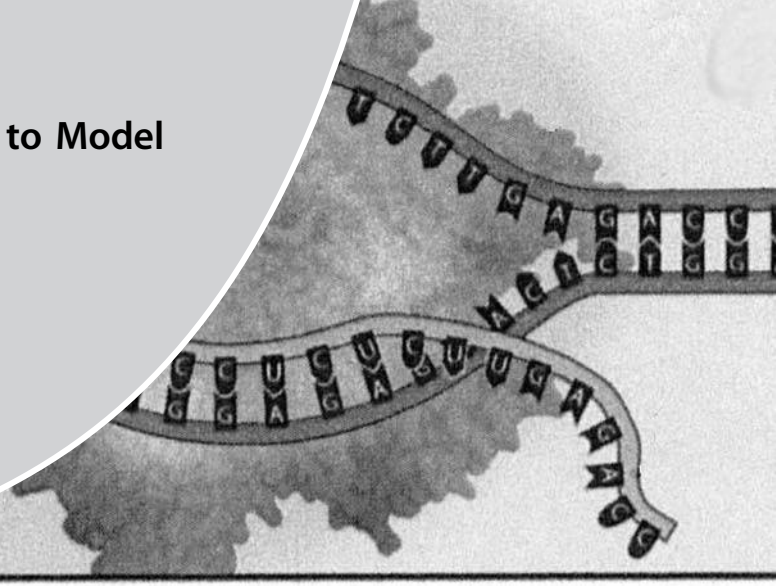
TIPS, TRICKS & TECHNIQUES

Using Storyboarding to Model Gene Expression



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Abstract

Students often find it challenging to create images of complex, abstract biological processes. Using modified storyboards, which contain predrawn images, students can visualize the process and anchor ideas from activities, labs, and lectures. Storyboards are useful in assessing students' understanding of content in larger contexts. They enable students to use models to construct explanations, with evidence to support hypotheses – practices emphasized in the Next Generation Science Standards (NGSS). Storyboards provide an opportunity for performance assessment of students' content knowledge against a backdrop of observing patterns, determining scale, and establishing relationships between structure and function – crosscutting concepts within the NGSS framework.

Key Words: *Central Dogma; storyboarding; performance assessment; Next Generation Science Standards; transcription; translation; DNA; gene expression; heredity.*

Introduction

Biology courses often challenge students, from middle school through college, with complex interconnected ideas and unique vocabulary that may pose barriers to students' understanding of biological processes. Students are frequently asked to simply identify and repeat meanings of terms in assessments. Exercises like these often result in students' inability to situate individual concepts into a larger, relevant, and scaled framework that demonstrates the relationships of the content in contextual environments (Hyerle, 1996; Korb, 2009; Duncan et al., 2011). In a practice we call "modified storyboarding," students are given preprinted images as visual scaffolds for anchoring science terminology (rather than creating storyboard frames or images themselves from scratch, either digitally or by drawing). Engaging students in modified storyboarding can help place difficult termi-nology and processes in a larger context, providing them an opportunity to develop the "big picture." Furthermore, storyboarding enables students to use models to construct an explanation that uses evidence to support a hypothesis – practices emphasized in the *Next Generation Science Standards* (NGSS). The related performance assessment measures students' content knowledge against a backdrop of observing patterns, determining scale, and establishing relationships between structure and function – all crosscutting concepts within the NGSS framework (Table 1).

Engaging students in modified storyboarding can help place difficult terminology and processes in a larger context.

Modified storyboards also provide a low-tech, accessible strategy for students to use difficult terminology while constructing explanations and supporting hypotheses with evidence from classroom activities and readings. Storyboarding and the use of computer-aided animations are strategies that have been reported in chemistry and biology education (Schank & Kozma, 2002; Songer, 2006) to contextualize complex processes. We have found little published in the literature regarding this particular use of *modified storyboarding* in the biological sciences, especially in non-science-major courses or at middle and high school levels. Although graphic organizers or advance organizers (Ausubel, 1963) are not new techniques in anchoring complex concepts, we present an updated perspective on their use as framed by the practices and crosscutting concepts outlined in the NGSS framework as a way for educators to develop and use storyboards as a type of performance assessment.

