Designing an NGSS-aligned Middle School Ecosystems Unit Using the Five Tools and Processes for NGSS

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ABSTRACT

This paper describes how the *Five Tools and Processes for NGSS* were used in the development of an NGSS-aligned middle school ecology unit, *Disruptions in Ecosystems: Ecosystem Interactions, Energy, and Dynamics*. This unit was developed as part of a larger project to support the vision of the K-12 Science Education Framework and the Next Generation Science Standards (NGSS). The unit supports the learning and instruction of a bundle of middle school Next Generation Science Standards and their related Common Core State Standards. The development of the instructional unit and accompanying professional development model is part of a larger collaborative effort between the American Museum of Natural History, the University of Connecticut, and the Lawrence Hall of Science to study the effects of implementing a professional development program designed around best practices and research-based results, and grounded in educative instructional materials (for the teacher and student). The initial development process utilized portions of the *Five Tools and Processes for NGSS* to develop a shared understanding of the learning goals and specifications of the unit, how the NGSS would be bundled within the chapters of the unit, and to begin the development of chapter assessments for the unit. The use of these tools provided the framework for development of the unit, now in its second year of field testing and revisions.

Introduction

Research on comprehensive school reform shows that changing instruction requires a complex understanding of the educational system and well-specified materials around which teachers can develop expertise (e.g., Borman et al., 2003; Cohen et al., 2014). With the advent of the Next Generation Science Standards (NGSS) there is a considerable need for new curricula that are designed to bring the NGSS to the classroom in a way that serves both teachers and students. The NSF-funded project described in this paper is intended to help with these considerable challenges. Through a partnership between the American Museum of Natural History (AMNH), the Lawrence Hall of Science (The Hall), and the University of Connecticut (UCONN), the project seeks to advance our knowledge of the effects of NGSS-aligned curriculum materials and professional development (PD) that are based on research and include educative elements for teachers (e.g., Davis & Krajcik, 2005) and students. Our hypotheses are that teachers who participate in well-specified PD that teaches them how to use well-specified NGSS-aligned curriculum concerning middle school ecology will show greater gains in their content knowledge for teaching and pedagogical content knowledge, and that their students will demonstrate higher levels of understanding of disciplinary core ideas about ecosystems, relevant science and engineering practices, and crosscutting concepts.

The Science Education for Public Understanding Program (SEPUP) at The Hall is primarily responsible for the curriculum development portion of the project, with significant feedback and support from AMNH. SEPUP developed a middle school ecology curriculum unit to support the vision of the K-12 Science Education Framework and a bundle of middle school NGSS and their related Common Core State Standards. This unit, *Disruptions in Ecosystems: Ecosystem Interactions, Energy, and Dynamics* (*Disruptions*), will have undergone three years of field testing and revisions by the end of the project, in 2018. This paper will focus on the curriculum developed by SEPUP during the project, and specifically how the Five Tools and Processes for NGSS (Five Tools) were used for curriculum planning and development. The Five Tools were previously developed by AMNH though a separate NSF-funded project (Kastel & Bintz, 2017). The Five Tools were originally created to assist professional development leaders working with teachers to articulate and refine their vision for teaching science. This project was the first to apply the Five Tools to a professional curriculum development process. This paper will outline which of the Five Tools were used, how they were implemented within the development process, additional processes employed, and the outcomes of this work.

The Five Tools and Processes for NGSS

The Five Tools were developed for professional development leaders to work with teachers on developing "a clear vision of science education that is coherent, focused, and rigorous" (AMNH, BSCS, WestEd, 2016). The Five Tools aim to do this by providing a structure for teachers to clearly map the three dimensions of the NGSS into cohesive instructional sequences that can form NGSS-aligned units. The Five Tools then further this process for the teacher by guiding them through development of a specific instructional sequence and correlated assessment task that focuses on the NGSS performance expectations linked to that sequence (NRC, 2012; NGSS Lead States, 2013). The original intent of the Five Tools was for teachers to work with each Tool in sequence as they developed new, NGSS-aligned instructional sequences. Below are brief descriptions of each of the Five Tools. Completed examples of each of the tools can be found on the *Five Tools and Processes for Translating the NGSS into Instruction and Classroom Assessment* website (https://www.amnh.org/explore/curriculum-collections/five-tools-and-processes-for-ngss).

