Movie Mitosis

Students make stop-animation films to illustrate the process of mitosis

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Mitosis and meiosis are essential for the growth, development, and reproduction of organisms. Because these processes are essential to life, both are emphasized in biology texts, state standards, and the National Science Education Standards. By the time most students complete a high school biology course, mitosis and meiosis have been presented to them in two or three different classes. In addition, some high school students elect to take upper level biology courses in which they revisit mitosis and meiosis. With this relatively high level of exposure, it seems logical to conclude that high school students master these concepts by the time they graduate. However, based on our teaching experiences and those of our colleagues, it is evident that many students have only a rudimentary understanding of mitosis and meiosis.

In this article, we present our methodology for teaching mitosis by having students produce stop-animation films. We have found that this approach is equally effective for teaching students about meiosis as well.

Act I: Introduction

We assert that the main difficulty for students in learning mitosis and meiosis is the physical scale of these processes. Phenomena that are extremely small or large cannot be observed directly and therefore are not part of students'

experiences. To facilitate understandings of very small or large-scale phenomena, it is necessary for students to address the "three conceptual levels of scientific understanding": macroscopic, modeling, and symbolic (Gabel 1999; Hitt and Townsend 2004, 2007).

First, students record their observations at the *macroscopic level.* This level is the easiest and most familiar to students because it requires them to use their senses to observe phenomena. For example, students can view different types of cells under a microscope and "see" the differences in the structure of plant and animal cells. Second, at the *modeling level,* students create mental and physical models that help them visualize the phenomena. After construction, students should explicitly reflect on the strengths and weaknesses of these models to prevent misconceptions and to develop a better understanding of the scientific concepts (Eichinger 2005; Gilbert and Ireton 2003). Finally, at the *symbolic level* students learn to apply the correct scientific terminology and formulas to describe phenomena. This instructional sequence facilitates student learning because it is anchored to students' experiences and guides them toward the more abstract scientific descriptions, terms, and symbols.

The trouble with models

To help students conceptually understand mitosis and meiosis, they need to investigate these processes at each of the three conceptual levels of scientific understanding, of which modeling is a key component. The idea of building mitosis models is not new, and we have seen many different approaches using assorted materials such as beads and pipe cleaners. However most of these physical models have a limited impact on students' conceptual understanding of mitosis or meiosis for several reasons.

First, models must often be disassembled after use, or they are too bulky or fragile to be taken outside of the classroom. To study or review the content at home, students must rely on their notes and textbook, instead of the model. In the end, the model and model-building process become just another "fun" classroom activity.

Second, it is difficult for students to literally and conceptually connect the "symbolic" terms and definitions to the model. Students may make labels with terms such as *chromatin* and *centromeres*, but they frequently do not contain any other substantive information. In addition, the physical cutting and pasting involved in making the model overshadows the targeted concepts.

Third, physical models tend to be immobile and display processes such as mitosis and meiosis as discrete snapshots or steps. As a result students may internalize mitosis or meiosis as a series of distinct events and fail to conceptualize them as a dynamic process.

Finally, most physical models are difficult to modify, which mitigates one of the key strengths of a model-based approach: a deeper understanding of scientific inquiry. In contrast, the construction of a good model can be analogous to approaches used by scientists when they conduct scientific investigations (Gilbert 1991; Gilbert and Ireton 2003). For example, scientists frequently devise theories or models of phenomena, conduct experiments to test their theories or models, and then modify them in light of new data. In effect, when students build, critique, and modify their own models, they are learning how science is done. Unfortunately, for the reasons cited above, physical models for mitosis or meiosis often do not enhance students' understanding of scientific inquiry.

Models that work

If mitosis or meiosis models are going to be effective for developing students' conceptual understanding of content and scientific inquiry, they must be

- relatively easy to modify and adapt,
- portable and convenient, and
- explain mitosis and meiosis as both a series of stages and as a dynamic process.

