Implementing New Media in Materials Science Education

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Abstract
New media offers a chance for the Materials Science instructor to rethink course structure and content. New media is just an addition to the variety of tools available to the Materials educator. I will give some examples of hypertext, video and animation, and simulations that are successfully being used to address educational goals. Through wise implementation of “old” and new media tools in the classroom, a richer educational experience will result.

Dispelling “Multimedia Dread”
“Multimedia dread” is prevalent in universities these days. Many professors feel they should use multimedia, or are told they must use multimedia to keep the department in step with the times. There is a simultaneous perception that media is difficult to use or understand, that it is displacing the instructor, that it is not an effective teaching tool, or that it requires the instructor to be an expert in multimedia authoring. Most professors still dread the idea of incorporating media into their courses. The goal of this paper is to show that new media is really just another tool in the educational toolbox, that it effectively solves some educational problems, and that it should be approached like all other media in terms of how it is used in the teaching environment.

The new media are becoming an important component of education due largely to the ready availability in the last few years of powerful, cheap desktop computers. Also, the “new student” is a member of the MTV generation, and is used to absorbing images and information much faster than the previous generation, and in a different way, in “information chunks.” It is wise to take advantage of new communication techniques made available by these new computing tools, particularly when we must adapt to meet the new learning styles evolving from use of these media outside the classroom. Use the new media to fill in the gaps, not to replace what is already going well.

By the end of this article, you should have a familiarity of the educational needs addressed by new media, the new media development and implementation process, and the current state of the art.

Consider some of the features of the old media. Lectures are a good way to simultaneously expose large numbers of students to new ideas, and represent and give opportunity to impress students with a sense of the instructor’s excitement about Materials Science. The features missing from lecture are the opportunity for students to get interactively involved in the material.
New media has caused us to reevaluate what was worthwhile about the lecture process, and incorporate it with alternative tools.

Likewise, no one has abandoned print as a good way to distribute core information. Print is a good way to expose students to information for the first time, and it is a good distribution medium: it is extremely portable. The value of print has not diminished just because we can now put words on screen as well as on a page. It is much easier to read on paper than on screen, and studies have shown that we retain much more reading on paper than on screen\(^1\). Do not be afraid to use print because it seems passé. There is no more effective way to distribute information on complicated subjects that require extensive verbal explanation. The key word here is *verbal*.

There are many cases where verbal explanation is not enough, and has never been enough. Labs have traditionally been used to introduce students to experiences that they can’t assimilate by listening or watching in lecture, or by reading and looking at pictures in a book. Labs let students make the kinesthetic connections with the concepts they are learning in class, and verify for themselves that some of the equations on the blackboard relate to verifiable physical phenomena.

Sometimes, however, physical phenomena are elusive. The reason multimedia has caused so much stir is that sometimes we can’t see or measure things that we need to understand, but we can model them or animate them. Computer modeling can be used to show complex structures in three dimensions that cannot be viewed physically. Videos can be used to show processes that are too dangerous to replicate in a university laboratory. Computer animation and simulators can be used to animate theoretical concepts.

There is no question that three-dimensional rotating pictures are superior to the static images in a book or on a blackboard. This gap in the toolset used by Materials educators was always felt, and new media was used as soon as it became available to fill in these gaps. There are few Materials departments that have not assembled a small collection of videos of steel forging, animations of Body Centered Cubics, and movies showing movement along phase lines in a phase diagram. They are obviously useful, and can easily be integrated into a lecture, or distributed for viewing in lab. This type of new media does not force us to work outside of the old paradigm, so it is easy to accept and integrate. I’ll begin the examples below with a project that grew out of some of these static videos and animations, originally intended for lecture purposes. These types of new media are *non-interactive*, and don’t force us to think about educating in new ways.

Think of interactive media as lab work on screen. Like good labs, it is challenging to create interactive presentations and exercises that are not just click-and-look, but are not so complex that they cause the student to give up in frustration. I will show some examples of hypertext projects that include true interactive exercises, and which use hypertext to guide the student in personal pathways through lecture-based material. Some of these examples use hypertext to invert the course, placing the overarching themes at the beginning, and allowing the student to wend their way down to the theoretical nitty-gritty. It is in this mode that hypertext and other interactive tools force us to reexamine the way we teach.
There are also examples of software tools that require interactive participation by design, such as simulators, mathematical calculation programs like Mathcad, and professional Materials simulation tools. These programs can be used to get the student involved in the theoretical side of Materials education, just as labs get them involved in the physical side. Exercises can be scripted that require students to use these tools, or they can be incorporated as part of a larger presentation.

Finally, I will show an example of hypermedia used as a tutoring system, in which it is used to capture some of an instructor’s knowledge of typical student questions and confusions, and has a set of responses that mimic one-on-one interaction with a human being.

