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About Our Cover

This fearsome creature – the African armored ground cricket (*Acanthoplus discoidalis*) – is certainly not your average cricket annoyingly chirping in some hard-to-find corner. Also called the Gobabis prawn, bush cricket, armored katydid, or corn cricket, this giant is in the subfamily Bradyporinae, more closely related to katydids than to the true crickets of the family Gryllidae.

These large insects are found in the semiarid areas of southwestern Africa, including Namibia where this photograph was taken. They are flightless, grow to a body length of about 5 cm, and have five rows of spines on their abdomen, spikes on the plate-like pronotum that protects the back of their thorax, and large biting jaws.

Certainly, one of the most interesting facts about these animals is their ability to defend themselves by reflex bleeding (autohemorrhaging) – squirting toxic liquid from gaps in their exoskeleton, to a distance of a few centimeters. Even more fascinating: if this defense is not effective, they can regurgitate food and bite their enemies. Omnivores, they are a pest of food crops such as sorghum and millet and will even attack nesting birds. If food sources are limited they engage in cannibalism, particularly when large numbers are crushed by road traffic.

Males attract females by rubbing certain body parts together to produce the classic cricket mating sound (called stridulation). Like some other insects, the males produce a spermatophore that contains a sperm pouch and a food-rich spermatophylax that acts as a kind of "wedding gift" to entice the female.

This digital image was recorded with a Nikon D850 camera using a 28–300 mm zoom lens with image stabilization. The photographer is *ABT* Editor William F. McComas, Parks Family Professor of Science Education and Director of the Project to Advance Science Education at the University of Arkansas (mccomas@uark.edu).

Contents

Feature Article

Research on Learning

Inquiry & Investigation

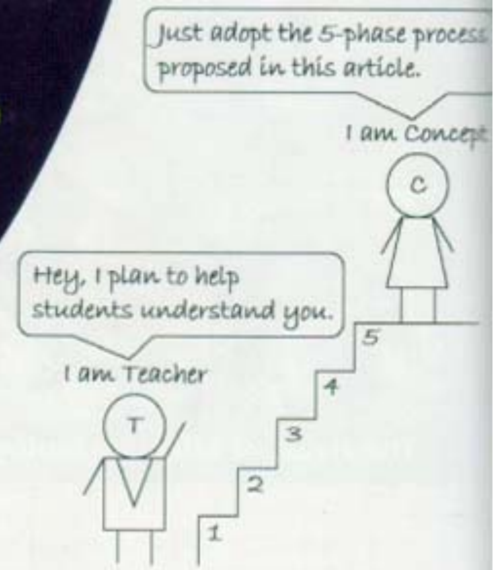
Tips, Tricks & Techniques

Departments

In our September 2019 issue, the last name of one of the coauthors for the Guest Commentary article has a misspelling in the Table of Contents. The correct spelling is Vedham Karpakakunjaram. We apologize for this error.

FEATURE ARTICLE

Preparing a Concept-Based Lesson from a Design Perspective: Facilitating Students' Understanding through Metacognitive Strategies



WENYUAN YANG, ENSHAN LIU, XINTAO LI, CHENG LIU

Abstract

A lesson plan is a design problem for a teacher. The desired solution to this problem is to design an instructional process that can guide students in constructing an understanding of scientific concepts through their own thinking. This article demonstrates a practical approach to designing an effective lesson plan. The approach has five phases: listing the concepts in a lesson, proposing questions that can be answered by each concept, sequencing the questions according to the logic of student cognitive development, selecting resources and designing tasks to create learning situations, and applying knowledge to scientific research and real life. A meiosis lesson from a high school biology course serves as an example for understanding the solutions to problems that may arise in each phase.

Key Words: *Concept-based instruction; questions about the natural world; design problem; teaching for understanding; meiosis.*

○ Introduction

Understanding of Concepts Is an Important Outcome of Science Education

The development of a student's understanding of scientific concepts is a key indicator of effective science classroom teaching. The term *concepts* refers to core knowledge that can explain how the world works, including knowledge of patterns, relationships, principles, generalizations, theories, models, and structures (Anderson et al., 2001). This type of knowledge reflects unifying rules in a disciplinary field and is essential for a conceptual understanding of the field. Understanding the concepts can provide an organizational structure for the acquisition of new knowledge and deeper learning. *A Framework for K–12 Science Education* emphasizes that an important role of science education in an information age is not to teach students to memorize "all the facts" but rather to help students construct a deep understanding of core knowledge so that they can later acquire and evaluate new information on their own (National Research Council, 2012).

The core problem that needs to be solved is designing a system that will help students gain an understanding of concepts through their own mental (and sometimes physical) actions.

Students Who Demonstrate Understanding Can Answer Questions about the Natural World

Scientists study the natural world and seek answers to questions about its many aspects. All the biological knowledge that we expect students to learn is part of the collection of answers to basic questions about living systems: what, why, where, how, how long, how many, and so on. In fact, teaching for understanding essentially guides students in answering questions about living systems. If, after learning, students can answer these questions scientifically, it is reasonable to presume that they have constructed an understanding of the corresponding knowledge. In *A Framework for K–12 Science Education*, every core idea and its component ideas are introduced with a question to show what aspect of the world this idea helps explain, and the subsequent description of the understanding of the idea is just the answer to the question (National Research Council, 2012). Accordingly, scientifically answering questions about the natural world is the performance of having gained an understanding.