Table 1: The Five Tools and Processes for NGSS

Tool	Function
1: NGSS Unit Blueprint	maps all components of the selected NGSS (PEs, DCIs, SEPs, CCCs, etc.) for a given instructional sequence
2: Using Performance Expectations to Plan Classroom Assessments	breaks down performance expectations using evidence of learning specifications to map outcomes for assessment of PE(s)
3: Using the 5E Instructional Model to Develop a Conceptual Flow	aligns phenomena and guiding questions to the 5E model to help create the storyline and flow of the instructional sequence
4: Using the 5E Instructional Model to Design Learning Sequences	lists anticipated prior knowledge of students and common student ideas about content; describes in more detail activities mapped to the 5E instructional model
5: Using Evidence of Learning Specifications to Develop Performance Tasks	uses Tool 2 and 4 to develop a summative assessment that incorporates DCIs, SEPs, and CCCs for PE being assessed

Tool 1

Teachers begin the planning process with Tool 1, an NGSS Unit Blueprint. Teachers select the NGSS Performance Expectations (PEs) that the instructional sequence will focus on and use Tool 1 to map out all of the correlated components as outlined in the Framework, including the Disciplinary Core Ideas (DCIs), Science and Engineering Practices (SEPs), Crosscutting Concepts (CCCs), Connections to Nature of Science, and Connections to Engineering, Technology, and Applications of Science (NRC, 2012). This allows teachers a visual reference for all of the components in one table, even if they are bundling together PEs from different content areas (e.g. two life science PEs on ecology and on earth science PE on modeling human impact). Teachers continually refer back to Tool 1 as they work through the other tools and develop their instructional sequence. Tool 1 has been used throughout the development of the *Disruptions* unit. The use of Tool 1 in this context will be described in more detail later in this paper.

Tool 2

Tool 2 helps the teacher to move into planning classroom assessments by laying out the evidence of learning specifications related to the PEs that will ultimately be assessed for the instructional sequence. The intent of this tool is for teachers to develop a general sense of what and how they will be assessing their students' understanding throughout the instructional sequence, prior to developing any activities or formal assessments. For example, in Chapter 2 of the *Disruptions in Ecosystems: Ecosystem Interactions, Energy, and Dynamics* unit the evidence of learning specifications for the associated PEs mapped to the following:

Develop a model (build it) of an ecosystem to:
1. describe the interactions among the living and nonliving parts of an ecosystem,
2. describe the interactions among producers, consumers, and decomposers in a variety of ecosystems,
3. show the flow of energy and cycling of matter (Earth's materials) in an ecosystem,
4. describe how matter is conserved in an ecosystem, and
5. describe how energy is transferred out of the ecosystem as heat.

Having this information compiled at the outset of planning the instructional sequence gives focus throughout the sequence development for the incorporation of appropriate informal and formal assessment opportunities. The use of Tool 2 in the development of the *Disruptions* unit will be discussed in more detail later in this paper.

Tool 3

Tool 3 provides a framework to develop the storyline and conceptual flow of the instructional sequence within the context of the 5E learning cycle (Bybee, 2015). Teachers determine the overall guiding question for the sequence, and for each phase of the 5Es they develop anchor phenomena, guiding questions, and links to DCIs, CCCs, and SEPs. An example of how this would look for an Engage activity can be found in Table 2.

