How Does the Delivery of Information Help Students to Learn?

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INTRODUCTION

At Toronto, we have been using the web to deliver information to Physics undergraduate students since September 1996; for the 2000-2001 academic year we delivered 1.2 million web documents to these 1500 students.*

In 1997 I introduced the term *encapsulated* as a way of classifying the type of information that was being delivered [Harrison, 1997]. Briefly, encapsulated information:

- Has only a few "quanta" of information.
- Exists in an already known context.

Encapsulated information can be read effectively on a computer screen; for most readers non-encapsulated information is best read as hardcopy. This distinction effects the way in which a document should be prepared and delivered to the student.

More recently I have used the same taxonomy as an aid in thinking about what actually happens in a classroom. This has helped somewhat in approaching a question that has bothered me for decades:

> I know that students do not actually *learn* in a lecture, but something related to the learning *process* is clearly occurring. But what is it that is happening?

Another change since I last wrote about this topic in 1997 is that, at least in Toronto, we can now assume that all students have at least medium-speed access to the web. In part this is because the University of Toronto has invested significant resources to make web access available at the libraries, residences etc. Before, our use of the web was usually viewed as a supplement to the more traditional delivery methods. Now it is often the only method that is used.

In this paper I shall first review, update, and extend the concept of encapsulated information and the delivery of information on the web. Next I shall discuss how I have

* A "document" can range from a small table of specifications for a particular voltmeter to a many-page set of class notes. In total we delivered 36 Gigabytes to our undergraduates last year.

found the concept of encapsulation to be an aid in thinking about effective classroom presentation. Throughout, phrases such as “most people” or “many students” indicate that different pedagogy works for different teachers and for different students, and that there is no single prescription that works for all. Also, the word “blackboard” below includes *whiteboards*.

WEB DOCUMENTS

Recently a “Home Page for Every Course” initiative was launched by the University of Toronto. This hardly makes Toronto unique. As such programs proliferate, it is important for all educators to understand the principles of good web page design. For some years Jakob Nielsen [Nielsen, 1995 – 2001] has been writing a regular web column on these issues which are an invaluable resource. In this section we discuss only one aspect of this huge topic: delivering documents via the web. Issues such as classroom education, *distance learning* and related topics will be examined in the following section.

Above we defined *encapsulated* information as information that has only a few bits of information and that the information exists in an already known context. Examples include:

- The date, time and location of a test.
- The email address of a professor.
- The accuracy of a particular voltmeter that has been used by the student in a lab experiment.

One may anticipate that documents providing such information can be effectively read on a computer screen.

For most people, non-encapsulated information, such as contained in supplementary course notes, is read more effectively as hardcopy. In the next section we shall speculate as to why this may be true.

When I discussed this issue with students in an upper-year University liberal arts course in September 2001, the majority of the 100 students were already keenly aware of the distinction, and expected to print non-encapsulated information for their own study. Thus, the suggestion I made in 1997 that perhaps this “new” screen-based medium can eventually be effective for *all* information has still not occurred. Note that beginning students often are unaware of this distinction, and left to their own devices will make poor decisions about whether or not to print a document to read it.

For delivering encapsulated information to students, the human factors of good web page design are paramount, so that the desired few bits of information can be quickly found. We shall not discuss this important topic.

For non-encapsulated information, when the web is used properly it is only a replacement for the Xerox machine, but with the following benefits:

- The information can be updated virtually instantaneously. For example, I regularly update a supplementary document after a class in which questions or comments from the students have indicated where improvements may be made.
- Xeroxing such material always leads to either not enough copies or too many copies of the document. In the former case, the student must wait until we run off more copies. In the latter case, trees have been needlessly sacrificed.
- For many documents, putting them on the web can generate a surprisingly large traffic from people other than the students for whom they were initially prepared. We maintain a *Physics Virtual Bookshelf* in Toronto and I get emails of compliments and questions from around the world a few times a week from people who have found the site. The URL is http://www.upscale.utoronto.ca/PVB/PVB.html.

