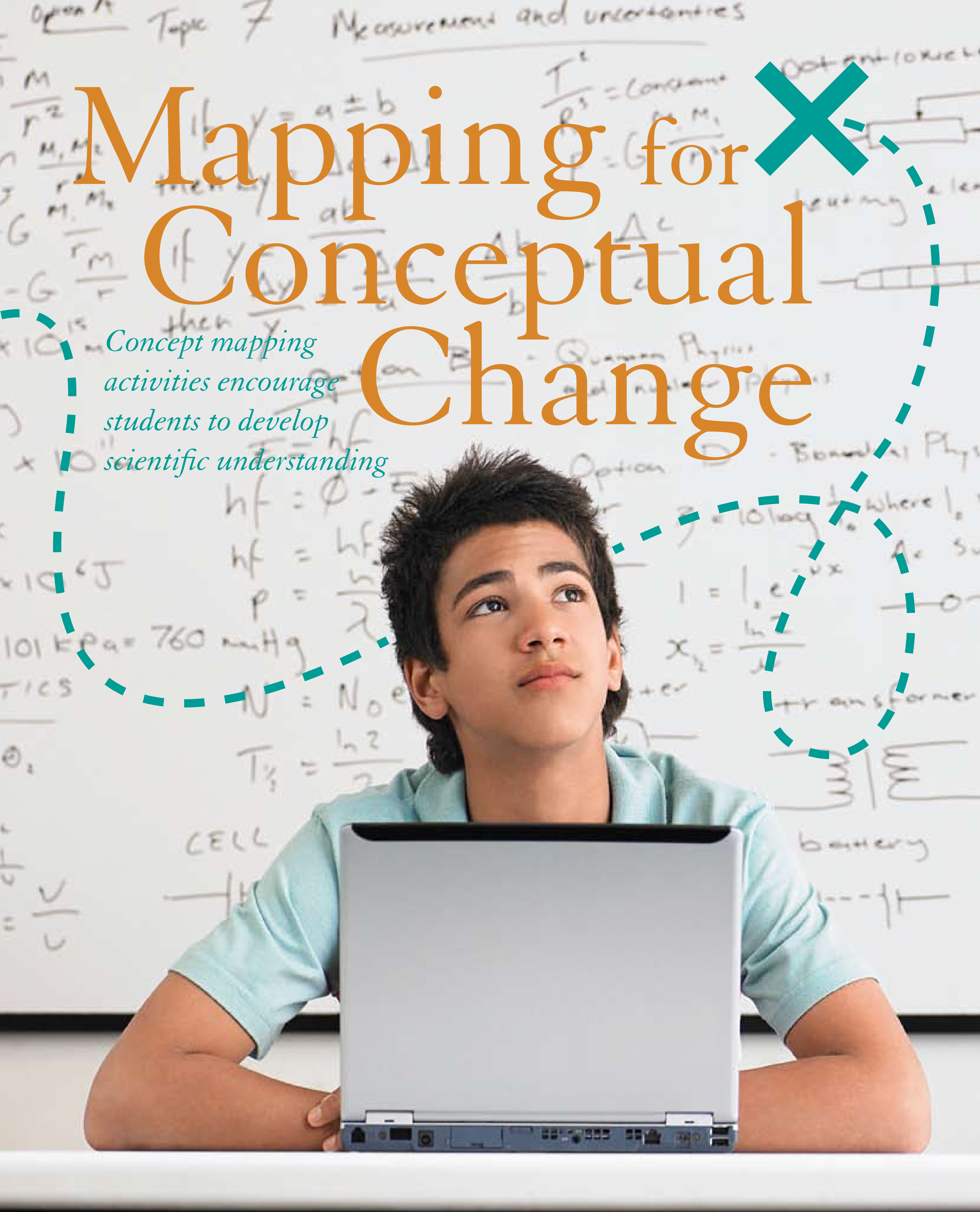
Mapping for Conceptual Change

Concept mapping activities encourage students to develop scientific understanding



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Students' understanding of science develops through everyday experiences—as a result they come to the science classroom with their own notions of how the world works. As teachers, we often must help students overcome their prior naive notions and move them toward a more scientific understanding. This process, known as conceptual change, is fundamental to student learning. It can be aided with strategies designed to help students rationalize their perceptions in light of accepted scientific understanding. This article outlines one such strategy: a process of recursive concept mapping we call "mapping for conceptual change."

