Translating Science into Pictures: A Powerful Learning Tool

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> *"The animation [I created] became an interface for learning."*
> *—Marianna Shnayderman, MIT student, 2003*

Look at any group of scientists sharing ideas and you will invariably see that, at some point, someone will take out a pen and paper or walk up to a chalkboard and start drawing. One need not be a serious artist to *communicate* the concept in the drawing. The purpose of the exercise is to visually represent and *communicate* an idea, nothing more.

This *thinking* about how to visually communicate a concept or phenomenon is an effective mode of sharing ideas with each another. Yet, there is another important component of the process that has generally been overlooked—thinking how to visually express an idea is also a means of *clarifying* the idea for the person making the drawing. We believe this process has the potential of revolutionizing the teaching of science. To encourage students to think visually and to clarify their thoughts for the purpose of communicating science, using drawings or other means of visual communication has the potential of changing the way they learn. In the same way that writing is about finding the right words to tell a story, so it is with making the "right" visual expression.

However, it is not enough to simply ask students to draw or animate a scientific concept for their own notebooks. The additional element of making it *communicativ*e, expressing an idea to another, gives the exercise another dimension.

The process is both *active* (in the sense that it requires the students to formulate their own understanding and to explain to others) and *different* from the familiar verbal and mathematical explanations. It thus provides a fundamentally new approach to teaching difficult concepts of science and engineering. It also trains students—the next generation of scientists and engineers—in new ways to communicate with the public.

Making Animations

We've explored this idea with a pilot project at MIT. Marianna Shnayderman, an undergraduate student, taught herself "Flash" to create a series of animations for high school students and for the non-scientific public. The animations addressed complex ideas behind the research in various laboratories investigating nanoscience.

The project gave her the opportunity to directly meet with the faculty and graduate students working in the relevant laboratories. Marianna would discuss various concepts with the researchers to first understand the phenomena of the investigations before setting out to produce the animations. She was able to ask the questions she would not ordinarily have the chance to ask—those beyond questions in the textbooks. More importantly, she directed the questions to those who do research, giving her a new and unusual perspective. Some of the errors in her thinking became apparent when she presented the first drafts of her animations—her errors became part of the learning experience.

Many of the concepts in nanoscience are challenging to understand and communicate. In fact, the scientists themselves are not in complete agreement with what is the "right" visual representation. An interesting and unexpected benefit for Marianna's was to observe the researchers, on occasion, argue how this and that should be represented. In addition, the ongoing theme of how deeply into the science

