From linear text to hypermedia in Physics educational documents

Authors: Víctor López (Victor.lopez@uab.cat), Roser Pintó

Affiliation: CRECIM (Research Centre for Science and Mathematics Education)

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Abstract:

This paper presents a discussion about how to transform Physics’ educational documents from printed-support to digital-support. We have not only looked at the technical features of a digital document, but we have also taken into account how students learn and which specificities of Physics must be faced in the process.

The result is a set of transformation guidelines presented in order to improve the educational quality of Physics teaching and learning materials, enhancing all the hypermedia potential. Guidelines are composed by three simultaneous itineraries: transforming from linear text into hypertext, from static pictures into multimedia files and from problem statements into embedded interactive applications.

1. Context

Our society is going through a progressive replacement of printed-support documents with digital-support documents, and therefore, education is also going through this replacement. With the entry of computers and Internet in schools, teachers, publishers and policy-makers began to invest time, money and efforts in transforming classic worksheets, static pictures, linear books, etc., into non-linear websites, virtual learning environments, multimedia documents, etc.

There are many qualitative differences between printed-support (figure 1) and digital-support materials (figure 2), such as the reading pattern, the interactivity that digital materials allow (links, control panels, simulation toolbars, etc.), and the possibility to develop multimedia communication. These differences lead us to talk about
“hypermedia”, a term that could seem a slightly old-fashioned word, but that is extremely useful to describe any digital-support document that includes the following three main features: hypertextuality (link-based non-linearity), interactivity and dynamic multimodality.

Not linear structure
Dynamic and interactive representations
Navigational links
Interactive online activities
External links

Figure 2

Those hypermedia documents have a great educational potential. They represent a chance for improving education, and thus, Physics education. Unfortunately, statements such as: “with these materials students learn better because they can press buttons and see images in motion” are rather frequent. That means that the benefits that the hypermedia materials are to bring to education are often taken for granted without any criteria, that is, without any theoretical framework. Therefore, it could seem that any change from printed support to digital support documents would improve per se the educational quality of those documents.

2. Rationale

There is a need for some general guidelines about what transformations should be done in Physics educational printed texts to obtain good hypermedia learning materials. These general guidelines should avoid the development of arbitrary, useless or weak transformations, and it should be helpful to optimally target the design of efficient and well designed pedagogical materials. That is to say it would be useful to specify the main features hypermedia materials should have to enhance Physics teaching and learning.

Nevertheless, to assure the good educational quality of these hypermedia documents we should not only look at hypermedia potential, but also at other implicit theoretical frameworks. It is important to take into account how students learn and which are the main features of learning processes (deep learning, knowledge structure, multiple representations, etc.). This framework can play a crucial role in the development of an educational approach to hypermedia designs.

We also believe that general rules for transforming classic documents into hypermedia documents should include content’s specificities. In our case, those specificities come
from Physics and Physics Education: Physics’ knowledge structure, Nature of Science, specific languages, etc. That might help us to define not only how to design good educational materials, but how to design good educational materials for Physics teaching.

In summary, we assume that different fields must be taken into account in order to determine the main features hypermedia materials should have to enhance Physics learning. These fields are “Hypermedia”, “Learning” and “Physics”, with their own intersections (figure 3).

So, we assume that the theoretical contribution of these three fields and their corresponding intersections can suggest many guidelines on the transformation process from classic to hypermedia documents (figure 4).

With this hypothesis, we aim at answering the following question: *Which transformations should be done in classic materials to obtain good hypermedia materials to enhance Physics learning?*

3. Methodological approach
This study is a theoretical discussion that was carried out throughout different processes. Firstly, we conducted a literature review of each of the fields shown in figure 3. Then, we conducted a theoretical research guided by the schema shown in figure 5, which includes some intermediate questions to deeply face the general question. Finally, we carried out an extensive review of hypermedia materials for Physics teaching available online, in order to identify examples of good practices, misuses or errors.

4. Guidelines for transformation

We propose three simultaneous itineraries for transforming classic, linear and printed-support documents into hypermedia digital-support documents:
- From linear text into hypertext.
- From static pictures into multimedia files.
- From problem statements into embedded interactive applications.

4.1. From linear text to hypertext

The transformation from linear text into hypertext implies a different pattern of reading and content organization. It is established that hypertexts differ from linear text as for the non-linear reading / navigation through links and nodes (pieces of information interconnected). They also differ in the role of links in the reading process (Puntambekar & Stylianou 2005).

We relate this hypertextual structure of a document with the learning process, where knowledge is organized and stored in learners’ mind (Bransford et al. 1999). Learning processes involve the construction of a web of hierarchically structured knowledge, where pieces of knowledge should be richly interconnected (Biggs 1987) to assure a
good and flexible retrieval of knowledge (Spiro et al. 1988). Under this assumption, we recommend the following guidelines:

- Node-link structure should be highly hierarchical: While some unorganized node-link structures promote free association and exploration (figure 6), a hierarchical node-link structure is helpful for students’ knowledge construction (Jonassen 2006).