Proposing questions about the natural world and seeking answers to them are fundamental to doing science. In science, a question is the beginning of studying the natural world. In the classroom, essential questions are conducive to promoting active learning and make learning thoughtful and meaningful (McTighe & Wiggins, 2013). Proper questions can open doors to student understanding and guide students through the process of thinking to gain an understanding of the world.

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To sum up, answering questions about the natural world is both the motivation and the achievement of learning science. It is necessary for teachers to frame questions that can be answered by the concepts conveyed in each class to clarify the direction of instruction.

A Lesson Plan Is a Design Problem for a Teacher

Since questions play an important role in science learning, asking and answering questions in class has been highly regarded. Generally, it is suggested that teachers should design a series of questions and adopt question-driven instruction to facilitate the learning process (Beatty et al., 2006a, b; Chin & Osborne, 2008; Krajcik et al., 2008). Indeed, questions are helpful for effective learning, and answering questions about the natural world is the performance expectation for students; however, powerful teaching is more than just asking questions. A teacher should also present information, data, materials, phenomena, and so on to support students in answering questions on the basis of evidence. Consequently, lesson preparation is similar to a design task, where the core problem that needs to be solved is designing a system that will help students gain an understanding of concepts through their own mental (and sometimes physical) actions.

A Practical Approach to Designing a Lesson Plan

For students, learning science is a process of seeking answers to questions about the natural world; for teachers, preparing a lesson is a problem of designing a learning situation that allows students to answer questions by using evidence. In light of this idea, we propose a process to show how to prepare an effective lesson for guiding students in constructing an understanding of concepts. The process has five phases:

(1) The concepts in a lesson should be listed in order to clarify the content objectives.

(2) All the concepts should be backed to initial questions – otherwise, learning them is just memorization.

(3) The questions should be reordered according to the logic of student cognitive development.

(4) To help students experience a process of evidence-based learning and develop an understanding of concepts through their own thinking, appropriate learning situations should be created.

(5) More situations for students to experience the applications of concepts learned in the lesson should be created.

Tasks designed in the last two phases comprise the learning process students are supposed to experience. Here, we use a meiosis lesson from a high school biology course as an example to feature the solutions to problems that may arise in each phase.

○ Phase 1: Listing the Concepts in a Lesson

Because the goal of learning is for students to gain an understanding of specific concepts, it is necessary to first determine the concepts in a lesson. Creating concept lists provides a clear view of content objectives and can be used to check the lesson plan afterward. To clarify concepts in a lesson, it is recommended that teachers consult national science standards and instructional materials. There is no single correct concept list for a lesson, and it is common for different teachers to propose different concept lists. The primary rule for a high-quality concept list is that it aligns with national standards and conforms to the logic of knowledge. The concepts for the example meiosis lesson are listed in Table 1.

○ Phase 2: Proposing Questions That Can Be Answered by Each Concept

Effective teaching is not telling students the correct answers to questions but guiding students to seek answers through their own thinking. Because the concepts listed in Table 1 are actually answers to the scientific questions involved in the meiosis lesson, presenting Table 1 to students is tantamount to directly telling them the correct answers. To start out in the expected instructional process and connect book knowledge to real-world exploration, all the concepts should be backed to the initial questions. Teachers should then guide students in answering these questions. In the case of the sample concepts listed in Table 1, the corresponding questions for each concept are proposed in Table 2.

Table 1. Concept list for meiosis lesson.

Concept Code[a]	Description
HS-M 1	In sexual reproduction, a specialized type of cell division referred to as "meiosis" is responsible for the production of sex cells – such as gametes in animals (sperm and eggs) – that contain only one member from each chromosome pair in the parent cell (National Research Council, 2012, 2013).
HS-M 1.1	Meiosis undergoes a single round of chromosome replication followed by two rounds of cell division: Meiosis I and Meiosis II.
HS-M 1.2	In Meiosis I, homologous chromosomes pair with each other, sometimes swapping sections, and then are segregated to separate daughter cells by the spindle apparatus.
HS-M 1.3	In Meiosis II, the sister chromatids are segregated to separate daughter cells.
HS-M 2	Meiosis produces four haploid daughter cells, each with half of the chromosome number of the parent cell; this process allows offspring to have the same number of chromosomes as their parents.

[a]HS = high school; M = meiosis.

○ Phase 3: Sequencing the Questions According to the Logic of Student Cognitive Development

Learning is a process of developing an understanding, and the role of teaching is to promote this process. Therefore, the instructional process should follow the logic of student cognitive development. The order of questions in Table 2 corresponds with that of the concepts in Table 1, which conforms to the logic of knowledge on the subject being taught. However, this logic is rarely aligned with the logic of student cognitive development (National Research Council, 2000). It is necessary for teachers to reorder the questions in Table 2 according to the logic of student cognitive development. Answers to some questions may provide the fundamental knowledge for answering other questions. The questions in Table 2 are thus reordered in Table 3.