A process of teaching and learning science

Conceptual change theory describes a well-established learning process (Duit 2003). The basic tenet of this theory is that humans develop strongly held notions about science that are not consistent with accepted scientific understanding. As a result, formal science learning must involve a process of addressing and reforming these ideas (Posner et al. 1982). Teachers need to help students identify their existing ideas and modify them based on scientific knowledge. National and state standards documents and adopted district curriculum are the vehicles for communicating the nature and structure of accepted scientific understanding, and assessments measure a student's ability to articulate and discern that understanding.

For students to experience conceptual change, they must first become dissatisfied with their prior understanding. An appropriate instructional strategy involves presenting an alternative idea that is consistent with accepted scientific understanding. To be considered successful, students must be able to properly apply their new science knowledge to a novel situation. For example, a student can use new understanding of natural selection to predict the consequences of removing an organism from a specific ecosystem.

Metacognition, the act of thinking about one's own thinking, is a critical component in the conceptual change process. Recursive concept mapping, which involves building on and restructuring the same concept map over time, can scaffold this change by providing an avenue for representing and evaluating students' thinking.

A conceptual workbench

Concept maps, graphic organizers that show connections among ideas, are thinking tools that can offer insight into how a student identifies relationships among science concepts. In a relatively short period of time, teachers can glean the following by viewing student concept maps: prior knowledge, misconceptions, and the acquisition and accommodation of new knowledge as maps are modified over time. The information derived from analyzing student concept maps can be used to tailor lessons to the immediate needs of students, resulting in a richer, more meaningful science learning experience. Students who are trained to think about their thinking (i.e., to be metacognitive) can use the process of concept mapping to identify how their ideas are similar and different from accepted scientific knowledge (Novak 2002). Recursive concept mapping affords them the opportunity to evaluate and restructure their evolving understanding of science. In our classrooms, concept maps provide a workbench for conceptual change.

The instructional process

Successful mapping for conceptual change requires a trusting classroom culture that encourages discussion and reflection. For the process to work, students must feel comfortable expressing their ideas and engaging with experiences intended to change those ideas. Using conceptual change-based instruction, intellectual growth occurs as a result of the partnership between students adjusting their understanding and teachers scaffolding the experience with feedback.

In our classrooms, mapping for conceptual change typically involves a series of four formal activities, as described in Figure 1 (p. 34); the content of a unit dictates the strategic location of each activity. Using computers at school and at home, students apply a list of provided concepts to create a series of personal concept maps, annotating and revising the same basic map over the course of the four activities, and saving a copy of each revision for the teacher to review. Students construct these maps using an open-source software called CmapTools (IHMC 2008), which can be freely downloaded (see "On the web" at the end of this article). When comparing maps over time, the changes demonstrated can provide insight into the conceptual growth of each student. The following examples were created from student work in a unit on evolution to illustrate the four formal mapping activities. (**Note:** Figures 3–6 [p. 35–38] show examples of student work for each activity.)

Concept mapping activity 1

The first mapping activity in the series is meant to elicit prior knowledge. Students are provided with a concept bank, which is a list of the major concepts for the pending unit chosen from the curriculum materials. We typically provide between 10 and 20 concepts in the concept bank (Figure 2, p. 35).

Our process for the first mapping activity follows a specific set of rules. A fixed concept bank is provided in advance, and concepts can only be added to the bank after whole-class approval. (**Note:** For example, concepts such as "evolution" and "common ancestor" were added as new conceptual understanding developed.) In addition, concepts can only be linked if a linking phrase is provided—arrows between concepts without a label are not permitted. For example, a correct linkage would be "analogous structures" are *evidence of* "convergent evolution." Concepts for which linking phrases cannot be provided are not deleted, but rather moved to the edges of the map for later inclusion once a relationship becomes known. Applying only their present knowledge, students use the concept bank to create their first map (Figure 3). Students work collaboratively to generate concept maps in large and small groups, but each student is responsible for generating his or her own map.