Table 2:
Tool 3 – 5E Storyline and Conceptual Flow

Unit: *Disruptions in Ecosystems: Ecosystem Interactions, Energy, and Dynamics*
Instructional Sequence 1: Wolves in Yellowstone
Guiding Question for Sequence 1: *What happens when a predator comes back into an environment?*
Big Idea of Sequence 1: *Humans can affect the relationships among organisms in an environment.*

5Es	Storyline Using Anchor Phenomena	Conceptual Flow Using DCI and CCC	SEP	Resources
Engage	**Anchor Phenomenon:** The reintroduction of wolves into Yellowstone impacted the ecosystem in expected and unexpected ways. **Guiding Question:** How do living things, including humans, interact with each other and with non-living things in an environment? Students explore the living and non-living things of their local environment near school, and compare it to other areas. Then students learn about the reintroduction of wolves in Yellowstone in 1995.	Animals and plants live in a variety of environments; humans are part of and can affect that environment. Animals need air, water and food – they eat plants and other animals. Plants also need food which they make from air, water and sunlight.	**Constructing Explanations** Construct an explanation that includes qualitative relationships between variables that predict and describe phenomena. **Engaging in Argument from Evidence** Construct an oral argument supported by scientific reasoning to support or refute a solution to a problem.	National Geographic Video – wolves, bison and ranchers in Yellowstone Interactive Map: Where Yellowstone Wolves Roam (website from PBS Nature)

Tool 4

Tool 4 is an extensive, detailed outline of the full plan for the learning sequence. It starts with a review of the NGSS being addressed (taken from Tool 1), then teachers list key prior knowledge students will need as a foundation for the instructional sequence, including information from previous grade band(s) for the DCIs addressed in the sequence. Teachers include a list of common student ideas that may need to be addressed (based on the teachers experience from teaching the topic and from resources such as the *NGSS Evidence Statements* (NGSS, 2013), *Benchmarks for Science Literacy* (AAAS, 1993) and *Making Sense of Secondary Science* (Driver et al., 2014).

Tool 4 then walks the teacher through developing a detailed outline that describes teacher facilitation and student activities in each of the 5E phases. Teachers refer to information from the storyline and phenomena developed in Tool 3 as they develop the outline, and include linking questions that help move students from one 5E phase to the next. A complete example of this tool can be found on the *Five Tools and Processes for Translating the NGSS into Instruction and Classroom Assessment* website (https://www.amnh.org/explore/curriculum-collections/five-tools-and-processes-for-ngss).

Tool 5

The final Tool, Tool 5, provides the teacher with a structure for developing the culminating assessment for the instructional sequence. Using the list of evidence of learning specifications (EoLs) outlined in Tool 2, the teacher aligns each element of the list with a performance task, such as a question, and with ideal student responses. Composing an ideal student response serves to ensure that the question is well-crafted and answerable within the scope of what students have learned in the instructional sequence, and can be used for development of a rubric to score student responses. This structure can be used for traditional pencil and paper assessments or for more hands-on, activity-based assessments. The example in Table 3 shows an example for one element of a performance task, linked to one bullet of the related evidence of learning specifications.

Table 3: Tool 5 - Using Evidence of Learning Specifications to Develop Performance Tasks

Alignment with EoLS	Performance Task to Address EoLs	Ideal Student Responses
EoLs 1b – Construct an explanation that predicts: Consistent patterns of types of interactions including competitive, predatory, and mutually beneficial.	Graybirds and whitebirds live on North Island. Both types of birds eat the berries of the berry bush. The seeds of the berry bush grow best after the berries are eaten by birds and dropped elsewhere around the island. Whitebirds are also found on nearby South Island. The whitebirds on South Island eat berries and	On North Island: • A predator-prey interaction between the rats and the birds (or rats are predators, bird eggs are their prey) • A mutually beneficial interaction (or mutualism) between the birds and the berries. • Competition between the two kinds of birds and

	the nuts of the nut tree. Rats are found on both islands. Berries and bird eggs are favorite foods of the rats. Predict the patterns of interactions between species on North and South Islands. Identify 3 relationships on each island. Use the words: competition, predatory-prey, and mutualism. Write a paragraph describing the relationships.	between the birds and the rats for berries. On South Island: • Rats are predators of the whitebird eggs (or rats are predators, bird eggs are their prey). • Rats and whitebirds compete for berries. • The whitebirds and berries have a mutually beneficial interaction (mutualism).