Students often struggle to understand individual genetics concepts (Deadman & Kelly, 1978; Moll & Allen, 1987; Lewis et al., 2000; Williams et al., 2012) and to connect the relevance of these individual biological concepts to the "big picture." While the practice of storyboards can be applied to a myriad of topics within biology, we will focus here on the concept of gene expression, with the sample storyboards reflecting specific topics connected

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Table 1. Summary of applications of modified storyboards to *Next Generation Science Standards* Science and Engineering Practices and Crosscutting Concepts (CCC) (NGSS Lead States, 2013; National Research Council, 2012).

Practice/Concept	Application to Storyboards
Asking questions	Storyboards can be used to facilitate questions that drive science and engineering. For example, "Why and how are certain life- threatening genetic conditions passed on?" (science) and "What can be done to improve the quality of life for affected individuals?" (engineering).
Developing/using models	Method of modeling a process and integrating facts, ideas, concepts, and events. Students add to or improve the model on the basis of additional facts or events that they discover or experience.
Constructing explanations	Students write, discuss, and provide clear evidence for their rationale in placing frames in the order that they do and using terms properly, based on evidence from class activities.
Communicating information	A familiar visual strategy (graphic organizer) where students are given preprinted visuals that allows them the cognitive space to interpret images, notice patterns or relationships between events in a process or interactions between various molecular structures, and anchor their prior and newly gained knowledge to these images without the stress of having to draw them.
CCC: Patterns	Students are given the opportunity to see patterns in the reactions between molecules and cell structures. The frames also scaffold the schema of size and the scale of cells and macromolecules.
CCC: Cause and Effect	Students can add to their story of gene expression by predicting and explaining events in a new context. For example, what might be the effect of inserting some "disturbance" in the system (e.g., mutagen, virus, or disease state)?
CCC: Systems/ System Models	A single storyboard may serve as a model to represent a linear process (gene expression), which can then be connected to other larger components (inheritance patterns) of a system (organism).
CCC: Structure and Function	Storyboards can be used by students to link the idea of structure and function to cause and effect by placing together various events and details in a larger process in order to make those connections (evolution/adaptation).
CCC: Stability and Change	Students can be asked to identify the aspects of the system that allow for stability in passing on genetic characteristics.

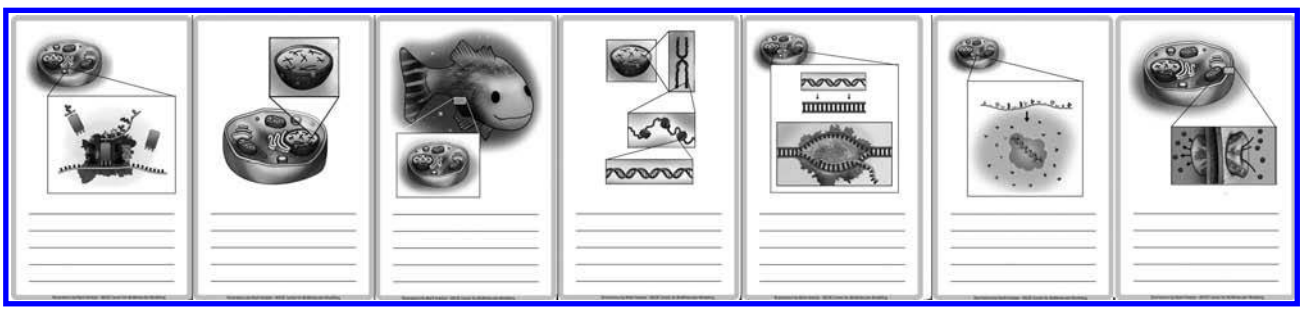

Figure 1. Predesigned storyboard frames are given to students in random order. A scientific illustrator on our team designed these images. Images can also be obtained from the Internet, stock photos, or textbook supplemental materials, or generated using online storyboarding programs.

within the larger idea of gene expression and inheritance. The storyboards, pictures, and an area for text (Figure 1) allow students not only to describe the structure and function of a cell's components, but also to document evidence from classroom experiences that support their knowledge of process in gene expression.