○ Phase 4: Selecting Resources & Designing Tasks to Create Learning Situations

Coupling knowledge with practice provides the learning context, whereas knowledge presented alone is memorization (National Research Council, 2013). Directly answering the questions in Table 3 is just a process of recalling content knowledge, which contributes little to the construction of an understanding of concepts. To help students experience a process of evidence-based learning and develop an understanding of concepts through their own thinking, teachers should carefully consider the problem of creating learning situations. Two major elements constitute learning situations. One is resources, which can provide students with direct or indirect evidence with which to answer questions, such as data, charts, experiments, history of science, and science-related issues. The other is tasks, which refers to the manner in which students obtain evidence, such as by analysis, observation, investigation, argumentation, and reasoning. The learning situations designed for each question in Table 3 are described below.

What Are Homologous Chromosomes?

- *Expectations.* Students will explain that chromosomes occur in pairs in the body cells of animals and most plants; in each pair, one chromosome came from the male parent, and the other came from the female parent; this pair of chromosomes is referred to as *homologous chromosomes*.
- *Resources.* Display of human karyotypes (Figure 1).
- *Tasks.* The task is to examine Figure 1. This demonstrates that in human body cells, chromosomes occur in pairs called homologous chromosomes. A pair of homologous chromosomes consists of one maternal and one paternal chromosome. Each pair of homologous chromosomes carries genes for the same traits.

What Is *Haploid*?

- *Expectations.* Students will explain that a cell with two of each kind of chromosome is called a diploid cell, and a cell containing one of each kind of chromosome is called a haploid cell.
- *Resources.* The resource provided is a display of human karyotypes (Figure 1).

Table 2. Initial questions that correspond with concepts in Table 1.

Concept Code[a]	Initial Question(s)
HS-M 1	What is meiosis?
HS-M 1.1	How is the chromosome number in the daughter cells reduced by half?
HS-M 1.2	What happens in Meiosis I? What are homologous chromosomes?
HS-M 1.3	What happens in Meiosis II?
HS-M 2	Why is meiosis necessary for organisms? What is haploid?

[a]HS = high school; M = meiosis.

Table 3. Logical sequence of questions in Table 2 according to student cognitive development.

Logical Sequence	Concept Code[a]	Initial Questions
1	HS-M 1.2	What are homologous chromosomes?
2	HS-M 2	What is haploid?
3	HS-M 2	Why is meiosis necessary for organisms?
4	HS-M 1.1	How is the chromosome number in the daughter cells reduced by half?
5	HS-M 1.2	What happens in Meiosis I?
6	HS-M 1.3	What happens in Meiosis II?
7	HS-M 1	What is meiosis?

[a]HS = high school; M = meiosis.