The more interactive the media is, the more options it gives us to address learning in ways that are different from the traditional media styles. These options are intended to show the breadth of what can be achieved with new media, and give a sense of the current state of the art.

**Problems and Solutions**

**Customizing the lecture**

The first problem with which educators have been grappling for years is that lectures can’t be custom-fit. You only teach a class once, in one way, during each semester. In that class there will be a wide range of student learning styles and levels of preparedness.

By adding hypertext and interactive media to class assignments, it is possible to address a wider variety of learning styles. Hypermedia can be very effective for students who have trouble with the traditional lecture/text format. It allows them to take tangents into background or advanced material, bring up supplementary media or tests, interesting side notes, and simulations, all without forcing an entire class to follow along with them. It allows them to explore problems visually instead of textually, and to experiment with problems to test their own knowledge.

As an example, consider John Russ’ CD, *Materials Science: A Multimedia Approach*. This project started with a series of animations and videos for teaching Materials Science in the traditional format, along with representative theoretical problems requiring calculation and graphing. The goal was to give students a closer contact with the media, and to customize their learning experience. Hypertext tools such as searching, topic indexing, and pop-up boxes (the hypertext equivalent to parenthetical comments, like this one) add organizational structure to the media examples. The computer presentation allows pictures to move, quizzes to give answers, and math to recalculate. The student can now take a very individualized look at the contents (See Figure 1).

PWS’ editorial and production staff worked with Dr. Russ to develop a more sophisticated interface based on his original Hypercard version, and test it with students and professors outside of his university. We helped refine the navigation, calculation and help features, and ported it to the Windows platform.
Consider the hypertext interface design. The opening screen was designed to give students access to all parts of the program from a single hypertext screen - similar in nature to a table of contents for a book. On the table of contents screen, several layers of information coexist using a visual representation of the modules, with text hidden underneath. Rolling over each of the module cubes brings up the module title, so that all the titles don’t have to be visible at once. Clicking on the cube produces a table of subtopics. Rolling over the subtopics highlights them so it is clear which one has been clicked on. All of this has been designed to help a student get to the piece of the course in which they are interested quickly and easily.

Most of these functions are duplicated as menu items, so that navigation can take place from within the individual topic pages as well.

Now consider the section on cubic unit cells in Chapter 3 (Figure 2). The hypertext and buttons at the page level show that there are many ways to examine the information on Cubic Unit Cells. There is a brief textual explanation, with some highlighted text in color, indicating that we can click on the colored parts and have them do something useful. Movies can be paused and replayed until the concept is clear.

The *Einstein button* on the lower left of the screen is used to launch one of the parenthetical comments described earlier - he’s known as the “Pop-up Professor.” These parenthetical comments give the student a little extra push while they are exploring information. There is also a mathematical example in Mathcad that goes with this topic, launched by the *Problems button* at the bottom center of the screen. Now, depending on the learning style of the student, they may choose to go linearly to the next or previous topic in the sequence, or they may choose to perform a search on the term “BCC” to see where else it appears in the study of Materials Science.
The student using this program can see multiple representations (visual, textual, mathematical) of a single concept such as BCC structures, they can get help on the principles used to develop the current topic, and they can see how the study of BCC structures relates to the rest of the course. This CD really functions like an expanded textbook.

Since this CD gives a linear presentation within each section of the material, it can be used as an extension of existing classroom techniques. It is possible, however, to use hypertext not only to link concepts and representations together, but also to restructure the way we think about the course materials, and hence how we teach them.

**Motivation through context**

The next educational problem that can be addressed using multimedia is that of context for skill study. There is a trend these days in engineering curricula towards case-based learning because the linear structure of lectures and textbooks often puts the cart before the horse in terms of why we study various topics. The origins of the linear lecture system lie in addressing the many levels of student preparedness. In explaining how something works, we need to be sure that all the supporting concepts are well developed in the student’s mind. However, it may be hard for students to see that studying atomic structure will help them to understand macro material properties, and hence to understand why steel is a better choice for bridge building than aluminum, for example.

It is possible to let a hypertext component of a course assist with this transformation of subject matter. If the hypertext structures is “inverted,” that is, case-based, it can create a compelling reason for study of underlying topics. This type of hypertext structure allows stream-of-consciousness connections between topics. Students will want to follow pathways into the theoretical and mechanical aspects of materials science if the top-level goal/concept is interesting. Then they start asking questions about “why” and “how”.

**Figure 3** Screen shot of Materials by Design Web site at Cornell University.

One simple example of this type of system is the Materials in Context project on the Web at Cornell (Figure 3). It gives an overview of why one might study materials science, via the types
of products that can be made with different materials. The student is encouraged to hyperlink into the Web site and find out what sorts of materials will be studied in the class, and what the Materials Scientist does.