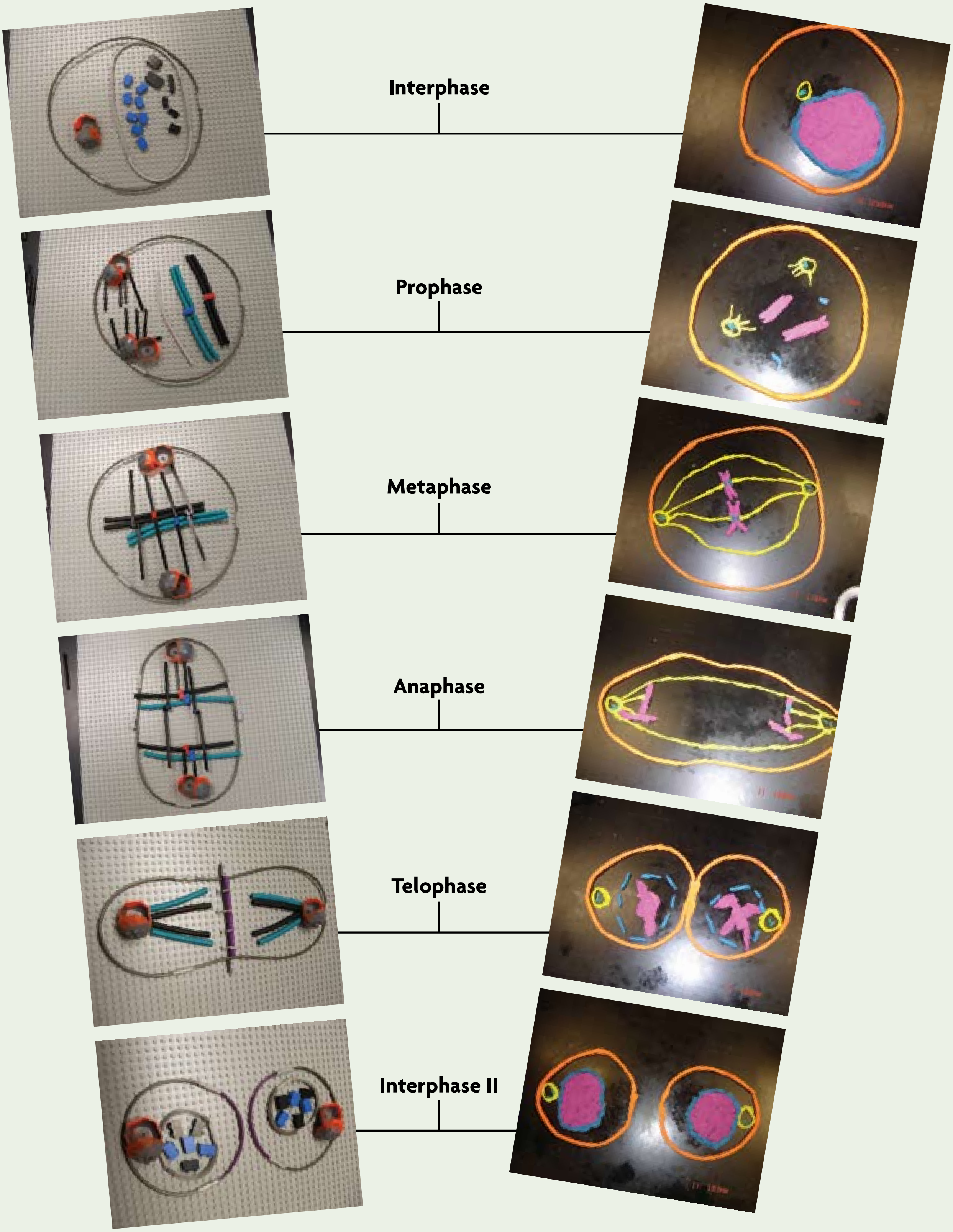
Our solution is to have students create their own stop-animation movies or models for mitosis and meiosis by using a digital camera. Stop-animation films are created by taking single pictures or frames of an object that is moved or posed in different positions. When the

FIGURE 1

Students constructing stop-animation movies.