Overall, the Five Tools provide a comprehensive set of instruments that take teachers from their initial thoughts on an NGSS-aligned instructional sequence through the necessary analysis and processing required to develop a lesson sequence that supports the NGSS.

Development Process

At the outset of the project, in 2014, developing a curriculum with the necessary tools for three-dimensional learning, incorporating the disciplinary core ideas, crosscutting concepts, and science and engineering practices was a relatively new challenge and materials were sorely needed (e.g., Bybee & Chopyak, 2017; Geier et al., 2008; McNeill & Krajcik, 2009). In response, our project developed the ten-week middle school *Disruptions* curriculum unit aligned with NGSS learning goals and based on bundled performance expectations. The unit also integrated Common Core literacy and mathematics standards as called for in the NGSS. The unit addressed a bundle of performance expectations through a series of instructional sequences based on the BSCS 5E Instructional Model (Bybee, 2015). The development of the curriculum utilized the essential elements of design-based research (Cobb et al., 2003; Cobb & Gravemeijer, 2008; Collins, Joseph, & Bielaczyc, 2004; Penuel et al., 2011). Additionally, an iterative process informed by the backward design model was used for both the development and revision of the curriculum (Wiggins & McTighe, 2005). This process included three steps: 1) identifying the targeted learning outcomes (NGSS performance expectations), 2) determining the acceptable evidence of student learning in order to develop performance tasks, and 3) development of instructional sequences to provide students opportunities to learn the core ideas, crosscutting concepts, and science practices described in the three dimensions of the NGSS performance expectations. These steps were completed through the application of Tools 1 and 2 from the Five Tools and Processes, as well as elements of Tools 3, 4, and 5. Once developed, the unit was field tested by 25 New York City middle school teachers during the 2015-2016 school year. The teachers subsequently provided work from their students and significant feedback for revisions. Several curriculum experts also reviewed the unit and provided feedback. The unit underwent an extensive revision based on this feedback. This process was repeated in the 2016-2017 school year with a second set of teachers and experts. Revisions based on that feedback are underway in preparation for a final round of field testing and revisions to be completed in 2018. Table 4 that follows shows a timeline for the *Disruptions* unit development and revisions.

Table 4: *Disruptions* Project Timeline

Timeframe	Milestones
September 2014 – July 2015	• Develop first field test instructional materials • Develop first field test PD model
August 2015 – February 2016	• 25 NYC teachers field test • Expert panel review
March 2016 – July 2016	• Revise materials and PD model for second field test
August 2016 – February 2017	• 25 NYC teachers field test • Second expert review
March 2017 – July 2017	• Revise materials and PD model for final field test
August 2017 – February 2018	• 25 NYC teachers field test • Further review if needed
March 2018 – August 2018	• Final revisions to materials and PD model

In order to begin the process of developing the *Disruptions* unit it was critical to first come to a shared understanding of what the learning goals and specifications were for the unit. While SEPUP already had procedures in place for implementing a backward design process from developing previous materials, none of the project partners had experience developing extensive curricula to support the NGSS. Of the Five Tools, Tools 1, 2, and 5 provided the necessary structure for developing the learning goals and specifications for the unit, and supported the team in "unpacking" the core idea from the NGSS that was to serve as the backbone of the unit.

Our team focused on NGSS core idea MS-LS2 (ecosystem interactions, energy and dynamics). We used Tool 1 to identify and refine the learning goals for the unit based on the NGSS performance expectations and associated disciplinary core ideas, science and engineering practices and crosscutting concepts related to the NGSS core idea MS-LS2. Tool 1 essentially creates a unit blueprint, which maps out the DCIs, SEPs, CCCs, and PEs, allowing those elements to drive both the instruction and the assessment in each instructional sequence. Our work with Tool 1 resulted in a blueprint for a five-chapter unit designed to comprehensively address MS-LS2 and included the bundles of PEs shown in Table 5.