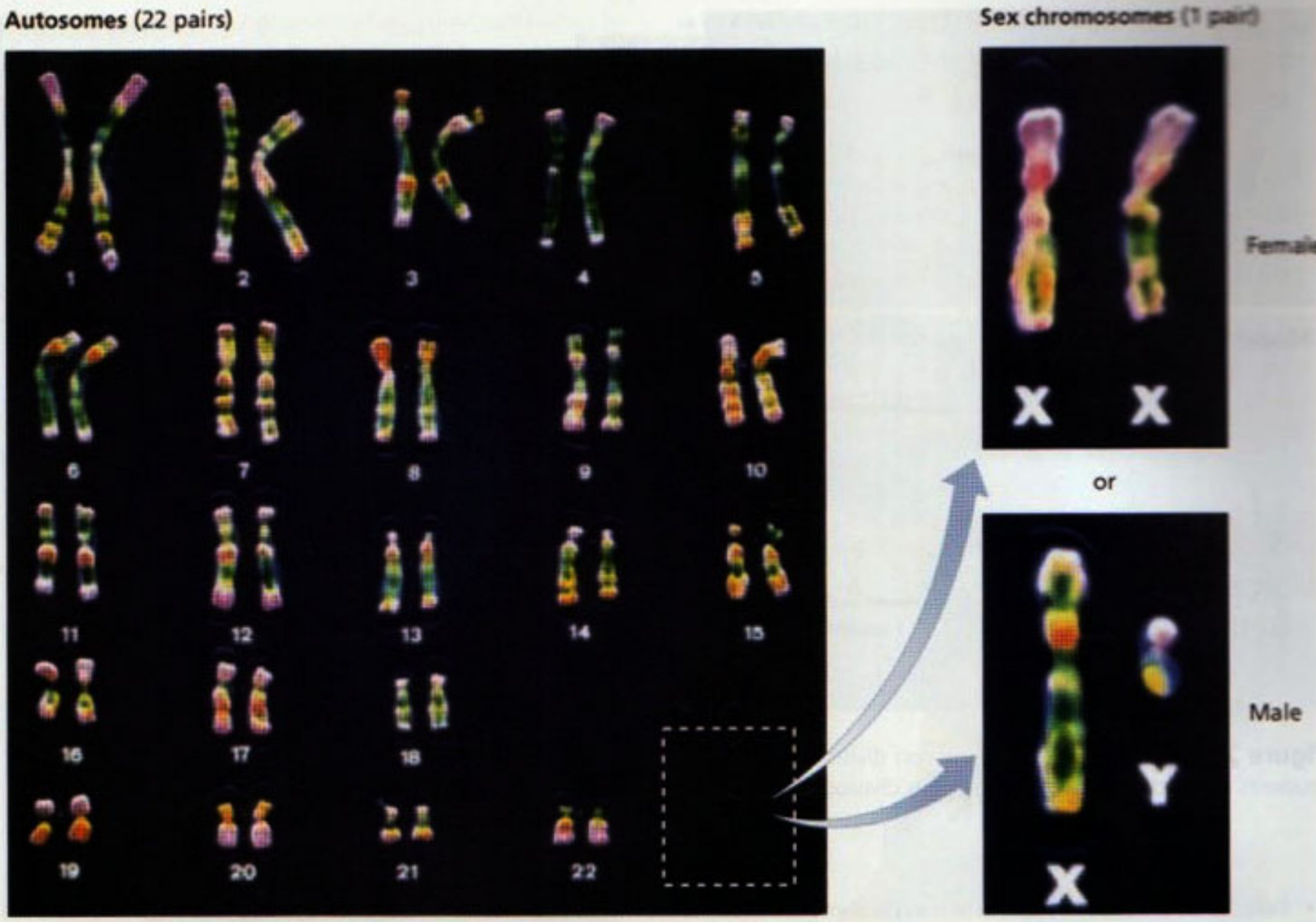

Figure 1. Human karyotypes. The 46 human chromosomes can be arranged into 23 pairs. In order of decreasing size, the pairs of chromosomes are numbered 1–22. The X and Y sex chromosomes are the 23rd pair. The sex chromosomes from a female and a male are shown in the insets (Belk & Borden, 2004; used with permission of the publisher).

- *Tasks*. The related task is to further consider Figure 1. This resource shows that a human body cell contains two of each kind of chromosome, which is said to contain a diploid, or $2n$, number of chromosomes. A cell containing one of each kind of chromosome is said to contain a haploid, or n, number of chromosomes.

Why Is Meiosis Necessary for Organisms?

- *Expectations*. Students will realize that mitosis is not the only means of cell division; there must be another form of cell division that produces gametes containing half the number of chromosomes as a parent's body cell.
- *Resources*. The corresponding resources are two studies in the history of biology. (1) In 1876, Oscar Hertwig observed sea urchin fertilization and found pronuclear fusion of sperms and eggs (Briggs & Wessel, 2006). (2) In 1884, Eduard Strasburger found a similar phenomenon in the process of angiosperm fertilization (Volkmann et al., 2012).
- *Tasks*. The corresponding task is for students to read the above materials and imagine whether reproductive cells are produced by mitosis. They should be asked, "What will happen in the offspring cell?" and guided to the following answer: "Each parent has 46 chromosomes and would produce gametes containing a complete set of 46 chromosomes. This means that each offspring formed by fertilization would have twice the number of chromosomes as each of its parents." Next, the following question should be posed: "Can you make a guess at how to ensure that offspring have the same number of chromosomes as their parents?"

How Is the Chromosome Number in the Daughter Cells Reduced by Half?

- *Expectations*. Students will understand that a reproductive cell possesses half the number of chromosomes of a body cell and propose their own model for the process of producing gametes; this model will be guided by an analogy with mitosis.
- *Resources*. The first resource consists of two studies in the history of biology. (1) In 1883, Edouard Van Beneden discovered that the number of chromosomes in a gamete of the horse ascarid is half the amount in a body cell, and a fertilized egg possesses the same number of chromosomes as a body cell (Hamoir, 1992). (2) In 1891, August Weismann proposed that gametes are produced through a process of reducing the chromosome number by half (Churchill, 2010). The second resource is enough colored clay for students to construct their own model demonstrating the process of producing gametes using an analogy with mitosis.

