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# WHITHER/WITHER THE PHYSICS TEXTBOOK IN AN ACTIVE/INTERACTIVE ERA?

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The textbook still seems to be the core element in the large introductory university physics course, determining the content, pace, notation, and orientation taken by the instructor and students. Yet a number of trends seem to portend deep change in how the textbook is conceived and used. Few instructors are satisfied with the textbook: "It covers too many topics, it does them in the wrong order, it doesn't do things in the way I like." Few students actually read the textbook. Research has increasingly demonstrated that "active learning" is much more effective for students than the "transmissionist telling" that seems to be the model for most textbooks. And finally, an upcoming generation of students seems much more comfortable with obtaining their information on-line, often with active game-like components and video. In this paper, I explore some ways text can be adapted to the current university physics learning environment that is increasingly incorporating more active learning elements. I then consider the future and whether web documents with interactivity will lead to the textbook's just "withering away" despite its apparent current vitality.

## 1. Introduction: Both learning and text-delivery environments are changing

The many different stakeholders involved in the construction and use of introductory university physics textbooks conceive of them as playing many different roles.

- Authors see a textbook as a way to establish their vision of a course and its content, build their academic reputation, and perhaps achieve financial success.
- Faculty adopters see it as a way to simplify, guide, and coordinate their instructional delivery.
- Students see it as a resource, a requirement, an encyclopedia, and a financial burden.
- Publishers see it as a revenue source.

We can consider the text from any of these perspectives and more. In this brief think-piece I consider the physics textbook and text materials from the point of view of delivering effecting instructional environments to help facilitate student learning.

Physics educators and developers of instructional environments have sought alternative approaches to the physics textbook for decades – computer tutors, self-paced instruction, distance learning. Despite this, the introductory college physics textbook is still with us. The textbook of today has not only failed to wither away, it has burgeoned – grown into a costly, overweight, cumbersome, and difficult to use encyclopedia packed with information. An introductory physics textbook now typically has over 1000 pages, full color pictures, cute drawings, and examples and photos to "make the text relevant to everyday student life." There are dozens of competing textbooks and even marginally successful ones come out with "new" editions every couple of years. On the surface, this looks like an incredibly successful component of our education system.

Nonetheless, in practice, most students buy a textbook only because the professor assigns problems (or readings) from it and because it contains collections of data (equations and factoids) that they can use to solve the required problems – or answer questions on a recall-without-thinking exam. In my experience, few students read their textbook as a part of their development of their knowledge of physics, and few keep their text as something of value after they have finished the course. (This is somewhat less true at the more advanced levels, but there is still some resistance to reading text.[1]) Despite this, textbooks still exert a powerful influence on introductory university physics classes, controlling content, pacing, notation, and orientation.

Although the text is still the nominal core of a physics class, in practice, things are beginning to change. As a result of research in physics education at the university level, the delivery of learning environments in physics has been evolving for more than a decade to include a collection of materials that may include a traditional narrative (textbook) but that may also expand to include more active-learning components, such as group-activity worksheets, laboratories, and in-lecture interactive demonstrations. The coordination and synchronization of these materials is an important step that we are now struggling with.

In this paper I focus on two of our goals for student learning in physics and discuss how text materials can contribute as one of many possible ways of engaging our students and helping them to accomplish these goals.

Our first goal is that students learn in the small – the facts, procedures, and sense-making of basic physics concepts and principles. Textbooks contain facts and items explicitly and often allow students to find them easily, but they do not always serve sense-making well. In the past quarter century, physics education researchers have demonstrated that creating active-learning environments – minds-on as well as hands-on – are more effective than the simpler-to-achieve transmissionist environments: didactic lectures plus assigned reading in a textbook and homework from traditional end-of-chapter problems [1].[2] In section 2 of this paper, I consider some of the issues in integrating text materials with these newer active-learning environments. As an example, I discuss *The Physics Suite* [2], an attempt at integration that my colleagues and I in the *Activity-Based Physics Project* [3] are carrying out.