Table 5: Bundles of Performance Expectations in each unit of Disruptions in Ecosystems

Chapter	Performance Expectations
1. Wolves in Yellowstone	**MS-LS2-2:** Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
	MS-ESS3-4: Construct an argument supported by evidence for how

	increases in human population ~~and per capita consumption of natural resources~~ impact Earth's systems.
2. Ecosystem Models	**MS-LS2-3:** Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
	MS-PS1-5: Develop and use a model to describe how ~~the total number of atoms does not change in a chemical reaction and thus~~ mass is conserved.
	MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
3. Interactions between Populations and Resources	**MS-LS2-1:** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
	MS-ESS3-4: Construct an argument supported by evidence for how increases in human population ~~and per-capita consumption of natural resources~~ impact Earth's systems.
4. Zebra Mussels	**MS-LS2-4:** Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
	MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
5. Designing Solutions	**MS-LS2-5:** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
	MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
	MS-ESS3-4: Construct an argument supported by evidence for how increases in human population ~~and per-capita consumption of natural resources~~ impact Earth's systems.

Tool 1 maps out each DCI, SEP, CCC, Connection to Nature of Science, and Common Core Standards linked to the PEs. By examining the NGSS in this way we were able to determine if the PEs were bundled most effectively, and eliminate gaps or overlap between the five chapters. We were also able to determine areas of some PEs that would not be taught within the unit. The PEs associated with MS-LS2 were considered primary PEs and covered comprehensively in the unit. The associated, bundled PEs from other categories were considered secondary. For example, for Chapter 1 the PE MS-LS2-2 was bundled with MS-ESS3-4. As is shown in Table 5, some portions of the secondary PE (MS-ESS3-4) are struck through, indicating that those portions are not covered in the unit because that content did not blend as well with the MS-LS2-related PE. It was expected that this content would be covered in other units or courses in a complete middle school sequence of instruction. The completed version of Tool 1 for the *Disruptions* unit can be found at sepuplhs.org/pdfs/Five Tools_NARST_2017_Tool_1.pdf.

Once Tool 1 had been completed, the development team moved to Tool 2 to map out assessment specifications aligned with the instructional sequences identified and laid out in Tool 1. Tool 2 provides the user with a framework for identifying and articulating what qualifies as evidence for students' demonstration of proficiency in each of the associated performance expectations. We completed this process for each of the five chapters. An example of Tool 2 completed for Chapter 2 of the curriculum developed for this project can be found in Table 6.

Table 6:

Tool 2: Using Performance Expectations to Plan for Classroom Assessments

Middle School Ecology Unit **MS-LS2 Ecosystems: Interactions, Energy, and Dynamics**

Instructional Sequence 2
Performance Expectation MS-LS2-3 ***Develop a model to describe the cycling of matter and flow of energy among living and non-living parts of an ecosystem.*** *Clarification Statement:* Emphasis is on describing the conservation of matter and flow of energy into and out of various ecosystems and on defining the boundaries of the system. *Assessment Boundary:* Assessment does not include the use of chemical reactions to describe the processes. **Performance Expectation MS-PS1-5** ***Develop and use a model to describe how ~~the total number of atoms does not change in a chemical reaction and thus~~ mass is conserved.*** *Clarification Statement*: Emphasis is on law of conservation of matter ~~and on physical models or drawings, including digital forms that represent atoms~~. *Assessment Boundary*: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces. **Performance Expectation MS-ESS2-1** ***Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.*** *Clarification Statement*: ~~Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the~~ cycling of Earth's materials. *Assessment Boundary*: Assessment does not include the identification and naming of minerals.
Evidence of Learning Specifications Develop a model (build it) of an ecosystem to: 1. describe the interactions among the living and nonliving parts of an ecosystem 2. describe the interactions among producers, consumers, and decomposers in a variety of ecosystems 3. show the flow of energy and cycling of matter (Earth's materials) in an ecosystem 4. describe how matter is conserved in an ecosystem 5. describe how energy is transferred out of the ecosystem as heat

Note: Color-coding indicates the dimension of the NGSS that the word or phrase originated from - blue for SEPs, orange for DCIs, and green for CCCs. Red text denotes language from the evidence statements.