Methods

Students, individually or in pairs or groups, are given the storyboards as a set of cards in a random order at the start of a unit on the flow of genetic information, or the "Central Dogma." As shown in Figure 1, the cards have an image on the top and lines for

comments underneath the image. Students can be given a list of terms, which may vary depending on prior knowledge or the detail and depth at which the topic will be covered. For example, with the "gene expression" set of storyboards, students are given the terms *water*, *protein*, *amino acid*, *DNA*, *RNA*, *transcription*, *translation*, *cell membrane*, *nucleus*, and *chromosome*. They are asked to use these terms in their initial (prelesson) labeling of the events and structures involved. Then they arrange the storyboards in an order that makes sense to them, based on the content of each picture and their prior knowledge. In the comments section of the card, students are asked to identify patterns or find commonalities from one picture to the next. The activity may begin as an individual or small-group process, or it can be initiated as a whole-class discussion to determine prior knowledge. Depending on the level of prior knowledge, the teacher may want to assist students in noticing some of the "players" in the story and point out some clues as to what might be happening in the frames. Students are then directed to write their labels on the picture sets and write a short description or any "I wonder . . . " questions in the spaces below each picture. One aim of this activity is to move students beyond just taking notes on a visual scaffold; it should engage them in discourse regarding the connections between ideas covered in class activities and readings and the process shown in the storyboard sequence. Students may also challenge the order of the sequence and provide more evidence (additional frames) based on new ideas learned.

We have observed that students arrange the storyboards in a myriad of sequences, from linear arrangements to groups of related pictures. Figure 2 shows a sample set of cards a student group created in a middle school classroom. At the end of the prelesson labeling process, the instructor facilitated a general class discussion of the various options of sequences created, indicating where these sequences are situated in larger settings (inheritance of traits) or connect to previous concepts (molecular structure, cell structure and function) or contrast with other processes (mitosis/meiosis).

Students can revisit their storyboard frames any time new content is covered to revise comments and labeling. For example, a teacher might lead the class through an activity on DNA replication, providing the students with more information about the topic. The teacher could then ask where or if these concepts fit into the story.