Because teachers use what they see in the maps to design the unit of instruction, students must be encouraged to generate a thorough and accurate representation of their thinking. This activity lays the groundwork for a powerful learning situation based on the conceptual needs of students. Over time, students come to understand that the better they understand their prior knowledge—whether it is correct or not—the better chance they have of learning and understanding new material.

From the perspective of the classroom teacher, the map depicted in Figure 3 suggests that the student lacks accurate scientific understanding about fitness, competition, natural selection, speciation, and descent with modification. The student is trying to connect evolution to previously taught units on genetics and biochemistry through the concepts of variation, homologous structures (confused with homologous chromosomes), and biochemistry, but many misconceptions are apparent.

Concept mapping activity 2

The second mapping activity occurs at a natural break in the unit, and students evaluate their first concept map in light of new learning. Students save and evaluate a copy of each map to journal their progress toward conceptual change. This evaluation is an essential meta-

FIGURE 1

Four activities used in mapping for conceptual change.

	Relative time	Emphasis of experience	Role of teacher
Concept mapping activity 1	Prior to starting a new unit	• Survey of prior knowledge	• Identify misconceptions and naïve understandings • Identify correct science understanding • Develop unit of instruction based upon student needs • Facilitate student-led whole- and small-group discussion
Concept mapping activity 2	Natural break in the content	• Dealing with strength of prior knowledge • Incorporating new science understanding into existing science conceptions	• Identify persistent misconceptions • Identify new misconceptions • Evaluate and reflect on instruction • Tailor instruction to student needs • Facilitate student-led whole- and small-group discussion
Concept mapping activity 3	Next natural break in the content	• Strong emphasis on restructuring prior knowledge • High cognitive and metacognitive engagement	• Continue to identify misconceptions and evaluate and reflect on instructional practices • Facilitate student-led whole- and small-group discussion
Concept mapping activity 4	Completed and turned in on the day of unit exam	• Demonstration of a conceptual understanding	• Assess for scientific understanding • Assess for key concept relationships • Evaluate for conceptual change

FIGURE 2

Concept bank.

Adaptation	Homologous structures
Analogous structures	Limited resources
Carrying capacity	Limited survival
Change in population	Natural selection
Competition	Origin of variation
Convergent evolution	Overpopulation
Descent with modification	Speciation
Divergent evolution	Species
Fitness	Variation is inherited
Genetic variation	Vestigial structures

cognitive process that encourages students to restructure their conceptual framework. The second concept map (Figure 4, p. 36) is the most critical for teacher feedback because students are dealing with two crucial factors: the strength of their prior knowledge and the process of incorporating new scientific understanding into their conceptual framework.

In the evolution unit we typically use in conjunction with this activity, students complete four inquiries that are used to develop an understanding of the evidence for evolution, including a comparative-structures lab and a comparative-genetics activity. The inquiries each take approximately five days to complete and concept maps are due two days after the completion of each segment. The sixth day is spent in small- and whole-group discussion focused on understanding as represented in the maps. Teacher and student feedback provided during the discussion can be used to change individual maps. The recursive loop of mapping, discussion with feedback, and reflection functions as a workbench for conceptual change.

FIGURE 3

Concept mapping activity 1: Naïve understanding.

This example represents the student's most naïve understanding and lays the groundwork for future conceptual change. Some linkages are inaccurate and will be modified as conceptual change occurs. (**Note:** Color added by authors to illustrate key elements.)