Articulating the required evidence of student learning in this way led to the development of three types of assessments for each chapter: formative assessments embedded throughout each chapter to track progress on the three dimensions, an embedded assessment in the final evaluate activity of the instructional sequence of each chapter, and an end-of-chapter summative assessment. The team started by developing the end-of-chapter assessments, in keeping with the backward design model. Each of the end-of-chapter assessments needed to assess all three dimensions associated with the PEs, as described in Tool 2. As can be seen in the example of Tool 2, for this instructional sequence the PEs map clearly to the development of a model that describes multiple DCIs and the CCC of flow of energy and cycling of matter. For the Chapter 2 end-of-chapter assessment, students developed a model of an ecosystem they had not studied within the unit. Students used their models to describe the DCIs and CCCs outlined in Tool 2, and to develop an explanation for how a disruption in the ecosystem would affect the organisms using evidence from their model. (Note that they had been introduced to the practice of explanation in Chapter 1.) As each draft of the assessment was developed, sample student answers were written. This often lead to revisions to increase clarity in the assessment questions and to better access student knowledge about individual points articulated in the evidence of learning specifications. While Tool 5 was not explicitly used in this process, the outcomes were similar to what they would have been using the scaffold of Tool 5. A copy of the Chapter 2 end-of-chapter assessment can be found in Appendix 1. A more detailed description of the use and revisions of the assessments has been reported on elsewhere (MacPherson et al., 2017).

After completion of the end-of-chapter assessments a clear framework was in place to allow the unit development to proceed. The elements of Tool 3 (anchor phenomena, guiding questions, etc.) were developed and revised in tandem with each chapter, as opposed to using the structure of Tool 3. Similarly, the elements of Tool 4 – more developed descriptions of student activities and teacher facilitation – were developed during the process of writing the student book and teacher's guide and not using the specific structure of Tool 4. A selective description of the iterative development process is described in Willcox, Nagle & Jackson, 2017.

Development Outcomes

The first full draft of the curriculum was field-tested by a group of 25 middle school science teachers in New York City during the 2015-2016 school year. During that same time period the unit was thoroughly reviewed by an expert advisory panel. Feedback from these groups was used to extensively revise the unit. During the revision process, we revisited Tools 1 & 2 to further inform this phase of the development process. Revisiting these tools, along with the feedback we received, allowed us to refine the alignment of the curriculum and assessments to the NGSS. This process was repeated for the second year of field testing (2016-2017 school year), and will be repeated one more time for the third year of field-testing (2017-2018 school year) to develop a final draft of the unit (summer/fall 2018). Each year the field test teachers also received extensive professional development, described in Kastel & MacPherson, 2017.

After the final round of revisions, the full unit including student and teacher materials, will be made publically available for use in classrooms and as a model for the development of NGSS-aligned curricula (anticipated completion in Fall 2018). It is the aim of this project that the work produced be a critical tool in helping classroom teachers, education researchers, and curriculum developers further their understanding of the complexities of implementing the NGSS.

Conclusion

Developing curriculum materials based on cohesive-instructional sequences is a complex task. Planning sequences that also incorporate the three dimensions of the NGSS adds many additional layers of complexity. The Five Tools provide an important support to teachers and developers who are attempting to develop NGSS-aligned curricula. Their implementation is flexible depending on the needs of the end-user and the products being developed. Tools 1 and 2 are particularly useful for a broad range of planning needs. The full implementation of Tools 3, 4, and 5 is appropriate for many users. Elements of these tools are helpful even for those who are not developing instructional sequences that use the 5E instructional model.