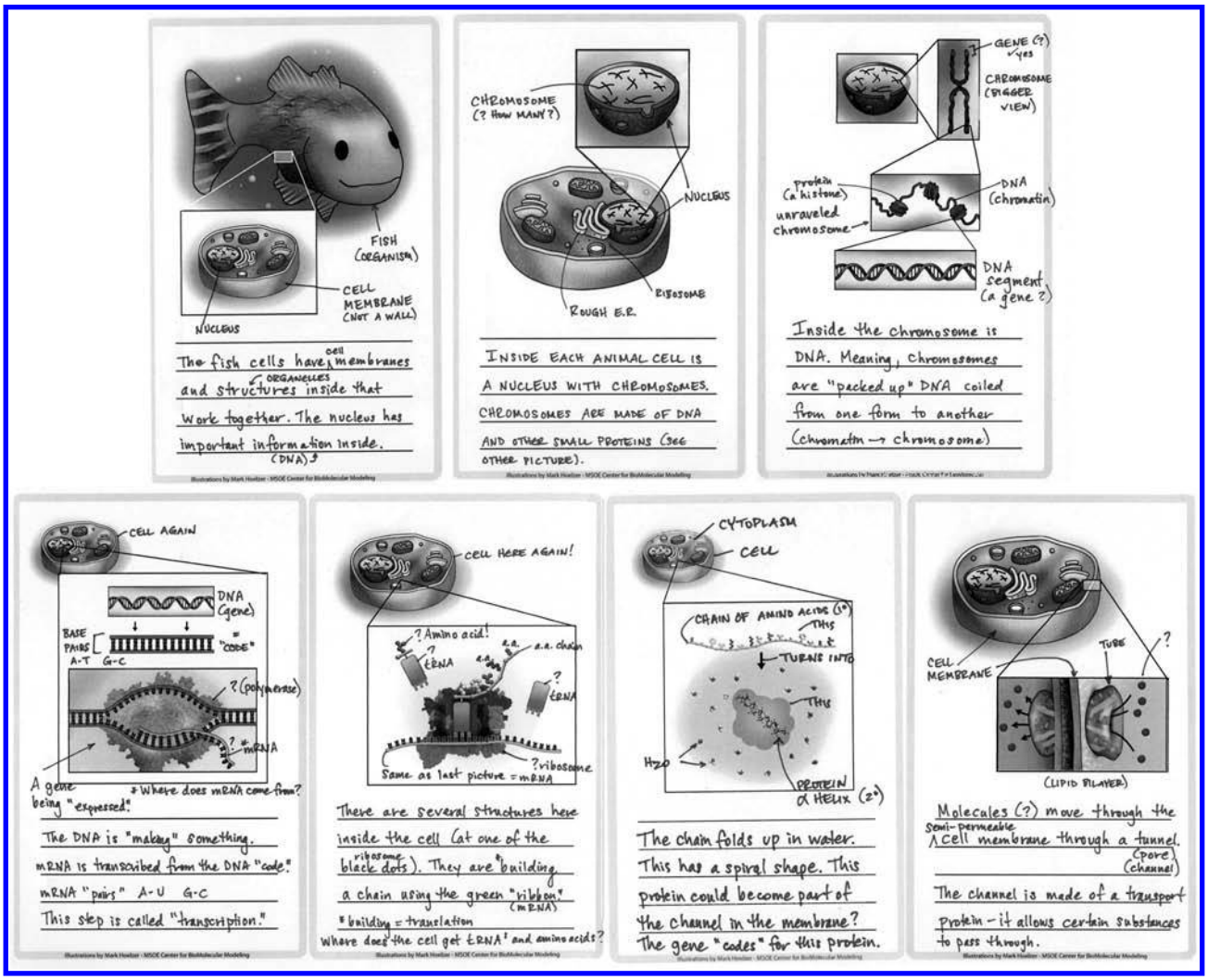

Figure 2. Sample student grouping (top three images: hierarchy of structure) and sequence (bottom four images: process of gene expression) of frames as a possible iteration of a "story" or description of cell structure and scale along with protein synthesis. Two sets of comments are used to show pre-lesson (plain writing) and post lesson (writing in boxes) additions to the frames. Some phrases indicate questions student may have to be answered later or included in their own additional frames to the "story." Original storyboard frames are in color.