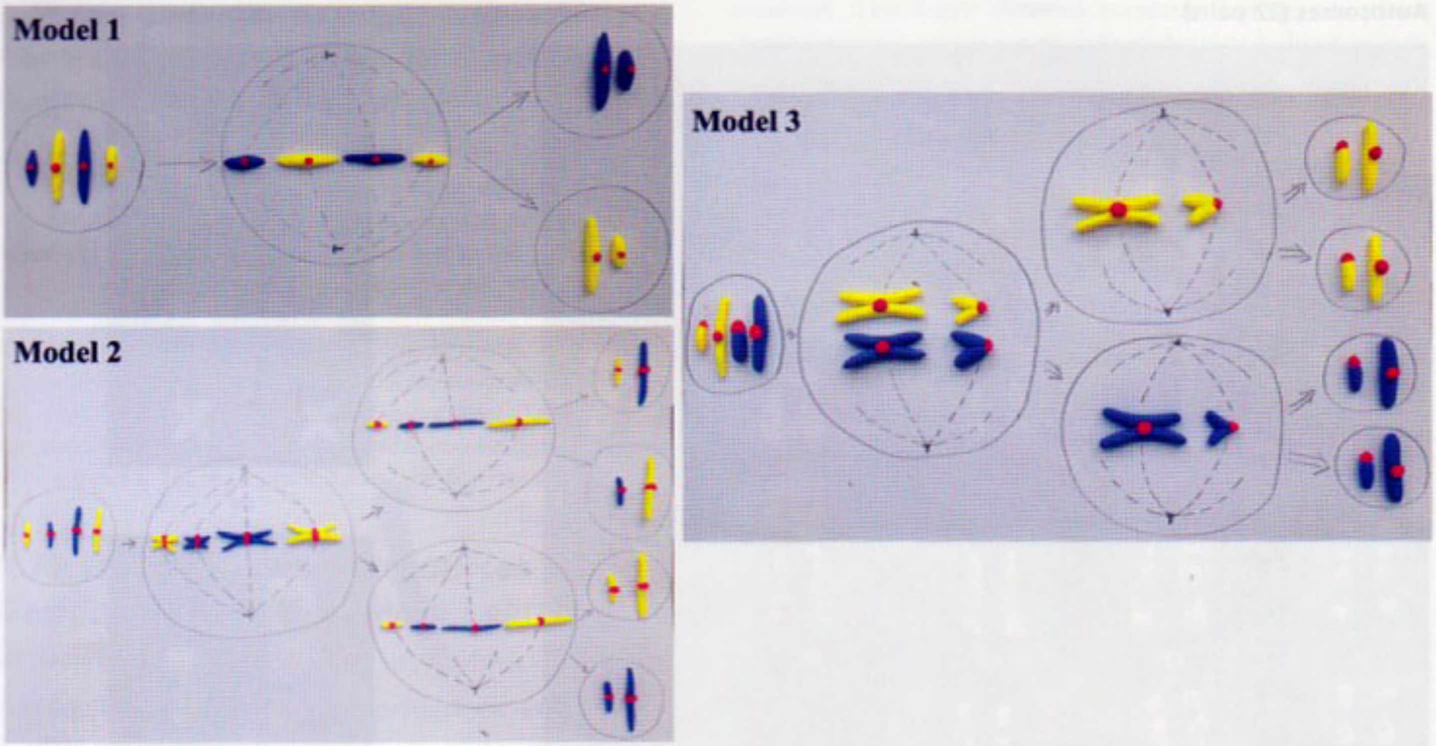

Figure 2. Students' models of reduction division. All students could propose models, but most of the models were faulty. Students' preunderstanding of reduction division should be addressed in the following learning situation.

- *Tasks.* The first task is for students to read the above materials and understand that a gamete has half the number of chromosomes as a body cell. The second task is for students to guess what happens in the reduction division and how the number of chromosomes in the daughter cells is reduced by half. The students must then construct a model to demonstrate their guess. Here are three examples of student models that demonstrate these guesses (Figure 2).

What Happens in Meiosis I? What Happens in Meiosis II?

- *Expectations.* Students will understand that meiosis uses many of the same mechanisms as mitosis; the homologous chromosomes are segregated to separate daughter cells by the spindle apparatus in Meiosis I, and the sister chromatids are segregated to separate daughter cells in Meiosis II. On the basis of this understanding, students will modify their previous models.
- *Resources.* The resource provided is a display of the stages of meiosis (Figure 3) and an explanation of the chromosome behavior in each phase.
- *Tasks.* The first task is for students to examine Figure 3 and listen to the explanation of the chromosome behavior in each phase. Then students must modify their previous models on the basis of their understanding of the process of meiosis. Below are three examples of students' modified models (Figure 4).

What Is Meiosis?

- *Expectations.* Students will explain meiosis in their own words, as well as how the process and outcome of meiosis differ from those of mitosis.
- *Resources.* Students must rely on their learning about meiosis earlier in this lesson as well as previous lessons about mitosis.
- *Tasks.* Students must first explain the definition of meiosis in their own words, based on the learning from this lesson. They must then compare meiosis with mitosis and seek to explain the differences between these two types of cell division.

○ Phase 5: Applying Knowledge to Scientific Research & Real Life

Through the process of evidence-based question answering described above, students gain an understanding of the concepts involved in the lesson. To examine and reinforce students' understanding, teachers should create two more learning situations for students to answer the questions "What are the applications of these concepts in scientific research?" and "What phenomena in real life can be explained by these concepts?" The learning situations designed for the application of concepts from the meiosis lesson are described below.

What Are the Applications of Meiosis in Scientific Research?

- *Expectations.* Students will understand that the chromosome behavior in meiosis provides the physical basis for explaining Mendel's results.
- *Resources.* Students must rely on their recall of Mendel's laws learned in the previous lesson.