FIGURE 2

Clips from two groups' stop-animation movies.



individual frames are put together in a sequence and played in rapid succession, it creates the appearance of a moving object. This process is analogous to creating a children's flip book, in which a sequence of slightly different images is drawn on the pages of the book. When rapidly flipping the pages the images on the paper appear to move.

Digital cameras have been demonstrated to be effective at helping students conceptualize the connections between hypotheses, data, and inferences (Leonard et al. 2004). Digital-movie models are also relatively easy for students to annotate and edit, which means that students can readily correct their mistakes and improve their models. In addition, since the model is digital, it can be easily stored on a CD or USB drive, or sent to an e-mail account for review at home or elsewhere. A digital model also makes it possible to upload the video to any number of video-sharing websites that are popular with high school students. This makes the digital-movie model an easily accessible and useful study guide that students can use practically anywhere. Finally, the digital movies can be viewed all at once or frame-by-frame, allowing students to conceptualize mitosis and meiosis both in terms of specific events and as complete processes.

We have found that when students go through the process of creating their own digital movies, they are more engaged and gain a deeper conceptual understanding of these processes.

Act II: Materials and procedures

The following list of materials is needed for the production of stop-animation films:

- digital camera (a tripod stand is helpful but not required)
- computer- and slide-presentation program or movie-making program
- beads, buttons, strings, pipe cleaners, and clay that can be used to represent structures such as chromosomes, spindle fibers, membranes, and centrioles
- colored pencils or markers
- internet connection

One concern teachers may have is the price of a digital camera. However, digital cameras have been shown to be a cost-effective alternative to expensive lab equipment (Abisdris and Phaneuf 2007), and the cost of digital cameras has dropped dramatically in recent years. In addition, the startup cost can be mitigated in several ways.

School libraries often have several digital cameras that teachers can use in their classes. If there are not enough digital cameras for each group of students, the teacher can stagger the activity and have some students working on the movie while others work on a different assignment. We have also found that many students own digital

FIGURE 3

Grading rubric.

Scoring criteria	Area for improvement (1 point)
Movie content	
Content	Most of the major events and required components of the cell are missing or inaccurate. For example, the scientific terms for the phases of mitosis or the cellular structures are labeled or described incorrectly or missing.
Sequencing	Some phases do not occur in the correct sequence or slides are not clearly labeled so that viewers cannot identify transitions between phases.
Aesthetics	Most of the cellular structures have similar colors or are built from the same materials, making it difficult to differentiate structures, or do not resemble the targeted cell structures.
Student oral presentation	
Content	Most of the major events and required structures are not addressed or are inaccurate.
Critique of model	Presentation does not address one of the following: ◆ how the model is similar to the target, ◆ how the model is different from the target, or ◆ how the model can be improved in order to more accurately reflect the target phenomenon.