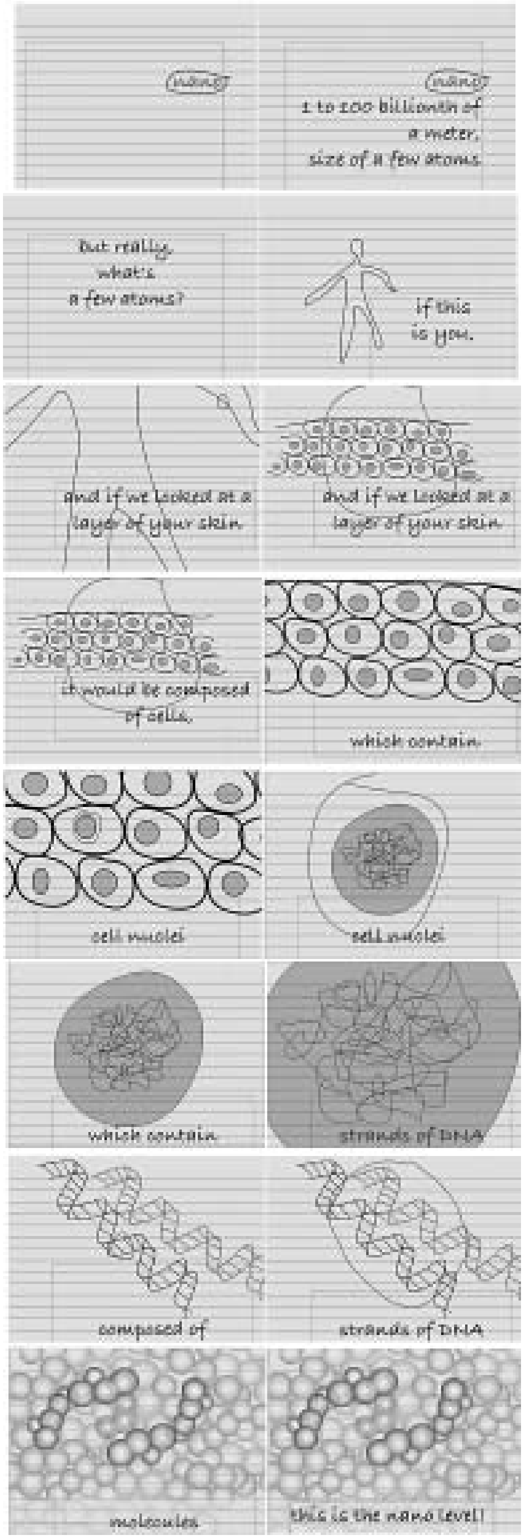

Figure 1. Frames from an animation describing the concept of "nano" scale.

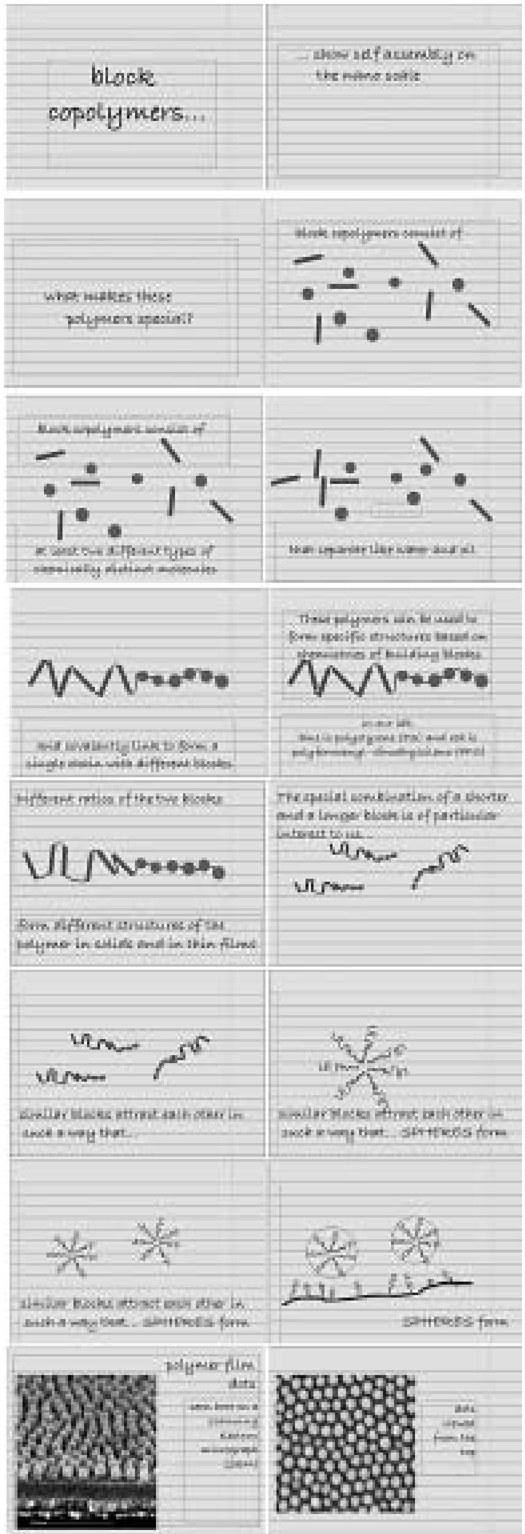

Figure 2. Frames from an animation illustrating block copolymers.

must we go to accurately explain an idea helped her think about ways to engage the non-scientist.

In our opinion, this concern for communicating with the public, using a visual language, should be part of the undergraduate curriculum. We plan to further explore these ideas in 2005 by incorporating various visual exercises in existing lecture classes on campus.

Below is Marianna's commentary from her final report.

"Visualizing concepts is probably the only way I can understand them; it's the only way science can make any sense to me.

In this undergraduate research opportunities project (UROP), I created animations that would explain concepts applying in the laboratory. I had to read up on the science from various textbooks and then had to figure out how to put all the concepts together for two kinds of audiences—high school students and adult non-scientists:

- *What is meant by the "nano" scale?*
- *What are block copolymers?*
- *What is self-assembly?*
- *What is templated self-assembly?*

The thought process was as follows: read descriptions, try to sketch the concepts, learn and use Flash software to actually animate the sketches, then meet with my advisor, Felice Frankel, over a period of time to discuss goals and communicative components. After getting the animation to a particular point, we then met with Professor Caroline Ross and her graduate student Joy Cheng to confirm accuracy.