The challenge in authoring such systems is to invert your thinking about a course, and then give the hypertext reader some threads back to the top level concepts. It is very easy to get “lost.” Words cast as hypertext must be judiciously chosen, and the controlling navigational scheme thoughtfully designed.

The Cornell project puts overall materials menus at the bottom of each hypertext page. These are helpful for getting back up to a higher level in the project, but don’t give much of a sense of the overall conceptual design. Unlike the previous CD discussed, the table of contents no longer serves to give you an idea of everything available in the course. It serves rather to show you what you will know when you’re done.

A more sophisticated example of this approach is used in Kristen Contant’s *Materials Processing: A Multimedia Approach*, where a two-sided approach to the topic of materials processing is used. One side of the educational materials are Products: the goal. On the other side are Processes: the means. Both of these ways of looking at the course point to the central educational resources: animations, virtual labs, calculation projects, and quizzes. You can move easily in and out from one side to the other, giving a strong contextual basis for the course.

![Figure 4 A conceptual map for *Materials Processing: A Multimedia Approach*](image1)

![Figure 5 Screen shot of *Materials Processing: A Multimedia Approach*.](image2)

We are working with the author to develop various navigational schemes that will address some of the “lost in hyperspace” phenomenon. Visual and textual approaches are being tried, as well as some strategies that work on the Web, such as a list of previously visited pages. It is also possible to avoid getting cognitively lost by being selective about where a student can navigate.
It is important to be very choosy about how many words are cast as hypertext. Pages with dozens of links are guaranteed not to tell a cohesive story.

I should add that this project includes a text component as well. We discussed how best to include some of the background information that students should be able to reference while working in this inverted environment. Whenever extensive verbal explanation was required to explain a process or material, the text is moved to the printed complement to the CD. This uses print to its best advantage, and forces the authors to evaluate all their textual explanations, to see if there is a better way of explaining that will involve the new media forms instead of the old.

**Limited resources, facilities, equipment**

Once a good hypertext structure is in place, we can address the problem of student access to physical experience. Physical laboratory space and equipment is often at a premium, limiting the experiments that can be done, or limiting the time each student gets to have hands-on experimental time. There are also many types of processes or measurements which can’t be done in the university environment because the equipment is too expensive, or the process is too dangerous.

Virtual lab access may not be a perfect replacement for the physical reality, but it can allow students to get lab access earlier or in cases where they would not get it at all.

Several of the multimedia projects already mentioned use images, video and virtual lab manipulation. John Russ uses video footage of fracture and stress tests, chemical reactions, and microscopy sessions to demonstrate experiments that students might not get to perform. One particularly entertaining set of videos documents a group of students demonstrating dispersion strengthening using frozen Jell-O, and a Jell-O composite containing crushed peanuts. The movies follow the students through the experimental process to a mechanical test of each specimen in which the material is fractured by repeated blows from a dropped 3-pound weight, from increasing heights.

Kristen Constant’s project contains a number of virtual labs, which add an extra level of participation. In some of her setups, the student can drag items around on the screen to simulate, for example, a particle grinding and sifting process: they pick the sieves, pour in the slurry, and later remove the contents of each sieve and graph the virtually-measured results.

It is easy to imagine the use of professional molecular modeling tools in this same context, as a virtual ball-and-stick model kit. These virtual models have the advantage that they can contain mathematical as well as physical properties, so the types of experiments can be extended in ways that wouldn’t even be possible in some physical labs. They aren’t a substitute for experimental hands-on experience: it is important to know how to run a microscope if you are going to use one professionally, but multimedia labs can allow students to participate in these types of experiences much earlier in the curriculum, or on a much more personal level.
Some students are fortunate enough to have access to well-stocked labs and facilities where they can see materials science being practiced. The trouble here is often that their inexperience with the subject matter does not allow them to appreciate what they are doing.

Inexperience can cause limited returns on labs not just because students won’t get the point, but sometimes because they may do labs incorrectly, and not realize it until well after the lab period is over. Prelabs have always been used to try to avoid this problem, but by using new media it is possible to give the student an experience which is much closer to reality, or which combine visual, theoretical and physical representations of concepts. These new media simulations can be much more useful for getting students prepared for the laboratory experience.

Some of the multimedia tools described before contain virtual labs, whose intent is to mimic lab experiences or show the student what can happen under different test conditions. But these won’t necessarily prepare a student to understand what the experiment is showing them. Prelabs should be addressed with simulation tools and multimedia worksheets which are specifically designed to prepare a student to perform and interpret experiments correctly.

Marc DeGraef and a team of students at CMU have been developing X-Ray diffraction simulators for use in a crystallography course. They do have the appropriate equipment to take X-Ray diffraction spectra, but it is tough for the first time student to know what to expect when using one of these machines. The simulators they have designed do not just mimic the measurement and analysis, but also incorporate visualization and animation of the appropriate crystal structures. The simulator has been specifically designed as a teaching tool, to address the prelab need. These tools won’t handle high-level spectral analysis, but they do help students to gain insight into the physical technique and its implications to the crystallography theory they are learning.