The default language of the web, *html*, is a poor choice for delivering non-encapsulated information that will be printed. This is because different browsers and choices of default fonts mean that the author has no control whatsoever over page breaks, etc. This can be particularly problematic for documents with large html tables or lots of figures. The difficulties can be so severe that parts of the hardcopy of some html documents are impossible to read.

A common and effective choice for documents that will be printed is the Portable Document Format (*pdf*) from Adobe (http://www.adobe.com/). The *Acrobat Reader* necessary to read such documents is free, and the *Adobe Acrobat* software required to produce them is fairly inexpensive.

Converting an existing html document to pdf with proper page breaks is often only a matter of iteratively adjusting table widths and inserting a few
 tags into the document, "pouring" the result into Adobe Acrobat, and viewing the result. I often make both html and pdf versions of the same document available to my students.

Beware of using pdf for all your web pages. Forcing users to browse pdf files makes usability approximately 300% worse compared to html pages [Nielsen, 2001].

WHAT'S REALLY HAPPENING IN THE CLASSROOM?

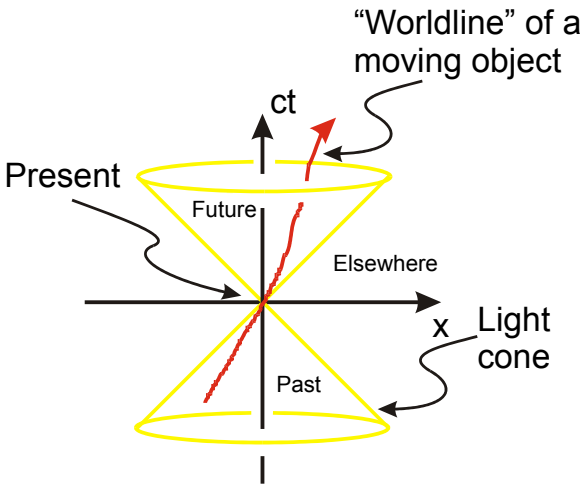
As already mentioned, I don't believe that students actually *learn* in a classroom, particularly where a large class size means that the format is almost exclusively a lecture instead of a discussion. However, something related to the learning *process* is clearly happening since otherwise the students would not continue to attend class. A few things that may be related to the learning process are:

- To do well on a test or to write a good essay or problem set requires a high degree of coordination between the students' eyes, brains, and the hands with which they write or type. The process of taking notes in class is good practice in acquiring this coordination.

- A good lecturer provides a sense of excitement and energy related to the content of the course.
- The student does not yet understand the context in which the content of the course exists. The class provides such a context. Note that this implies that the information delivered in class is non-encapsulated.

I shall argue that for many teachers these three points all mean that the use of an overhead projector or making a *PowerPoint*® presentation is a poor idea. As an example I shall use a common visualisation tool from the Special Theory of Relativity, the *spacetime diagram*. In an upper-year liberal arts course in Physics without mathematics I make a lot of use of these diagrams, and have tried a variety of ways of teaching it. The result of test questions over a number of years has pointed to one method that works best.

Although the details of these diagrams are not important here, to the right I show one. As can be seen, the diagram has a number of parts. Simply showing the complete diagram via, say, an overhead projector makes it seem a bit intimidating. Drawing it in stages on the blackboard allows us to build the complexity piece by piece. It also insures that the students have time to draw it into their notes, since I am drawing it too. Thus the correct *pace* is automatically used. Also the physical act of drawing the diagram on the blackboard necessarily requires an expenditure of some energy, which adds to the general level of energy in the classroom. Finally and perhaps of greatest importance, by using a blackboard I can leave the diagram in place while I go on to discuss it and other topics, and the student can glance back at it whenever they wish.



Of course, when drawn on a blackboard the spacetime diagram is not nearly as "pretty" as the version above. However when reviewing the topic in the next class the version that appears above, in color, is shown on the overhead projector. Finally, this "pretty" version is made available on the web.

So the three steps in presenting this topic to my class are:

1. Draw it on the blackboard.
2. Show a "pretty" version on the overhead projector in the next class as a review.
3. Make the pretty version available via the web.

I have found through trial and error that all three of these steps, in the order shown, are necessary for my students to optimally learn this material.