Our second goal is that students learn in the large – that they make sense of the relationships among the various parts and that they build a broad, coherent, interlocking web of knowledge. The introductory physics textbook, as it has convergently evolved over the past half-century, does not serve this purpose well. Although some of the alternative approaches mentioned above are modular and attempt to give overviews (e.g., PhysNet [4]) they have not caught on. The web offers possibilities along these lines that could be much more effective in helping students develop a breadth and coherence to their physics knowledge. In addition, the web is likely to break the lock publishers have on the delivery of text, producing dramatic changes. The multi-tasking graphical user interface of modern computers and the universal web-delivery system offer powerful opportunities for extending and expanding the delivery of text information: through structuring and linking, the association of multi-media and text – videos, calculational tools, simulations, etc. In addition, new group authoring tools such as Wikis have powerful implications for the longer term. I discuss the web in section 3.

[1] It is my sense of more advanced students' textbook use that they tend to follow the equations but skip or only skim the author's carefully constructed paragraphs of text.

[2] Faculty teaching classes in this traditional mode often assume that students will create and carry out their own intellectually engaged active learning by themselves. This proves to be the case for only a very small fraction of the students. Many fail to do this because they either don't know how to, or because they think that it is not required.

## 2. Research has shown that "active-learning" is more effective than passive

### *2.1. Many developers have created effective research-based learning environments.*

Researchers in discipline-based physics education research (PER) [1] have been studying specific student difficulties for 25 years. As a result of this research, they have developed a much better understanding of the kinds of challenges physics students encounter. Building on this research-based knowledge, developers have begun creating learning environments through a cycle of research and re-development. (See figure 1.)

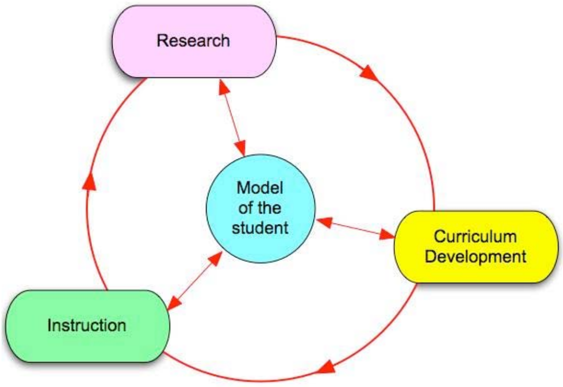


Fig. 1: The research and re-development cycle for the creation of effective, well-tested, and well-documented learning environments.

In discipline-based PER, a philosophical and theoretical consensus of curriculum design is beginning to emerge. This consensus is based on a constructivist model of student thinking and learning and a peer/mentor supported active-learning model of the classroom. Some examples of these environments include:

- *Peer Instruction*, conceptual problems for use interactively in large lectures [5]
- *Tutorials in Introductory Physics*, group-learning worksheets for developing conceptual reasoning skills and learning basic physics concepts [6]
- *Workshop Physics*, a full laboratory (no lecture) environment enhanced by powerful computer data acquisition and analysis tools [7]
- *Real-Time Physics*, a concept-building laboratory environment using the computer tools of Workshop Physics in a more traditional lab setting [8]
- *Interactive Lecture Demonstrations*, a set of worksheet guided lecture demonstrations [9].
- Tasks Inspired by Physics Education Research (TIPERS), a set of research-based home-work problems [10].

Research-based active-learning environments can have a dramatic effect on improving student learning [11][12].

### *2.2. Traditional textbooks often ignore this research.*

In my experience as a teacher of introductory physics in large lecture courses, I have found that traditional physics textbooks often

- are largely didactic, giving no epistemological or empirical base for the knowledge given, introducing terms and equations at the beginning of a chapter that cannot be made sense of without material appearing much later in the chapter.
- contain highlights, boxes, and summaries to help students select items for memorizing.

- contain mostly problems whose answers can be given as numbers, listed in the back (for the odd-numbered problems).
- ignore what has been learned from PER about student difficulties, giving examples that encourage students' inappropriate associations or interpretations.

These and other such characteristics of traditional textbooks not only fail to support the proven and effective modern environments, they can confuse students, sending meta-messages about the nature of the knowledge to be learned that contradict what the new active-learning environments are trying to do. Once I began adopting active learning environments in my teaching of introductory large-lecture physics classes in the late 1990's, I began to not require that my students purchase a text, and indeed, I began to discourage them buying one.

### *2.3. A textbook can complement active-learning environments: Example: Understanding Physics; The Physics Suite*

In the late 1990's, my colleagues in the *Activity-Based Physics Project* and I [3] decided to explore whether the traditional physics textbook could be coordinated with the new active-learning environments. We conceived *The Physics Suite* – an environment that integrates a variety of active-learning environments with a transformed text.