There are other good examples of simulators, for example the set of Java applications being developed by John Pilling at Michigan Technological University, for various microstructural simulations. Using Java on the Web he’s made this set of software available to a much wider audience. Again, these tools are designed to teach, rather than to complete professional analyses.

I stress this difference because it is possible to use professional software tools in a similar manner. Worksheets can be designed using commercial software that will serve some of the same functions. However, these tools are typically not designed to be educational. It is necessary to strike a balance between how much effort is spent teaching the use of a tool itself and how much effort is spent teaching the actual course theory.

This dilemma can be resolved either by choosing software that is so easy to learn or of such critical professional value that it is valuable to incorporate its use into the curriculum. That choice is a very personal one for each instructor. There are several mathematics packages that come under this kind of scrutiny regularly. The resulting worksheets can achieve the kind of educational emphasis that is designed into the simulators described above. For example, Keith
Bowman at Purdue\textsuperscript{8} has produced Mathcad implementations of several important calculations in Materials Science. He developed these worksheets because he wanted to inspire students to use the tool as an extension of themselves, and felt that the interface was simple enough that they could work up the learning curve quickly. Any tool should ideally function as an extension of the student.

**Lack of immediate feedback**

No matter how many tools you give your students, no matter how many exercises and prelabs are assigned, no matter how you try to structure the course material, there will always be questions from the students. The real problem in almost any educational environment is that there aren’t enough teachers to answer the questions right away. Often, students take a wrong turn in a homework or lab, because they’ve answered their own question incorrectly, and they don’t have a way to get back on track. Computers can help when they’ve been trained to answer some of the questions that you, as an instructor, have learned to expect from most students. It is possible that you can store some of this educational experience in software.

Beverly Woolf of the University of Massachusetts at Amherst has been developing some Stamping and Molding simulators\textsuperscript{9} using artificial intelligence techniques that do just that. Using animations and a knowledge base of correct forms for developing molds and stamps to produce various injection molded parts, she has the student design and devise manufacturing for three-dimensional part. If the student makes a wrong turn somewhere in the process, the program catches the mistake, and guides them to some diagrams and animations that show them what would happen if they did it the wrong way, as opposed to the right way. This back-and-forth training technique helps students to assimilate the material much more quickly, because they don’t get “stuck” halfway through the problem.

**Introducing Multimedia into the Classroom**

If you are contemplating teaching with multimedia, remember the most important tenet of all educational media: define your educational goals. Many attempts to use new media result in student and faculty frustration because the goal was to incorporate “multimedia” and not to teach more effectively. The best strategy is to evaluate the shortcomings of your present environment, and then choose media tools that address those problems. For example, if your students have trouble understanding phase diagrams, putting a phase diagram on the screen is not better than putting it in a book. But if you find or generate media that make the diagram an extension of the student’s thought process, and lets them manipulate it in symbolic and conceptual ways, then you’ve made an improvement on the process.

Additionally, ask your students to get involved in the decision. Their perspective will be very different from your own. I have done significant beta testing with students, and find that students will offer strong and intelligent opinions on what works for them. Instructors are good judges of the quality of the educational materials, but students are good judges of what helps them learn, and offer terrific opinions on how to improve products like the ones mentioned above. If you
involve undergraduates in the process of selection, you may also gain insight into what areas concern them most, which will also help you to choose media.

**Conclusions**

New media offers us an opportunity for self-evaluation. Use the advent of cheap, ubiquitous computing as an opportunity to reflect on what’s working well in your teaching, and what isn’t. The instructors who created the tools above developed their initial plans this way, and were true to their goals, as demonstrated in the examples.

I have demonstrated a project in which hypertext is used to bind a course together and give the student the freedom to explore the content in their own personal path. I’ve shown examples of inverted course structure using hypertext and virtual labs, which will affect not only the way the new media is used, but also the old media. I’ve also discussed the relative merits and traps of developing educational simulators vs. the use of off-the-shelf software tools.

The success of the projects I’ve used as examples is due to careful planning and collaboration between developers of diverse talents. I have found that the scope of the team is very broad, including instructors who teach with new media, and the students who must learn with it. Since the people who use new media ultimately determine the success or failure of a new media project, its important for them to be involved in the development process.

New media works hand in hand with old media. New media solves a number of contemporary curriculum issues. There are many more examples in addition to the ones I’ve shown here. One of the best ways to learn about the potential of new media is to look at what other people are doing with it. You have the option to choose both the media and how you will teach with it. It is much like choosing a textbook, and with the same goal: offering the best possible education for your students.

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**References**


2 Mathcad Software is manufactured and distributed by MathSoft, Inc., http://www.mathsoft.com/