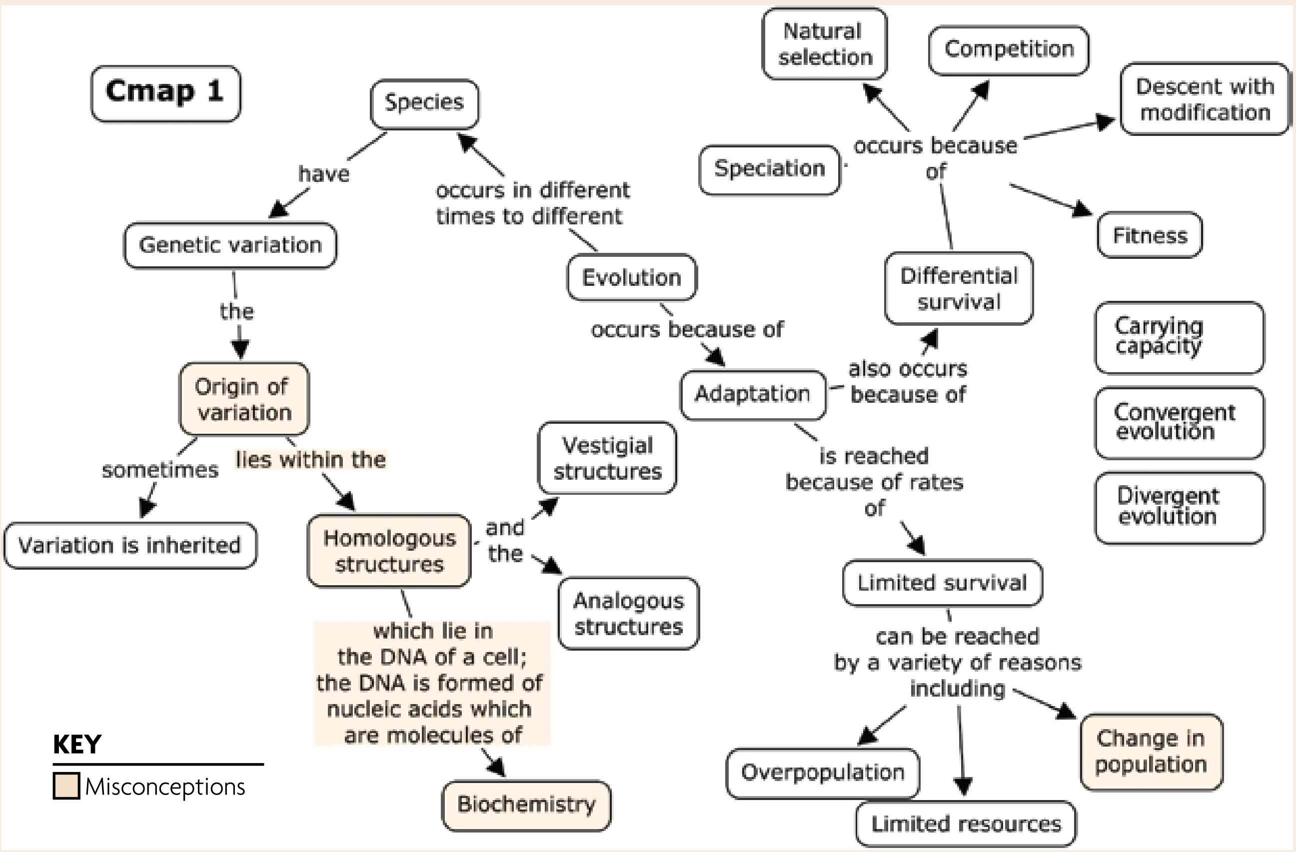
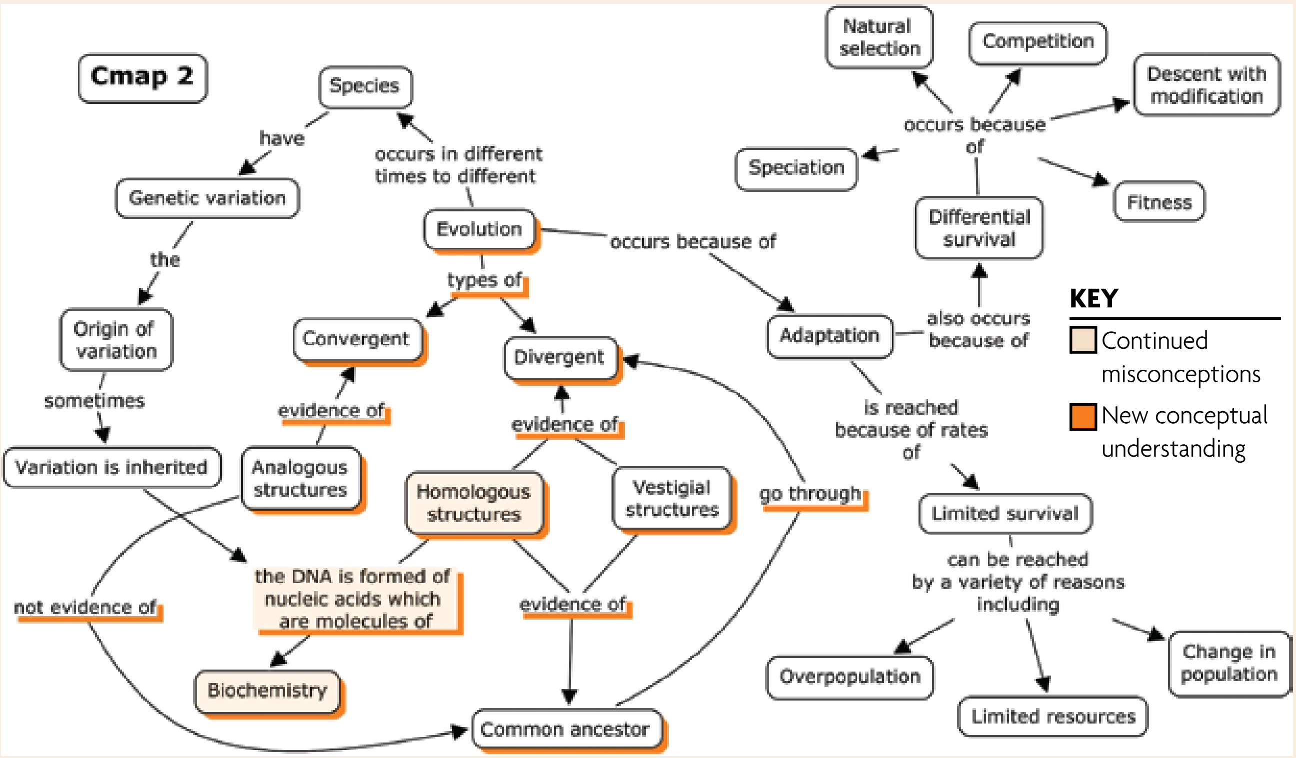