	Developing (2 points)	Proficient (3 points)	Exemplary (4 points)
	Most of the major events and required components of the cell appear to be present and accurate. For example, some of the scientific terms for the phases of mitosis or the cellular structures are labeled or described incorrectly or are missing.	All of the major events and required components of the cell appear to be present and accurate. For example, all of the scientific terms for the phases of mitosis or the cellular structures are present and correctly labeled.	All of the previous categories have been met and the content information on the slides is succinct, relatively easy to see on the screen, and the location and font style add information without detracting from the model.
	All phases are in the correct sequence, and most of the slides are clearly labeled so viewers can identify transitions between phases.	All phases are in the correct sequence; all of the slides are clearly labeled so viewers can easily identify transitions between phases and follow the process from beginning to end with minimal visual distractions or glitches.	All of the previous categories have been met and practically all of the slides are clearly labeled so viewers can easily identify transitions between phases and follow the process from beginning to end. There are practically no visual distractions or glitches present.
	Most of the structures can be differentiated by their distinct color and material, and resemble the targeted cell structures.	All of the structures can be differentiated by their distinct color and material, and resemble the targeted cell structures.	All of the previous categories have been met. Overall, the film is easy to follow, relatively colorful, and uses unique materials to represent the cellular structures.
	Most of the major events and required structures are addressed or are inaccurate.	All of the major events and required structures are accurately addressed.	All of the previous categories have been met. Overall, the presentation is focused, relatively easy to understand, and consists of smooth transitions.
	Presentation addresses one of the following: ◆ how the model is similar to the target, ◆ how the model is different from the target, or ◆ how the model can be improved in order to more accurately reflect the target phenomenon.	Presentation addresses all of the following: ◆ how the model is similar to the target, ◆ how the model is different from the target, and ◆ how the model can be improved in order to more accurately reflect the target phenomenon and multiple improvements (three or more) are stated for each category.	All of the previous categories have been met and all of the rationales and approaches for improving the model are reasonable and scientifically valid in terms of materials, expenses, and scientific accuracy.

cameras or cell phones with digital cameras that can be used inside or outside of class. We know several teachers who have applied for and received small grants for purchasing digital cameras from their school or school district. For this activity, it is not necessary to purchase a sophisticated and expensive camera. We have found that a basic digital camera with a purchase price of $50 or less is all that is needed.

We prefer to use slideshow programs rather than movie-making software in this activity because most students and teachers are familiar with these programs. When using movie-maker software, we have had to extend the activity in order to teach students how to use it. In addition, students who already know how to use the movie-maker programs tend to dominate the group discussions and design process. However both approaches can effectively engage students in learning about mitosis and meiosis.

The following procedures can be used to facilitate mitosis movie making in the classroom.

Observing mitosis (macroscopic level)

The class is divided into groups consisting of three to four students who observe microscope slides or other images of cells during mitosis. The teacher then leads a class discussion on mitosis and addresses concepts such as the cell cycle, the stages of mitosis, and the relationship among chromatin, chromatids, chromosomes, the mitotic spindle, spindle fibers, and other structures. Afterward students revisit the slides and images in order to correctly identify the relevant stages and structures.

Planning and building the model (modeling level)

Student groups plan and gather supplies for constructing their models. They can select materials provided by the teacher or bring in their own supplies. We prefer to have students bring in their own materials because it gives them a greater sense of ownership and results in more creative movies.

During construction, students explicitly reflect on the strengths and weaknesses of their scientific models (Figures 1a and 1b, p. 38). This procedure helps them to critically analyze their models in terms of accuracy and function. We use the following prompts based on Eichinger's (2005) and Gilbert and Ireton's (2003) suggestions for guiding students' critiques of scientific models:

- How is the model similar to the target, a real cell undergoing mitosis?
- How is the model different from the target?
- How could you improve your model to make it more accurately reflect the target?

It is during this movie-production phase that we observe one of the biggest benefits of this approach—a higher level of student involvement and creativity. In one of our classes, several student groups added special effects such as soundtracks, voice-overs, and diverse visual displays without any prompting. This is a dramatic change from our traditional lecture-based approach, in which students passively listen and memorize the information for the tests.

Making the movie (symbolic level)

Student groups take pictures of their models using a digital camera and then download the pictures to a computer (Figure 1c, p. 38). The digital images are inserted into a slide presentation program and the cellular structures and phases in the slides are labeled (Figure 1d, p. 38). Finally, students are ready to present and discuss their mitosis movies.

One approach to the presentations is to have students present their work as a traditional lecture-based slideshow. Another option is to present a live-action movie. A moving picture can be created by setting the slide-presentation program's timer so the slides change after a few seconds. If the time interval is short enough, the slide presentation resembles a stop-animation film. (**Note:** Movie-making programs can produce similar or smoother pictures by using the provided editing tools).