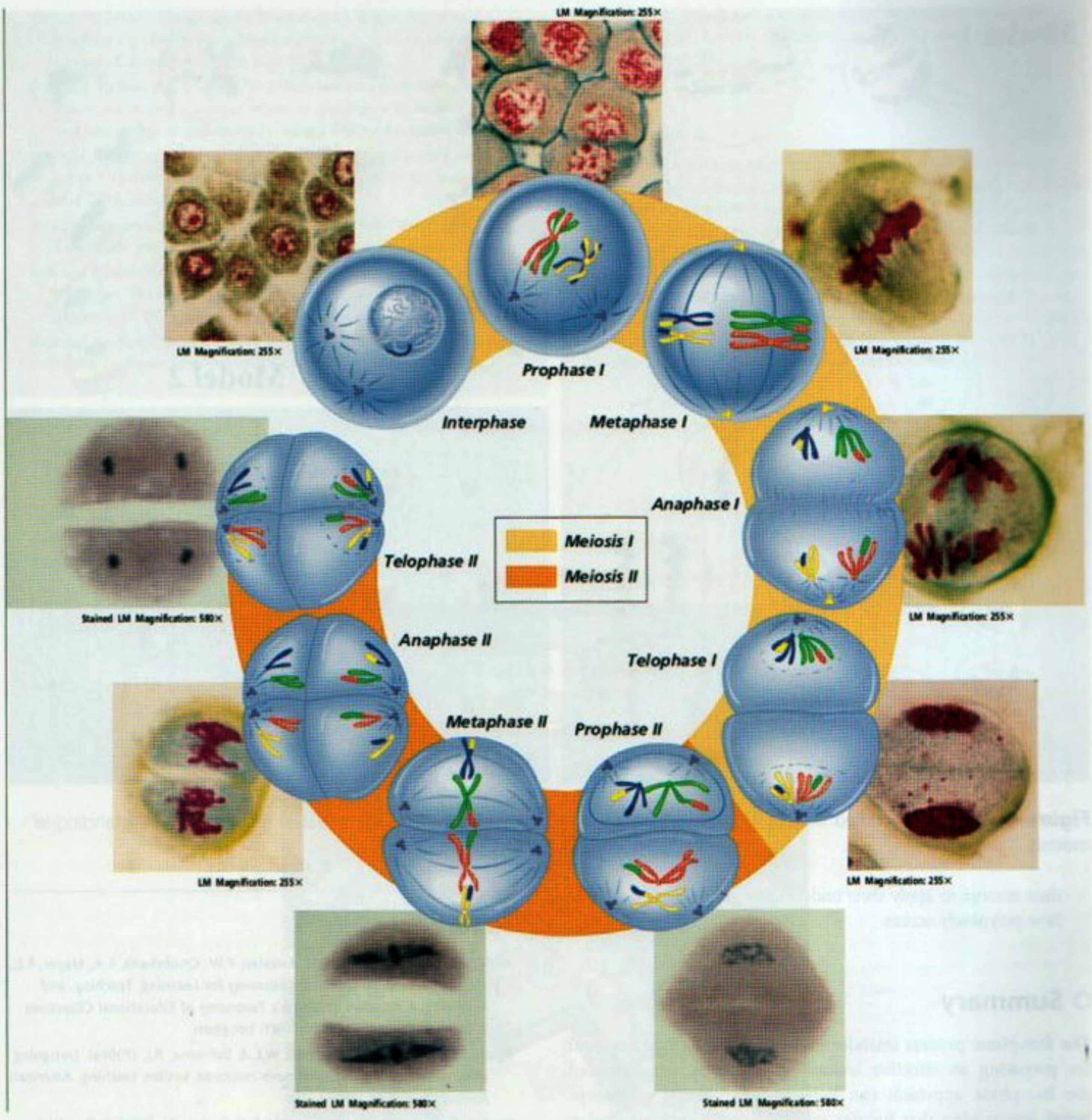

Figure 3. The stages of meiosis. There is a single round of chromosome replication followed by two rounds of cell division. Note the chromosome behavior in each phase (Biggs et al., 2004; used with permission of the publisher).

- *Tasks*. The corresponding task is for students to attempt to apply their understanding of meiosis to explain Mendel's results.

What Phenomena in Real Life Can Be Explained by Meiosis?

- *Expectations*. Students will explain that polyploidy occurs when chromosomes fail to separate in meiosis. Polyploidy is rare in animals and almost always causes death; however, the same process frequently occurs in plants, and many polyploidy plants have significant commercial value.
- *Resources*. The corresponding resources are pictures of triploid (3*n*) bananas, triploid (3*n*) apples, hexaploidy (6*n*) wheat, and polyploid chrysanthemums.
- *Tasks*. Students must appreciate the value of a thorough understanding of meiosis and genetics for plant breeders. Students must