FIGURE 4

Concept mapping activity 2: Developing understanding.

In this example, new conceptual understanding has occurred, but some misconceptions remain. A few linkages are inaccurate and will be modified as additional conceptual change occurs. (**Note:** Color added by authors to illustrate key elements.)



Within their small groups, students compare maps to find similarities and differences. This can be quite an amazing process to watch, and it is not uncommon to see students illustrating their points by drawing a concept map in the air with their hands. Students cite examples from previous lessons, draw on prior knowledge, and work through examples they believe will help members of their group better understand the concepts. As facilitators, teachers closely monitor the discussions to help ensure that misconceptions are not being propagated. When a misconception is identified, it is best to bring the entire class together to address the idea.

Important changes in understanding are illustrated in the noticeable structural differences between the concept maps in the first (Figure 3, p. 35) and second (Figure 4) mapping activities. Color has been added to the example student maps to illustrate key elements for teachers to understand student progress and provide feedback. The second map suggests that the student has gained a good understanding of the relationship between the evidence and types of evolution. Restructuring of the conceptual framework is evident, yet a persistent misconception related to homologous structures and biochemistry remains. This is likely an issue of vocabulary and can be addressed through teacher feedback for the class as a whole or in a one-on-one conversation.

Concept mapping activities 3 and 4

The third and fourth concept mapping activities are facilitated with the same process used for the first and second map. The third concept map (Figure 5) suggests that the student is beginning to piece things together, but cannot grasp the connectedness of the overall picture of evolution. In addition, the concept of change in population is represented in the total number of individuals in the population rather than at the genetic level. This is a common misconception and can be addressed in a whole-group discussion following a laboratory activity on the Hardy-Weinberg principle, which demonstrates the change in allele frequency when a phenotype is subjected to selective pressures. In the third concept map, the student demonstrates a limited understanding of the interrelationships among the following concepts: overpopulation, competition, limited resources, carrying capacity, limited survival, and change in population. The structure is linear, the linking phrases are simple, and there is only one interrelationship indicated.

The fourth and final concept map (Figure 6, p. 38) has a nonlinear structure with multiple interrelationships and meaningful linking phrases, indicating a more robust conceptual understanding. This map demonstrates that the student has achieved true conceptual change and a significantly more accurate view of evolution.