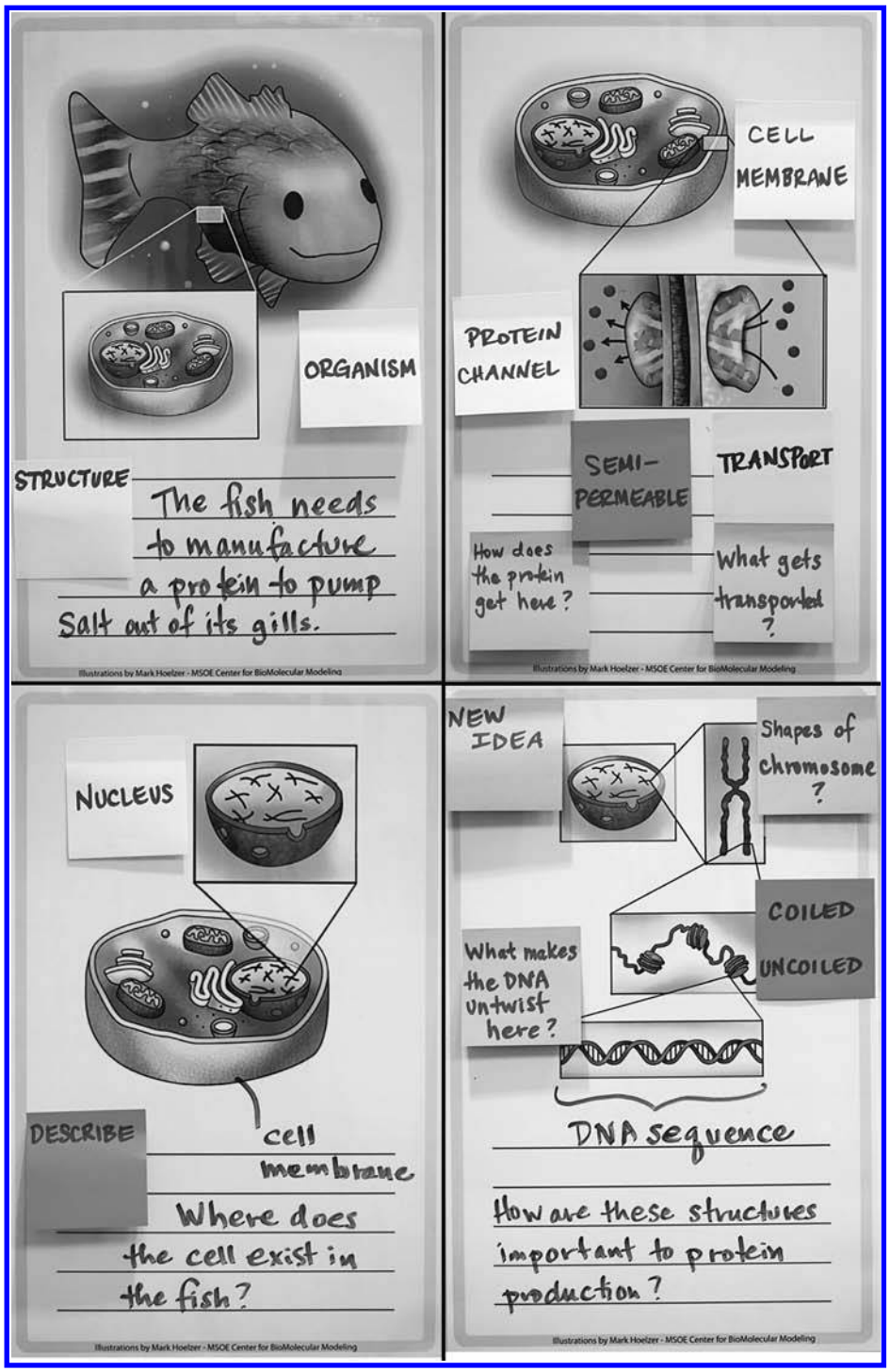

Figure 3. Poster-size images with phrases, questions, and sticky notes to indicate structures, processes, new ideas, and descriptions can be used to anchor class discussions at any point along the process of tying concepts together. Prompting students to ask questions in order to improve their own storyboard sequences assists them in creating new models and organizing concepts.
Figure 3 continued on next page.

The opportunity to revise the storyboard frames as new knowledge is gained enables the students to make connections between the details and larger processes. Students can also be encouraged to identify patterns within the frames, allowing practice in incorporating crosscutting concepts. As an extension activity, we have also posted larger versions of the storyboard frames in the classroom (Figure 3) to illustrate the different groupings students have developed. We asked them to discuss differences and whether the groupings are supported with accurate evidence from lectures, readings, and activities.

Students may be given laminated cards with dry-erase markers or paper versions on which they can write with various colors