In our conception of this project, the textbook was demoted from the central element of the class to one tool among many that could be offered to the students. At the center of our vision was a common philosophy and pedagogical approach. Briefly, we assume

- that a large fraction of our students can get value from studying physics, not just the small percentage destined to be physicists.
- that careful education research can help to identify student difficulties and resources.
- that we have to listen carefully to our students in order to understand what they really have learned. Success at traditional numerical problem solving can be misleading.
- that students learn more effectively when they engage the physics mentally and that this is best done for most students through active discussion with their peers.

This is explained and discussed in detail in the teacher's guide to the Suite [11]. The elements of the Physics Suite are displayed in figure 2.


Fig. 2: The elements of *The Physics Suite* [2], created by *The Activity-Based Physics Group*.

In order to carry out this project, John Wiley and Sons gave us permission to modify one of their popular textbooks [13]. We made lots of changes to coordinate the narrative ("textbook”) with the active-learning elements of the Suite – so many that they gave us a new title and authorship [14]. Some of these coordinating changes include:

- matching notation across the many different elements (harder than it sounds!).
- rewriting didactic elements to motivate and base them in experience and experiment.
- elaborating issues known to be difficult or confusing for students, taking into account what has been learned from PER
- replacing artist-constructed idealized graphs by real data of the type the students might take (or see taken) in the other elements of the Suite.

This last point is illustrated in figures 3 and 4 below.

In figure 3, Newton’s 3rd law is illustrated by the data taken by two force probes attached to carts of different weights banging into each other. This experiment can be done by the students using the same computer assisted data acquisition equipment in other elements of the Suite – RealTime Physics, Workshop Physics, Activity-Based Physics Tutorials, or Interactive Lecture Demonstrations.

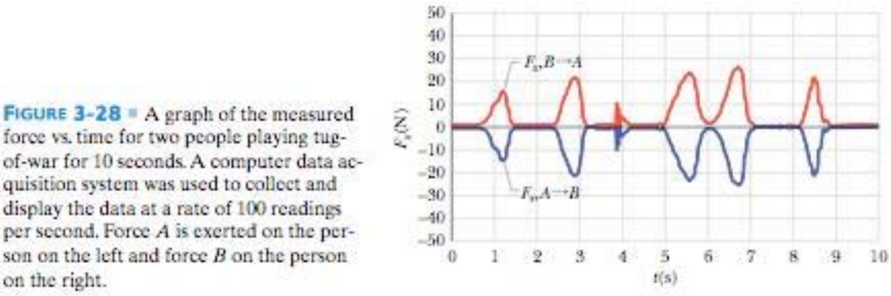


Fig. 3: A figure from *Understanding Physics* showing Newton’s third law by displaying the forces read from two force probes attached to carts of differing weights [13].

In figure 4, the data taken from a video of a walking woman is converted to a graph using *Videopoint*™, a tool for taking data from videoclips created for and used in Workshop Physics.

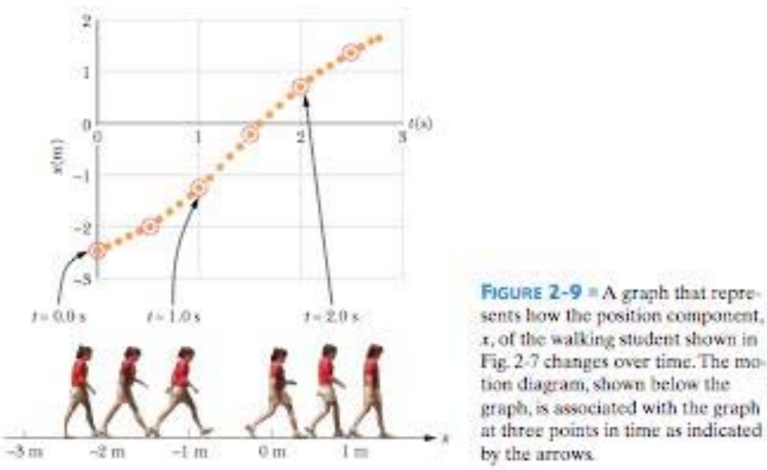


Fig. 4: A figure from *Understanding Physics* showing the mapping of linear motion into a graph of position [13].

It’s not enough to just transform the text so it doesn’t get in the way of active-learning elements in a course. One should begin to have the text encourage more self-motivated active engagement while reading. Here are some of the things we have tried to do in our text for The Physics Suite, *Understanding Physics* [14].