Assessment

Assessing these conceptual change activities includes formative and summative elements. The first three maps (Figures 3–5, pp. 35–37) serve as formative assessments that can be assigned completion and effort grades. The final concept map (Figure 6) is a summative assessment due on the same date as the unit exam—this serves as a test preparation strategy in which students use their map as a study tool. Many factors should be considered when grading the final map, including: the complexity of the map, existence of key linkages, and the quantity and quality of linkages (Vanides, Yin, and Ruiz-Primo 2005). The University of Minnesota has created a useful rubric for assessing concept maps that can be found online (see "On the web").

When evaluating the final concept map for conceptual change, it is important to pay particular attention to how students have restructured their thinking. Mapping for conceptual change involves recognizing—holistically—that a student has moved toward a more scientific understanding. When assessing a concept map in this way, we address such questions as:

- Has the student overcome persistent misconceptions?
- Did the change in thinking over time build upon previous knowledge, or did restructuring of conceptual understanding occur?
- When reading the final concept map, at what level does the student demonstrate his or her scientific understanding: little or no scientific understanding, emerging scientific understanding, or conceptual scientific understanding?

Students can have errors on their maps and still display an acceptable conceptual understanding. For teachers, the biggest question to consider when evaluating the series

FIGURE 5

Concept mapping activity 3: Further developing understanding.

In this example, additional changes in conceptual understanding have occurred, but some misconceptions still remain. A few linkages are inaccurate and will be modified as conceptual change continues to occur. The student was unable to meaningfully identify relationships among some concepts and opted to set these concepts (i.e., descent with modification, natural selection, speciation, fitness, and differential survival) aside. (**Note:** Color added by authors to illustrate key elements.)