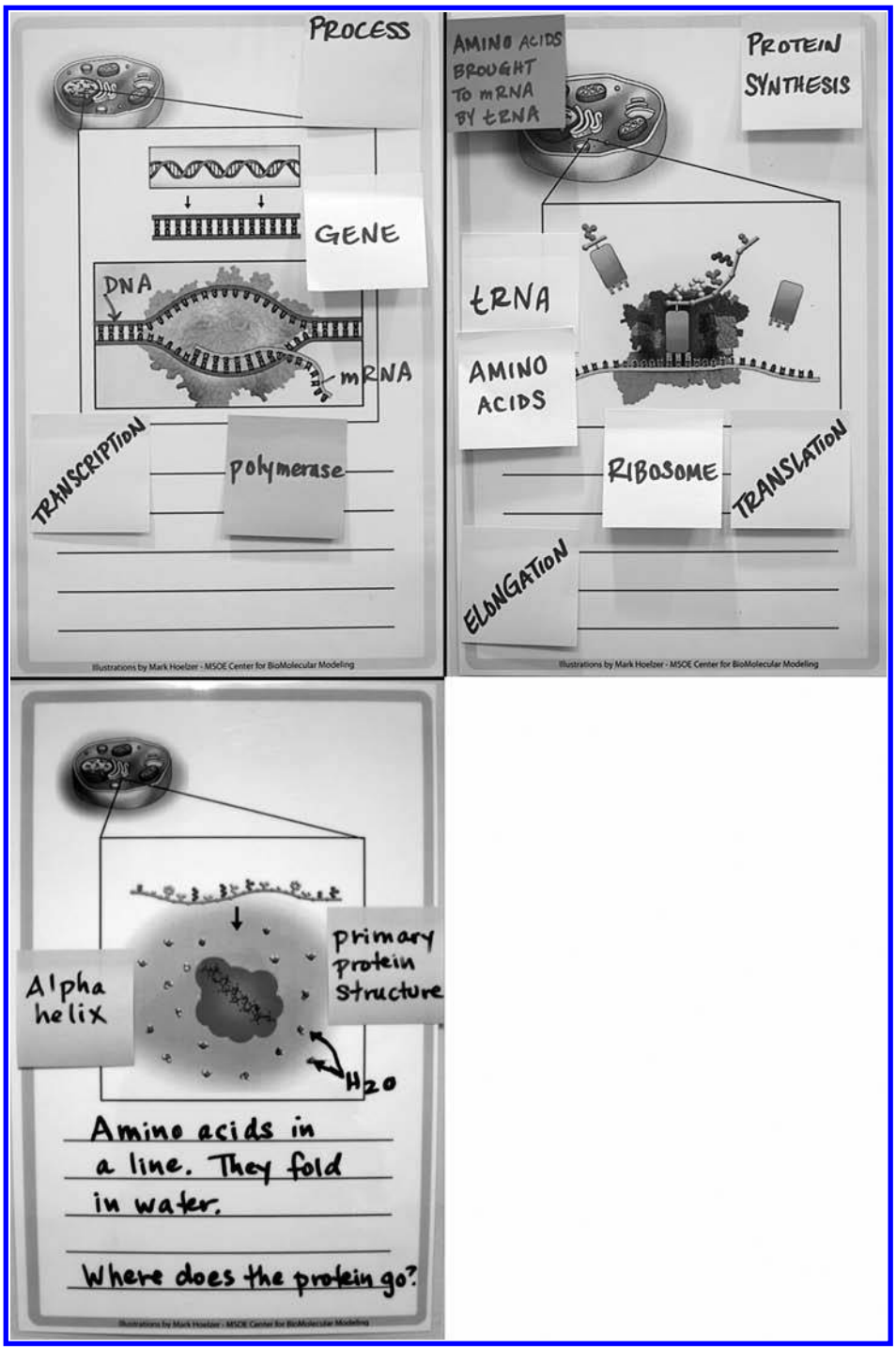

Figure 3. (*continued*) Poster-size images with phrases, questions, and sticky notes to indicate structures, processes, new ideas, and descriptions can be used to anchor class discussions at any point along the process of tying concepts together.

representing the addition of new information and new evidence from activities, reading, or laboratory experiments. We find that students and teachers prefer the paper versions. If technology is available (there are various free online storyboarding programs), digital versions of the storyboards could be used in the classroom as well, to map learning or as an alternative assessment option. Teachers may have the students keep their own storyboards in a notebook or journal, or leave them in a class folder file for use in class each day or week. The laminated versions have been used most commonly as a reusable resource with teachers in preservice and in-service professional development.

○ Assessment Practices

The use of modified storyboarding is a great example of a performance assessment, which is emphasized in the NGSS. We have assessed students' understanding through their ability to (1) use

the pictures to model/tell a story using terminology appropriately; (2) show a change in their understanding of the "story" itself as their knowledge expands; and (3) apply the situation to a novel scenario or make new connections to related concepts. The cards can serve as either a formative or a summative assessment. Postassessment can occur after any set of concepts has been covered. Teachers may decide on the nature of the assessment (summative or formative) that is appropriate for their students.

Using these storyboards as an assessment tool, teachers can document students' accurate use of terms; ability to assimilate new content; shifts in understanding of concepts (i.e., identifying their own misconceptions and correcting them via evidence from activities, readings, etc.); use of questions that demonstrate movement from simple use of terms to making connections between terms, ideas, events, and processes; and application of ideas to novel scenarios.

A possible extension activity is to incorporate an example of a mutation within the storyboard. For instance, a student could explore cystic fibrosis, in which a 3-base-pair deletion from the CFTR gene (cystic fibrosis transmembrane conductance regulator) results in a protein that is missing a phenylalanine residue at position 508. This gene encodes for a chloride channel, and the 3-base-pair deletion results in a nonfunctional chloride channel, which leads to the signs and symptoms associated with cystic fibrosis. This also deepens the possibility of assessing students' ability to apply knowledge to a new context. Using the modified storyboards presented here, students could indicate the connection between genes and proteins, which results in a nonfunctional protein (as seen in the storyboard with the ion channel illustrated). In performing this exercise, students are asking questions, developing models, constructing explanations, and communicating their newly gained knowledge in such a way that allows them to identify patterns and to see the causes and effects of mutations.

○ Conclusion

By using modified storyboards, students can make connections between content learned in a specific lesson and a more complex biological process. Building an understanding of the relationships between topics such as genes, heredity, and protein synthesis is a complex process, one that is often further complicated by covering material over a number of months within the classroom, or over several chapters in a textbook (Duncan et al., 2011). With individual, predesigned frames depicting stages of a biological process in front of the learner in one space (i.e., their desktop or classroom), students can organize these frames to facilitate their efforts to make connections between individual activities and a bigger picture by actively engaging in discourse. Students who are engaged as authors of their ideas are more likely to contribute to discussions about a topic (Greeno, 2006) and can transfer their knowledge to larger conversations across a variety of activities over time (Engle et al., 2011). The storyboards create a "touchstone" that can be revisited, revised, and restructured over a period of months as various topics are covered. Storyboards provide a low-tech setting to make concept accessible to students and provide a performance assessment option.

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