can you use what you have learned? Are there any leverage points to change the system?
- Can you recommend policy changes?