Although the example just discussed involves graphical information, I have found that the same process provides the best learning of textual or mathematical information.

Some colleagues respond to the above, especially the blackboard step, by stating that their blackboards end up "messy" because of poor writing or drawing skills. Recently, when discussing this topic with a group of science graduate students at York University in Toronto who are interested in education, they began to complain strongly about a professor in one of their graduate courses who used beautiful PowerPoint® presentations in class. They were essentially unanimous in preferring a messy blackboard to a neat projection.

Above I mentioned that using the blackboard allows us to keep information where the students can see and "re-scan" it for as long as they and I wish. I am beginning to think that this is one of the factors that is crucial for the delivery of non-encapsulated information in all contexts. In a classroom, using an overhead or PowerPoint® necessarily means that once we go on to another slide the previous one is not visible. For a hardcopy document, our peripheral vision allows us to quickly find and re-scan a part of the document to glance at a piece of information we have already read. This is much more natural and effective than using the scroll bars of a browser to go back to a part of the document.

An example of the problems in using a screen to learn may be helpful. When I first moved to Toronto from the Southern United States I watched a few ice hockey games on television. I had never seen a hockey game and couldn't figure out what was going on. The problem was that the action that I could see on the ice existed in the *context* of what all the players whom I could not see were doing. I was ignorant of that context, and the television medium was therefore not effective in allowing me to follow the game. After attending a few games in person, I began to understand this context and television became an effective way of learning why the Maple Leafs were losing again. Put in the language being used here, the information had become *encapsulated*.

One consequence of the above relates to basic verbal communication. When we speak with someone face to face, although we may be making eye to eye contact with the other person, we see peripherally other cues related to the information by "reading" at least subconsciously their body language. If we substitute a "talking head" in a computer monitor all these nuances and richness of the in-person conversation are lost. This implies that at least with anything resembling current technology, distance education, in place of real classroom lectures, is doomed to limited educational effectiveness.

We close this section with a final example. If one attends conferences at which research results are presented, such as many of the papers at Improving University Teaching conferences, overhead projectors or PowerPoint® are the dominant media and have been for decades. Usually this works very well, which at first glance may seem to contradict some of the arguments above. However, the fact that the audience is already familiar with the context of the work being presented may be crucial. Thus of the two criteria I have

proposed for defining encapsulated information, number of bits and a known context, the existence of a known context may be the more important of the two.

CONCLUSION

A common image of the coming educational enterprise is dominated by the possibilities of using technology to reform and re-invent the whole process. This image is so widespread that it has become the orthodox view in some circles. Certainly much of this paper attempts to be iconoclastic if not actually curmudgeonly in regards to this orthodoxy.

I have argued that whether or not information is encapsulated is crucial for deciding on how that information may be effectively prepared for delivery via the web. The advantage of reading non-encapsulated information in hardcopy may relate to the fact that we can quickly and naturally re-scan parts of the document that we have already read.

I have then proposed that by its very nature the educational process that occurs in a typical classroom involves information that is non-encapsulated. Although other factors are present, the fact that having a piece of information on a blackboard where it may be re-scanned by the students when they wish is important. The other factors include developing student hand-eye-brain coordination, setting the correct pace of the presentation, and raising the energy level in the classroom. All these factors imply that the use of overhead projectors or PowerPoint® in place of the traditional blackboard hinders the learning of the students.

For Physics education, as well as many other related disciplines, the re-scanning problem can be particularly acute since we often do long complicated multi-blackboard derivations of mathematical relationships.

The same arguments then paint a rather bleak picture of the possibilities of distance education. If our political masters end up insisting on implementing such a system, as seems likely, then thinking about the process in the ways described here may at least minimise the damage. And it is important to remember that if a prospective student is physically isolated, providing what we can by using the technology is certainly preferable to providing nothing.

Finally, using this technology for delivering information such as a timetables (encapsulated) or course notes (non-encapsulated), and even doing multi-media demonstrations in class which can then be reviewed via the web has certainly improved the educational process.

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ABOUT THIS PAPER

This is a somewhat longer version of an invited paper delivered to the 27th International Conference on Improving University Teaching conference, Vilnius, Lithuania, July 2002