1. *Take an epistemological orientation* – Instead of simply stating results, a text can try to begin where the student is beginning and work through reasoning that takes one to the desired conclusion. This encourages the student to focus on how things are figured out, not just on the results.[3]
2. *Provide well-chosen "stop and think" problems* – Include frequent "reading exercises" that challenge well-known student preconceptions and are good starting points for a class discussion.
3. *Remove the chapter summaries and help students learn to build their own* --- Creating one's own summary is one of the most effective tasks in learning to organize the knowledge one is developing. Giving summaries severely discourages the student from carrying out this valuable exercise.
4. *Model problem solutions but not algorithmically* -- Teaching students that problems should be approached by rote without sense making is the wrong message. Model solutions should include thinking about problem structure and mechanism, use of basic principles, and evaluation of the plausibility of the result.
5. *Offer a rich variety of problems* – Too often physics texts offer problems that are either too simple (exercises – simply find the equation, manipulate a bit, and plug in numbers to get the answers) or too hard (complex problems requiring a high level of expertise). We include a wide variety, including conceptual questions, essay questions, estimation problems (Fermi questions), representation translation problems, and context rich problems. (See [10, Chapter 4] for a discussion and examples.)

Many texts are now beginning to include such elements.

It would be appropriate if the text contained active elements of its own, but thinking on these issues appear to be at an early stage. And it is not clear how students and faculty would respond to an active textbook environment.

### *2.4. The culture of paper-based textbooks creates serious constraints.*

Despite the presence of dozens of introductory physics texts, all carefully and beautifully prepared as the cost of extensive labor by both authors and publishers, most physics texts are very similar. It would be wonderful to be able to choose from a wider range of possibilities: much shorter and more concise texts, texts that do not cover every topic in massive detail, texts with a more historical or philosophical orientation, texts that vary the order of content dramatically – say starting with optics instead of Newtonian mechanics. Almost no such texts exist (although there is some evidence that variations may be beginning to appear – see [15] for a good example).

Perhaps the greatest impediment to the creation of powerful and integrated active-learning suites is the unwillingness of many faculty to spend the time and effort to understand the results and implications of education research and to go beyond teaching the way they were taught. They largely focus on "What content should I present?" instead of "What skills do I want to help my students learn?" Publishers are driven by the bulk market and tend to drive textbooks to a mediocre sameness, trying to please everyone rather than be willing to take a leadership role and explore innovative approaches. When a few faculty at major univer-

[3] Note that this does not necessarily mean taking a historical approach. An individual's cognitive learning no more recapitulates scientific history than ontogeny recapitulates phylogeny. Students begin neither with the skills nor the mindsets of ancient scientists.

sities dislike a particular innovation, the publishers exert strong pressures on authors to return to the norm. The fierce competition for trying to achieve a large market share drives out any text that isn't similar to the most popular one. (For a Darwinian explanation of why this sort of thing happens in competitive situations, see Stephen J. Gould's article on why there are no longer any .400 hitters in baseball in [16].) The growing strength of PER and increasing breadth of interest in its results may be beginning to work to change this situation. Many textbook publishers have started to add physics education researchers to their writing teams in order to create texts that are more research-based.

A second factor in textbook mediocrity is the short time in the "new edition" cycle. The primary reason that texts go to new editions every few years is to "kill the used textbook market" which would otherwise almost completely eliminate new book sales in three to four years. Publishers of texts competing for market share release new editions in a rigorous three-year cycle. The largest customers typically reconsider new textbooks in the year when their old text goes to a new edition. If you don't get your book out in the year to match the competition, the largest customers will have just switched and be unwilling to consider your variant. Publishers can exert severe pressures on authors to meet this time scale and to produce enough cosmetic changes to justify a new edition. This pressure tends to drive authors away from the more thoughtful and time-consuming activity of considering serious or deeper changes.

## 3. Web technology is changing the way we can create text environments and the way people interact with text

The internet and its associated world wide web are widely understood as being a "disruptive technology" in many areas of human behavior. A disruptive technology is one that transforms or replaces the dominant technology or product [17]. Book sales, and indeed all "brick-and-mortar" commerce have been dramatically transformed by the presence of Amazon. Travelocity and its competitors have changed the way we plan and book travel. And iTunes has transformed the music delivery industry. No such dramatic change has yet transformed textbook delivery, though some developments like on-line course delivery, can be expected to have long-term implications for university courses when an effective format is found.