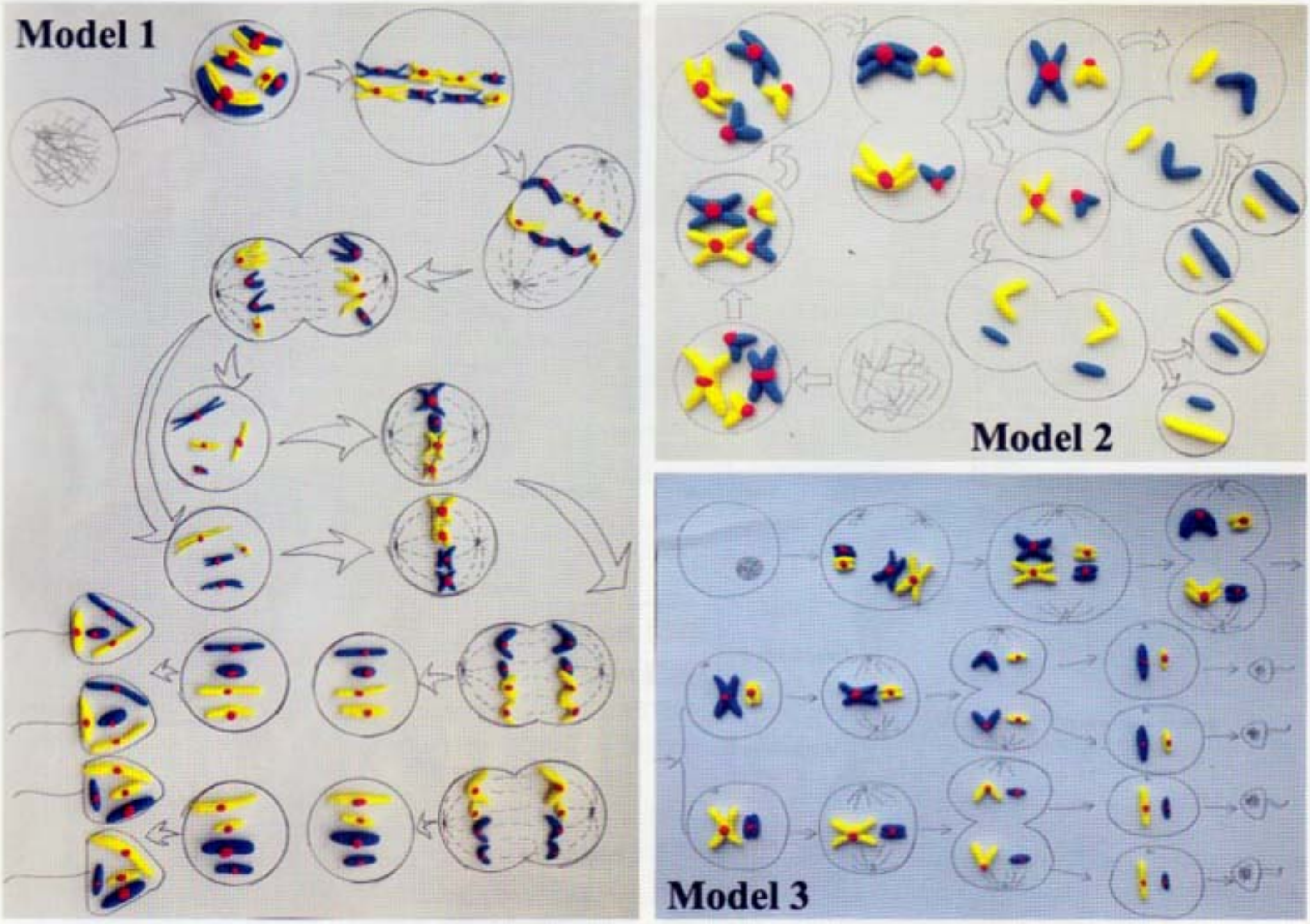

Figure 4. Students' modified models of meiosis. Most of the students, if not all, demonstrated a scientific understanding of meiosis.

then attempt to apply their understanding of meiosis to explain how polyploidy occurs.

○ Summary

The five-phase process introduced above is a practical approach for preparing an effective lesson. As has been demonstrated, the five-phase approach can help teachers design a concept-based lesson plan that focuses on the development of student understanding of scientific concepts. Additionally, learning situations designed for the instruction process can provide students opportunities to gain an understanding through their own explorations. Proposing questions and then seeking evidence to answer them is the basic way in which scientists study the world and is how scientific knowledge is produced. Meaningful learning occurs when students experience this exploration and production of knowledge. Content knowledge and practice must be intertwined in designing learning experiences (National Research Council, 2012, 2013). A lesson plan designed using the five-phase approach integrates concepts with practices and contributes to the development of an understanding of concepts as well as practical abilities.

References

Anderson, L.W., Krathwohl, D.R., Airasian, P.W., Cruikshank, K.A., Mayer, R.E., Pintrich, P.R., et al. (2001). *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives (Complete Edition)*. New York, NY: Longman.

Beatty, I.D., Gerace, W.J., Leonard, W.J. & Dufresne, R.J. (2006a). Designing effective questions for classroom response system teaching. *American Journal of Physics, 74*, 31–39.