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Appendix 1:
Disruptions in Ecosystems Chapter 2 End-of-Chapter Assessment

Name ____________________

Chapter 2 Assessment

1. The tables below lists organisms in a grassland ecosystem.

- In the box on the next page, **draw a model of this ecosystem** that shows the cycling of matter.
- Use arrows to show how **matter** moves between organisms in the ecosystem.
- Write a caption below your model that explains how matter cycles in the ecosystem.

Biotic components for your model:

Make a check mark if it is in your model	Organism	What It Eats
	Grass	Makes its own food
	Grasshoppers	Grass
	Garter snakes	Grasshoppers
	Eagles	Garter snakes
	Decomposers (mold/bacteria/fungi)	Dead and decaying organisms

Abiotic components for your model:

Make a check mark if it is in your model	Component
	CO_2 (carbon dioxide) in air
	H_2O (water)
	Soil

Name ______________________________

Ecosystem Model (Version B)

Caption:

____

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____

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Name ______________________________

2. Suppose there was a large volcanic eruption and a thick cloud of ash blocked most sunlight from reaching the ecosystem for several months. Use the model you made in Part 1 to construct an explanation for what would happen in the ecosystem.

Construct a complete scientific explanation that answers the question, "How would an ash cloud from a volcano affect the *cycling of matter* in the ecosystem?"

Your explanation should include the following:

- The scientific question
- Your claim
- The relevant evidence that supports your claim (use evidence from your model)
- The science concepts that support the evidence
- Your scientific reasoning that links the evidence and science concepts to the claim

Name SAMPLE STUDENT RESPONSE

Chapter 2 Assessment

1. The tables below lists organisms in a grassland ecosystem.

- In the box on the next page, **draw a model of this ecosystem** that shows the cycling of matter.
- Use arrows to show how **matter** moves between organisms in the ecosystem.
- Write a caption below your model that explains how matter cycles in the ecosystem.

Biotic components for your model:

Make a check mark if it is in your model	Organism	What It Eats
	Grass	Makes its own food
	Grasshoppers	Grass
	Garter snakes	Grasshoppers
	Eagles	Garter snakes
	Decomposers (mold/bacteria/fungi)	Dead and decaying organisms

Abiotic components for your model:

Make a check mark if it is in your model	Component
	CO_2 (carbon dioxide) in air
	H_2O (water)
	Soil
	Sun

*[The answers for questions 1 are shown on the **model page**.]*

Name ______________________

Chapter 2 Assessment

2. Suppose there were a large volcanic eruption and a thick cloud of ash blocked most sunlight from reaching the ecosystem for several months. Use the model you made in the first three questions to construct an explanation for what would happen in the ecosystem.

Construct a complete scientific explanation that answers the question, "How would an ash cloud from a volcano affect organisms and the transfer of matter and energy in the ecosystem?"

Your explanation should include the following:

- The scientific question
- Your claim
- The relevant evidence that supports your claim (use evidence from your model)
- The science concepts that support the evidence
- Your scientific reasoning that links the evidence and science concepts to the claim

The scientific question is, "How would an ash cloud from a volcano affect organisms and the transfer of matter and energy in the ecosystem?" An ash cloud from a volcano would make many organisms in the ecosystem die. The energy that flows through the ecosystem comes from the sun. Plants use light from the sun to make glucose, and then herbivores eat the plants for the energy. But if the light from the sun is completely blocked, then plants cannot photosynthesize and will die. The herbivores (rabbits and grasshoppers) would lose their food source. If the herbivores die, then the consumers (rabbits, snakes and eagles) would die as well, because they would not have any food. By blocking the sun, the ash cloud stops the flow of energy and transfer of matter into the biotic component of the ecosystem.