According to Gould [16], the narrowing of variance in a competitive environment is a natural result of mature competition – competitors adapting to a stable environment. Only when the environment changes radically does one observe evolutionary radiations – the dramatic branching of well-established species into new forms to take advantage of new ecological niches. Web technology may be creating sufficiently different "ecological niches" for text distribution that we can hope for some dramatic changes in the near future.

In particular, two highly promising ecological niches opened by the web include environments that promise to promote our two stated goals more effectively than standard text: "learning in the small" through active-learning and "learning in the large" through new kinds of navigational visualization tools. For examples, I will draw on some of the text delivery I am currently experimenting with in my class, "Intermediate Theoretical Methods" (Physics 374) at the University of Maryland.

### *3.1. Web technology allows the inclusion of active-learning multi-media components for learning in the small*

For many years now, people have talked about how computer technology would enable "living texts" – videoclips instead of static pictures, explorable simulations instead of graphs, and complex problems solving tools such as spreadsheets, data acquisition probes, and symbolic manipulators [18]. In principle, these tools could be very effective in helping students to "learn in the small" – to pick up the detail, both procedural and conceptual.

Textbook publishers tried to jump on this bandwagon, creating CDs with videoclips and simulations supplementing their texts, but these have had little impact in practice. The web allows for a community of individuals to share resources, providing access to a wide range of supplementary tools.

In my Physics 374 class, I am beginning to explore ways to integrate these tools into my pedagogy, providing links to supplementary reading that allow students to go beyond the problems at hand, links to webpages that include simulations, and links to downloadable programs that the students can run and modify on their own computers.

### *3.2. Web delivery of text allows non-linear structuring and linking for learning in the large*

One of the most exciting ideas in computer-based text delivery is hypertext. The earliest implementations include Ben Shneiderman's Hyperties [19] and Apple Computer's Hypercard for the MacIntosh [20]. Programs such as these allowed linking of text elements and the modes of connecting text they explored form the basis for the now well-familiar world wide web of information.

Although text delivery using the web over the Internet is now common, there has not been much study of how to best structure text materials in order to facilitate the learning of complex topics by novices. For example, the on-line encyclopedia, *Wikipedia* [21], provides the a page of information on Fourier series, a topic I discuss in Physics 374, beginning on the page shown in figure 5.

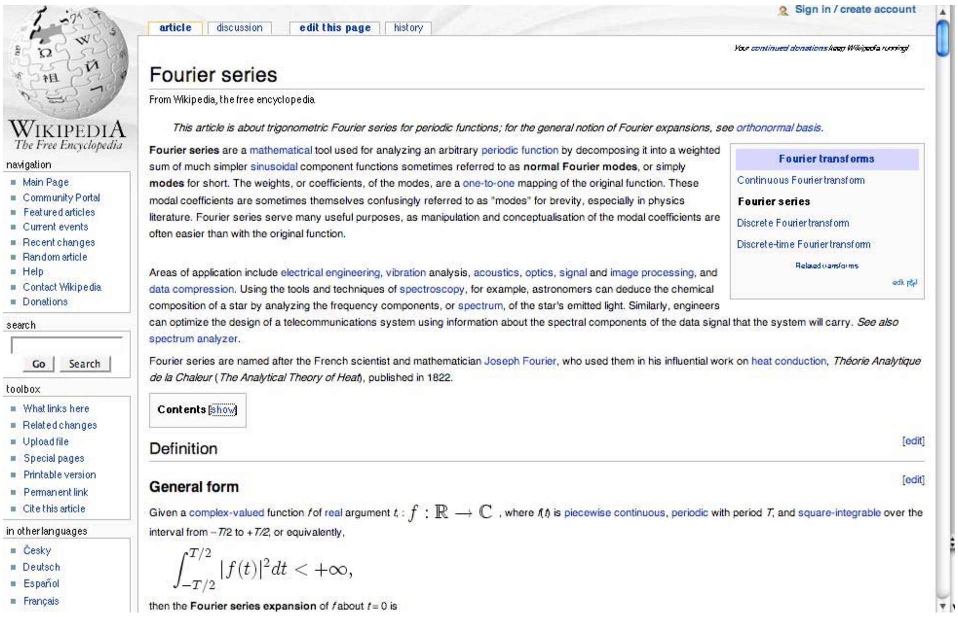

Fig. 5: A page from Wikipedia [18] giving information on Fourier series.