This last step was crucial in the learning process: coming to a teacher with a visualization of what I thought the science meant made it possible for the professor to see where my thinking was wrong and what had to be explained differently. The animation became an interface for learning.

Usually lectures and books are not responsive to how a student understands complex ideas, and even if the student can answer problems on exams, the standard system does not consider what understanding the student actually comes out with.

When I became responsible for teaching others about the concepts through animation, I felt that I really had to understand what I was talking about and learned a great deal from the process.

Figures 1 and 2 show an edited series of frames from Marianna's animations communicating what "nano" scale means and what "block copolymers" are. The original animations were produced with Flash and are in color.

The Visual Metaphor

Another tool we are exploring is the use of the "Visual Metaphor." We consider this exercise as a means for students and others to initially grasp a particular concept in science. We also anticipate incorporating this kind of thinking in various undergraduate courses in 2005. In June 2004, we posted Figure 3 on the MIT homepage along with the following text:

The Envisioning Science project in MIT's School of Science is piloting a series of programs to develop new ideas in the visual representation of scientific concepts. Thinking about how to visually translate and communicate ideas in science is both a powerful teaching tool and an approach to finding an accessible language to communicate science to the public. The visual metaphor on today's homepage is a reference to "templated" or "directed" self-assembly. In this example, chairs set up for graduation are a "template" for parents and will direct them where to sit. (Does the image in Figure 3 remind you of some other concept in science? Felice Frankel would like to hear from you. Send your ideas to felicef@mit.edu.)

Self-assembled systems are expected to become increasingly valuable for the fabrication of nanoscale or molecularly based devices. Moreover, almost every other area in science

Figure 3. A directed self-assembled system?

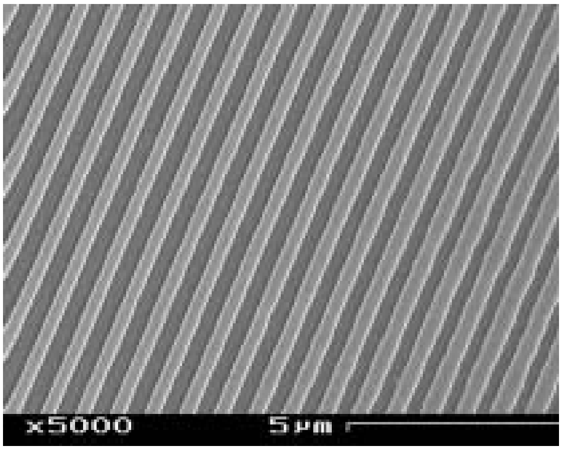

Figure 4. A template directing the uniform assembly of block copolymers.

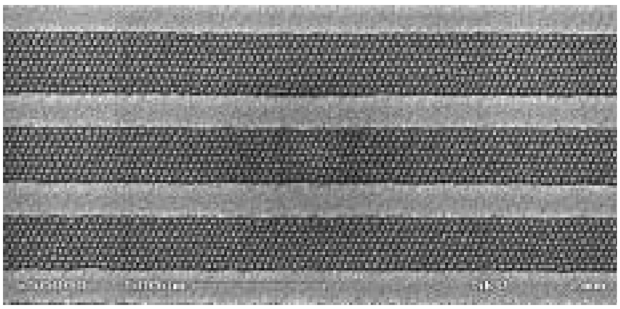

Figure 5. Block copolymers.

involves principles in self-assembly. The most widely appreciated example of a form of templated self-assembly is the replication of new DNA, as older DNA acts as a template for new strands.

> *MIT postdoctoral associate Joy Cheng's grooves, seen in Figure 4, do something similar. The grooves are used as a template to direct the uniform assembly of certain materials called block copolymers (Figure 5).*

Conclusions

Although our experience is at this point anecdotal, we believe we have introduced an important idea in teaching and learning science and engineering. Teaching students (who include the next generation of researchers) to insightfully think of how to visually represent science to others could have a profound effect in advancing their understanding of science. As research becomes more interdisciplinary, our need to discover new ways to talk to each other continues to grow. We believe that the visual expression of scientific ideas will begin to fill this need. Just as important, students who would not ordinarily consider science as part of their educational experience might, in fact, become drawn to science as they see and use the more welcoming and accessible tools of the visual language.

> *"We only see what we look at.*
> *To look is an act of choice."*
> *—John Berger,* Ways of Seeing