We recommend that student presentations use both approaches. The lecture-based technique allows students to easily divide up the presentation and clarify any questions about their models. Additionally, the lecture-based format allows the teacher to make a frame-by-frame analysis of students' understanding of mitosis. In contrast, the animated-film model helps students to conceptualize mitosis as a dynamic process instead of a series of compartmentalized phases. It is also possible to present the same slideshow using both approaches: first as a traditional slideshow and then replaying the show as an animated film (by changing the transition settings). See Figure 2 (p. 39) for sample film clips from two groups of students.

The use of a video-hosting website can add another dimension to the project that further models the scientific process. If students post their movies to a video-hosting website that allows for a simple rating scale (e.g., 1–5 stars) and comments, students can receive feedback from a global audience about their projects. Although some of the unfiltered comments on such sites can be questionable, this gives students a chance to critically evaluate their "reviews." (**Note:** In addition, although sites generally forbid the uploading of inappropriate or defamatory material, the inability to check all videos before they go online means that occasional lapses occur, and teachers should monitor students to be sure that they are not encountering offensive content. Further, teachers should also review students' videos for appropriateness before permitting them to be posted to a video-hosting website.)

This effectively expands the classroom to include collaborations with students, teachers, and professors and parallels the peer-review process among scientists.

Assessing students' presentations

At the beginning of the movie project students receive a rubric. The rubric informs students about the structures and labels that should be applied to the models and what should be discussed during their presentations (Figure 3, pp. 40–41). In addition to the movie presentation, we require students to submit a frame-by-frame script. The script allows the instructor to make a more thorough evaluation of the project. Students can create their scripts using the note-taking format of a slide-presentation program or by copying the slides into a word-processor program and then typing in their comments.

Act III: Discussion

Digital-movie models are beneficial for students and teachers for several reasons. First, we have found that when students plan, write, and direct their own movies, they become highly engaged learners because the movie project allows them to personalize the learning experience. For example, one group of students was so enthusiastic about the mitosis movie project that (on their own and without credit) they created a second film that features themselves as the chromosomes.

Second, digital-movie models integrate science content and technology. Because the movie is digitized it can be uploaded and viewed in a variety of formats. Outlets such as video-posting websites, podcasting, and blogging can contribute to student understanding and information exchange. The mitosis movie can be shared with a global audience of students and teachers.

Third, when students construct, modify, and present their digital-movie models, they are learning about the content and scientific inquiry (Gilbert 1991; Gilbert and Ireton 2003). In addition, digital-movie models are a way that teachers can integrate best practices in their science classes. Both the American Association for the Advancement of Science and the National Research Council recommend that science be taught using a contextual and project-based approach (1989; 1996). The movie-modeling activities described in this article address both of these recommendations.

Finally, the movie model–based approach can be applied to other biological concepts. As noted, one reason students have a difficult time understanding mitosis and meiosis is that they cannot "see" these phenomena. Students face similar difficulties when they are learning about concepts such as photosynthesis, the citric acid cycle, or electron transport. To help students visualize and internalize these phenomena they need to construct their own models. We believe that movie-based models can be particularly effective at teaching students about processes at the cellular and molecular levels. For example, instead of memorizing a diagram or making a drawing of the citric acid cycle, students can create a moving model that reflects the dynamic nature of this process. It has been our experience that students find topics such as the citric acid cycle to be relatively boring and arcane, but a movie-based approach can be used to increase students' interest. Further, although outside the scope of this article, it is not hard to imagine applications of movie-based models in other science disciplines.

Even if students do not build outside-of-class or highly creative models, we are confident they gain a deeper understanding of the content. As one student said, "It is one thing to read about [mitosis] in a book, but it is another to visually create the process by yourself." In the same class another student stated, "I had to know what was happening in every phase so I could get the picture right." Based on this positive feedback from students and their improved performances on assessments, we believe that the digital movie model is a big hit! So now when students tell us they do not understand mitosis, meiosis, or any other difficult biological concept our response is, "Well, make a movie!" ■

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