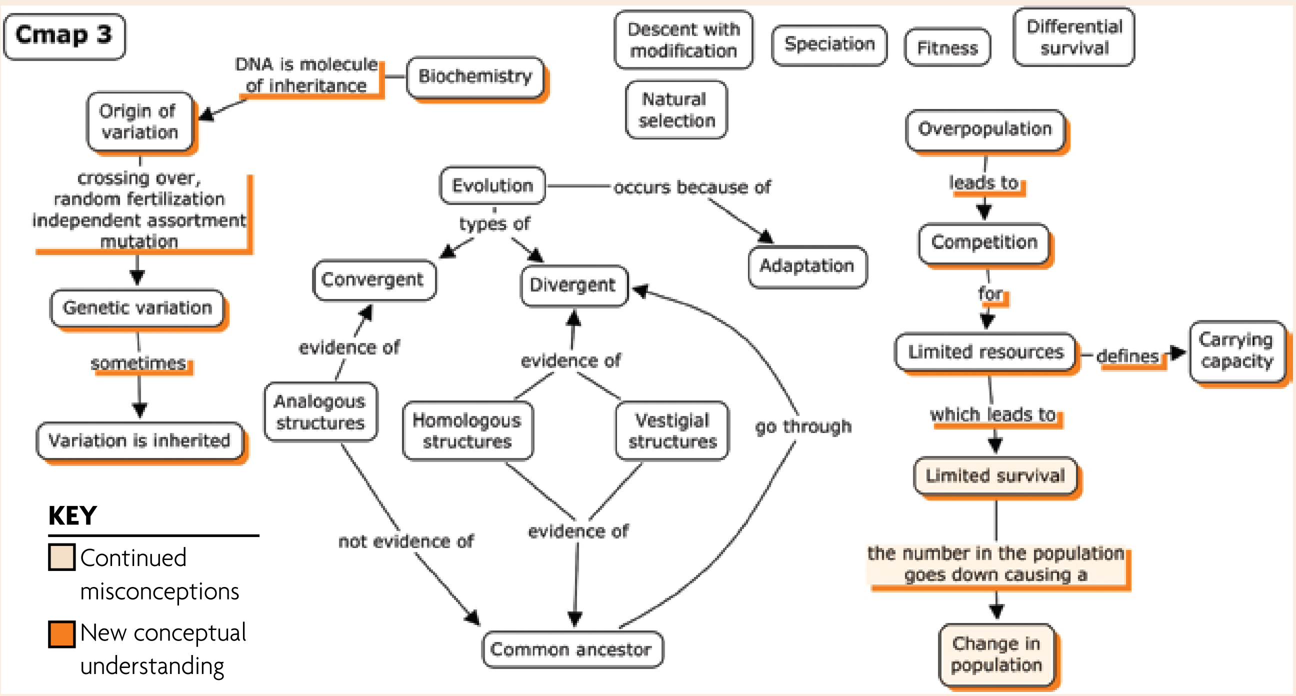
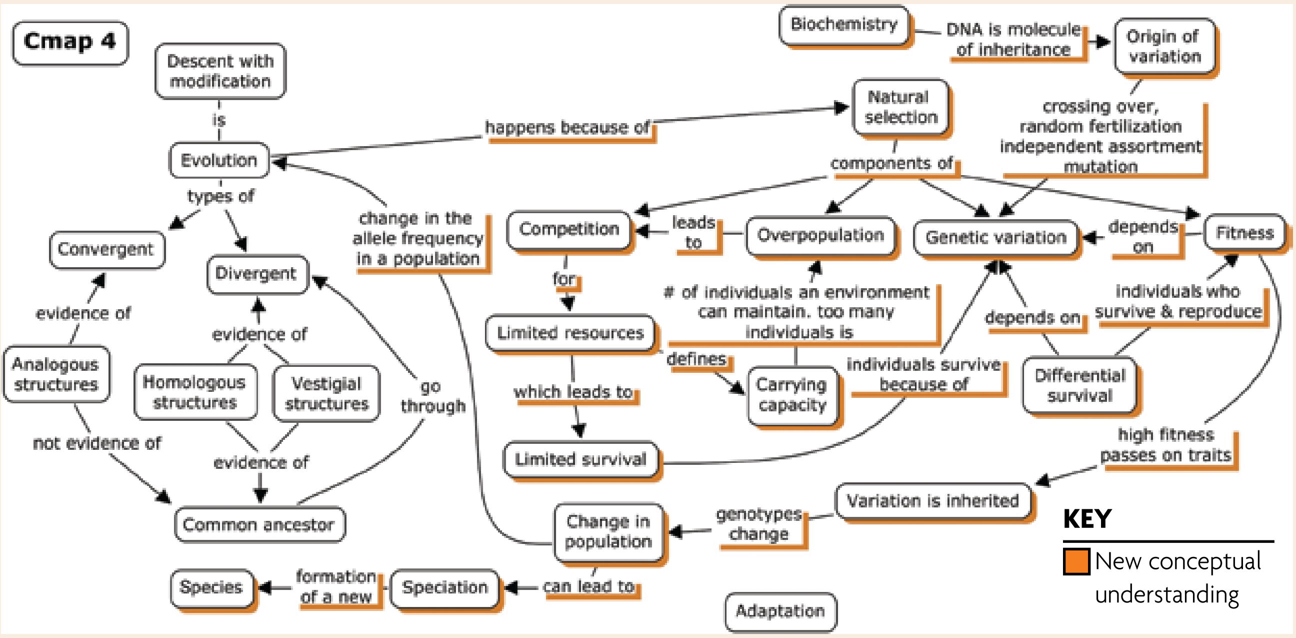


FIGURE 6

Concept mapping activity 4: New conceptual understanding.

This example represents the student's new, and often most accurate, scientific understanding. Conceptual change, spurred from the previous three activities, is evident. (**Note:** Color added by authors to illustrate key elements.)



of four maps is whether or not meaningful conceptual change is evident.

Conclusion

Educational theory is often lost in the journey from research to practice. Mapping for conceptual change marries two well-established educational theories, concept mapping and conceptual change, within the context of a trusting and engaging science classroom. A concept map can help move thinking toward scientific understanding. Conceptual change is a very individual process, and the results from each mapping activity can provide both students and teachers with information for evaluation and reflection.

Mapping for conceptual change is an embedded strategy that helps students learn how to think, recognize the importance of metacognition, master a strategy for identifying relationships among concepts, and implement a study skill for conceptually understanding science. Mapping for conceptual change also helps to support reflective teachers in their quest for teaching science based on student needs. ■

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On the web

University of Minnesota Digital Media Center: *http://dmc.umn.edu/activities/mindmap*

Institute for Human and Machine Cognition (IHMC) CmapTools: *http://cmap.ihmc.us*

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