The page contains a linear table of contents outline plus every sentence contains links to pages explaining technical terms. This material is encyclopedic (as intended) rather than pedagogic and it takes what appears to be an unplanned approach to linking. That is, the text is written in a linear fashion and then links are added after the fact to any term that has available information on other pages.

Although Wikipedia is an extreme case, many web-rich instructional environments "grow like Topsy," with links being added almost by whim, with little attempt to produce a way for the users of the web environment to obtain a coherent overview – to "learn in the large."

An alternative and an approach oriented more to helping students build breadth and coherence is to realize that students often don't really have any idea why they are doing what they are doing at any particular point in time; they have trouble getting the "big picture" and putting the bits of knowledge they are struggling with into perspective. The use of linked hypertext with appropriate navigational visualizations might provide structures and markers that could help students see broader relationships.

In figure 6 below, I show the main elements of a set of text materials I am creating on the web for my Physics 374 class. I plan to use the hierarchical tree structure with progressive disclosure as a table of contents and to use the tree reduced in size with different boxes highlighted as icons at the start of each text element to show which items the text relates to.[4]

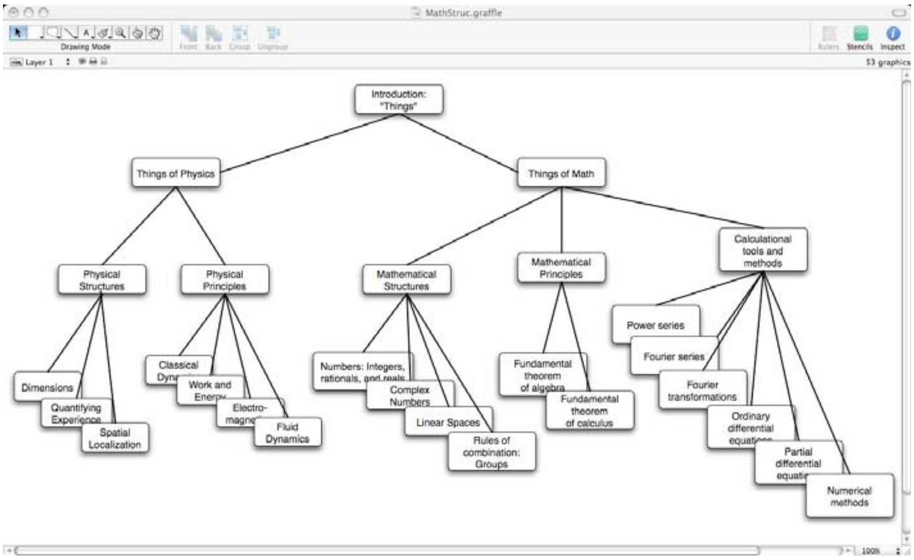


Fig. 6: The structure for the content for a web text in mathematical physics.

A second element one might introduce is iconic markers to identify threads and motifs throughout the material. In my Physics 374, I want students to focus on the issue of thinking both about the physics and the math and weaving their knowledge of the two subjects together. This is often problematical for them: they either use their physics knowledge or their math, often making bizarre errors by cleaving to one side or the other. To focus students on this issue, I have created a diagram that allows us to talk about the components of blending the two subjects together. It is shown in figure 7 with associated icons that will identify the components of various problems and readings available on the class website.

[4] Such trees have occasionally appeared in texts – especially large complex ones – to help students get the big picture. But the dynamic capabilities of the web may be able to enhance the effectiveness of these diagrams dramatically.