Beatty, I.D., Leonard, W.J., Gerace, W.J. & Dufresne, R.J. (2006b). Question driven instruction: teaching science (well) with an audience response system. In D.A. Banks (Ed.), *Audience Response Systems in Higher Education: Applications and Cases* (pp. 96–115). Hershey, PA: Idea Group.

Belk, C. & Borden, V. (2004). *Biology: Science for Life*. Englewood Cliffs, NJ: Pearson Education.

Biggs, A., Hagins, W.C., Kapicka, C., Lundgren, L., Rillero, P., Tallman, K.G., et al. (2004). *Biology: The Dynamics of Life*. Columbus, OH: McGraw-Hill.

Briggs, E. & Wessel, G.M. (2006). In the beginning . . . animal fertilization and sea urchin development. *Developmental Biology, 300*, 15–26.

Chin, C. & Osborne, J. (2008). Students' questions: a potential resource for teaching and learning science. *Studies in Science Education, 44*, 1–39.

Churchill, F.B. (2010). August Weismann embraces the protozoa. *Journal of the History of Biology, 43*, 767–800.

Hamoir, G. (1992). The discovery of meiosis by E. Van Beneden: a breakthrough in the morphological phase of heredity. *International Journal of Developmental Biology, 36*, 9–15.

Krajcik, J., McNeill, K.L. & Reiser, B.J. (2008). Learning-goals-driven design model: developing curriculum materials that align with national standards and incorporate project-based pedagogy. *Science Education, 92*, 1–32.

McTighe, J. & Wiggins, G. (2013). *Essential Questions: Opening Doors to Student Understanding*. Alexandria, VA: Association for Supervision and Curriculum Development.

National Research Council (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington, DC: National Academy Press.

National Research Council (2012). *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: National Academies Press.

National Research Council (2013). *Next Generation Science Standards: For States, by States*. Washington, DC: National Academies Press.

Volkmann, D., Baluška, F. & Menzel, D. (2012). Eduard Strasburger (1844–1912): founder of modern plant cell biology. *Protoplasma, 249*, 1163–1172.

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FEATURE ARTICLE

Bridging the Gap: Bringing Professionals into the Classroom to Effectively Teach Environmental Science Concepts

MALLORY WARE, CHRISTIE SAMPSON, DELANEY LANN, ERICA LINARD, LAUREN GARCIA CHANCE

Abstract

Hands-on learning is a highly effective teaching method for topics in STEM disciplines. Unfortunately, environmental science teachers sometimes lack the tools to engage their students in hands-on experimentation in real-world research outside of the classroom. Partnerships between science professionals and teachers can help address this disparity, and operating within an established community science program is an excellent way for teachers and professionals to provide K–12 students opportunities for involvement in real-world research. We developed a four-stage program that maximizes the benefits of bringing together members of the professional and academic sectors; the stages include Learn, Collect, Report, and Communicate (LCRC). The goal of this program is to bring science professionals into a K–12 classroom to emphasize the importance of conducting research using the scientific method, to promote responsible community science, improve students' data literacy and critical thinking skills, and highlight the relevance of science communication. We demonstrate this program with a case study using water quality research in high school AP classes. Evaluations of the case study indicate this framework, and the engagement with science professionals alters students' perceptions of science and scientists while giving them the skills, knowledge, and confidence to pursue scientific endeavors.

Key Words: *Water quality; mentor; scientific process; research; community science.*

○ Introduction

Understanding environmental processes, the benefits provided by healthy ecosystems, and how individual citizens impact the natural world is crucial not only for professionals in scientific fields, but also for members of the general public. *Community science*, also called *citizen science*, often refers to research partnerships between scientists and the public, during which data are collected by community members to be analyzed in response to science-based questions (Eitzel et al., 2017). Community science helps engage the public in observing and understanding the ecosystems that surround them, generally for the purpose of collecting data to monitor, for example, any fluctuations in environmental conditions or changes in animal populations (Huang et al., 2018). Due to the hands-on experience provided by participation in community science, introducing students to such programs can help them develop a better understanding of the natural world through active learning. Studies have shown that for students to retain scientific knowledge and understand the scientific method, hands-on experiences and interactions with STEM field partners (e.g., industry, academia) are immensely important (Simmons, 2017). The implementation of community science programs in the classroom creates an environment where students can learn science in a socially and environmentally relevant way.

For students to retain scientific knowledge and understand the scientific method, hands-on experiences and interactions with STEM field partners are immensely important.

Furthermore, introducing scientists from industry or higher levels of academia can bring multiple benefits into the K–12 setting. Small lesson modules taught by scientific experts can supplement middle and high school curricula, helping prepare students for standardized or AP exams. In addition, introducing students to a broad range of professional scientists can help combat negative stereotypes (e.g., about age, gender, race, and personality) that often discourage students from pursuing STEM fields or engaging in research. Interactions with a diverse set of scientific professionals have been shown to help change K–12 students' perceptions of scientists and can additionally enhance their interest in the scientific field (Scherz & Oren, 2006). Implementing a project based on community science programs helps the student truly become involved in a scientific community and foster an identity as an emerging scientist, as well as gain authentic participation in scientific practices (Koomen et al., 2018).

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