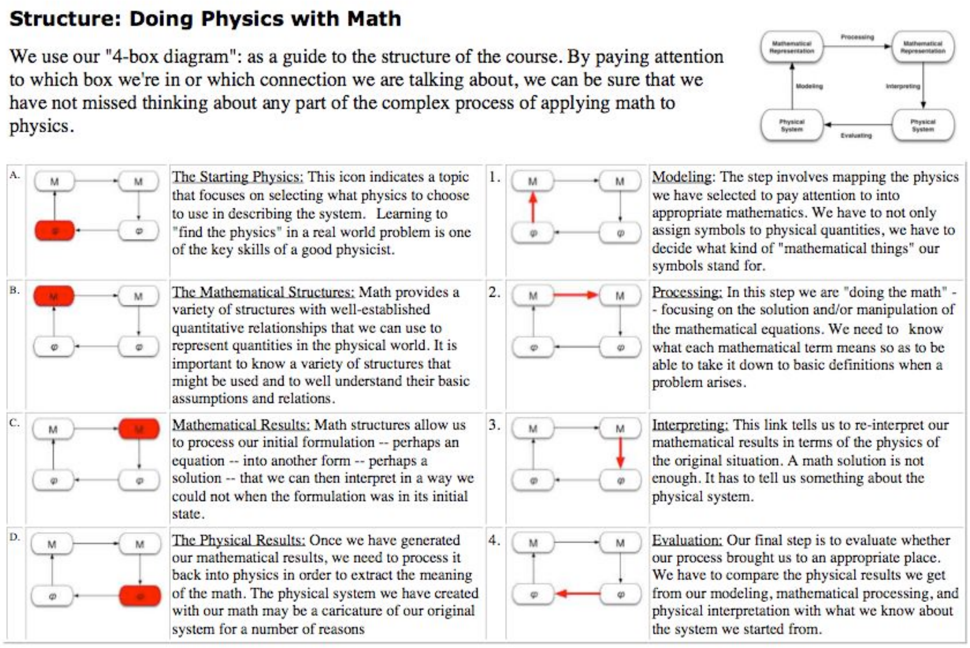


Fig. 7: Illustrating the use of iconic markers to place diverse text items into a broader perspective.

These web approaches offer the possibility of getting students to take a longer view and to begin to see the relation among the many elements of the class. Of course there is always the problem that students may get "lost in hyperspace" – a problem identified immediately upon the creation of hyperlinked material in the 1980's. Unfortunately, this is an issue that is often discussed but not yet solved. Much research will be needed on this in the next few years.

### *3.3. Wikipedia allows a community to create a text*

A final point about web delivery is that it can be more dynamic and evolving than a printed text. It can involve many authors and be less focused on deadlines and a production cycle. One example is the Wikibook, built on the Wikipedia model.

Wikipedia [21] offer more than just an on-line example of hypertext. This on-line non-commercial encyclopedia has the intriguing feature that it is developed by a community rather than by an individual. Anyone can contribute or modify an article. As of this writing, Wikipedia has more than 1,000,000 articles in English and translations of many of those articles into many other languages. This technology would permit a group of interested teachers (perhaps a group of 25-50 authors) to jointly construct an online textbook. Text materials produced by such a collaboration might have a different look from the textbooks currently created by one, two, or four authors.

This could also help break the cycle-time lock that impedes traditional textbook improvement as it could evolve incrementally. Moreover, a Wiki text could be more blog-like, having frequent links to the many excellent web-based simulations that are beginning to appear and including student questions and author responses. The problem remains of finding a way to create a revenue stream to support such activities.

## 4. Conclusion

Technology is changing the pattern of text delivery in many ways, offering many new opportunities not just for delivery of materials but also for restructuring them. But a rapidly changing environment produces dangers as well as opportunities. For example, putting large efforts into developing materials dependent on a particular software or hardware element could result in losing the fruits of those efforts as markets change. What is needed is the development of a deeper understanding not only of what is possible, but what the issues are and what works.

Most publishers seem to have not yet understood the implications of either the new educational research stressing active learning or the way technology is offering new opportunities for delivery mechanisms. I expect that “GarageBand” is a better metaphor for what is about to happen to textbook delivery than Amazon [22]. GarageBand is a program that allows a small group of individual musicians to produce CDs of nearly professional quality, obviating the need for multi-million dollar recording studios. The songs and CDs produced by these small groups can be distributed on iTunes cheaply and easily. Major marketing teams are replaced by “Hot Bloggers” – independent reviewers who seek out new and interesting music and spread the word quickly and effectively on the internet.

Sony and Deutsche Grammophone are still multi-billion dollar operations. They have not yet been shut down by GarageBand and iTunes. But most of the CDs I buy are from individual producers and the writing is on the wall. It is possible that individual authors and groups of authors will be able to implement both the active learning components and hypertext navigation cheaply and easily on the web without the intervention of publishers. Will the textbook “wither away” to be replaced by active learning components and interactive web delivery with marketing replaced by faculty collector pages and student reviews? Not today or perhaps even tomorrow, but it is clear that some dramatic changes will happen – and soon.

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