- Navigation should be guided by meaningful links between parts: Students’ awareness of the reasons for navigating from one node to another (de Jong & Van der Hulst 2002) can be helpful. Associating links with key questions is a good way to connect concepts and engage students through the hypertextual reading (figure 7).

- Only few links should be placed in each node: Some problems have been identified with links, such as disorientation and cognitive overload (Amadieu & Tricot 2005), and for this reason only few links have to be placed in each node, leaving readers to their own navigation but avoiding these problems (Troffer 2001).

- Node-link structure should be represented through a navigation map: It can enhance students’ orientation through the document and the content comprehension (Salmerón et al. 2009).

In addition, if we take into account Physics features, those hypermedia documents should also include some specificity such as:

- Links should represent rigorous relationships from a conceptual point of view (Bramón 2000).

- Central ideas of Physics should be placed in high hierarchical order according to Physics content structure (Leonard et al. 1999).

- Node-links structure should promote a navigation pattern from the qualitative to the quantitative “equation-centred” analysis (Van Heuvelen 1991).

Different hypermedia documents available online are useful to discuss about these previous recommendations. For example, in figure 6 we can observe a node of the collaborative web Wikipedia. The location and features of the links (many links on blue-highlighted words) can be very useful for exploration, but they do not facilitate students’ knowledge organization because there is no organized node-link structure. There are too many links and they are usually meaningless. Hypermedia documents for Physics education which contain this overload of links usually misuse hypertextual potential.

Simple harmonic oscillator

The simplest mechanical oscillating system is a mass attached to a linear spring on an air table or ice surface. The system is in an equilibrium state when the mass is at the equilibrium, there is a net restoring force on the mass, tending to bring it back to equilibrium position. It has acquired momentum which keeps it moving beyond that equilibrium. If a constant force such as gravity is added to the system, the period of oscillation to occur is often referred to as the oscillation period.

The specific dynamics of this spring-mass system are described mathematically by motion is known as simple harmonic motion. In the spring-mass system, oscillations are periodic where the mass has kinetic energy which is converted into potential energy stored in the system illustrating some common features of oscillation, namely the existence of a free motion phase further the system deviates from equilibrium.

The harmonic oscillator offers a model of many more complicated types of oscillation.

Figure 6: Available at http://wikipedia.org/
Something different occurs in figure 7, where links are placed at the end of the text. Here, links guide students through the reading because they are formulated as meaningful questions to be solved when navigating from one node to another.

![Figure 7](http://reptools.rutgers.edu/)

Figure 7: Available at [http://reptools.rutgers.edu/](http://reptools.rutgers.edu/)

Figure 8 shows a navigation map where a node-link structure is represented. Even if it is hierarchically structured, the conceptual relationships between nodes are implicit and arbitrary. This can be considered another example of misuse of hypertextual potential.

By contrast, figure 9 shows another navigation map that includes correct relationships from a conceptual point of view and links (blue text) establishing clear connections between different ideas of Physics. Moreover, in the centre of the map the central idea has been placed, which can be considered a good practice. As in figure 7, links are formulated as questions.

![Figure 8](http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html)

Figure 8: Available at [http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html](http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html)

![Figure 9](http://baldufa.upc.edu/arcadi/)

Figure 9: Schematic representation of the navigation map available at: [http://baldufa.upc.edu/arcadi/](http://baldufa.upc.edu/arcadi/)

4.2. From static pictures to multimedia files
Digital-support allows the use of a wide range of multimedia objects such as dynamic gif images, real videos, Flash animations, Java simulations and other dynamic embedded objects. It allows representing concepts and processes not only through static images but also through dynamic representations (i.e., images can move, appear, change, etc.) and through multimedia support (combining sound and view). This can enhance the use of more complex Multiple External Representations (Ainsworth 2006) in order to optimize the communication of Physics concepts, and it deal with the multiplicity and density of languages (text, pictures, graphs and equations) (Van Heuvelen 1991). In addition, dynamic representations are useful to reproduce both real (videos) and realistic phenomena (digital animated images), and they allow representing time-dependent processes at different velocities. Finally, these representations are useful to reproduce complex phenomena, non-perceptible phenomena (too big or too small systems) and dangerous or non-implementable phenomena (Trinidade et al. 2002).

For example, in figure 10 a MER can be observed, composed by a video of real magnets behaviour and an animation of magnets properties. This combination of different representations can be useful to bridge the gap between real and ideal world in Physics.

![Figure 10: Picture available at: http://www.librosvivos.net/smte/homeTC.asp?TemaClave=1073](http://www.librosvivos.net/smte/homeTC.asp?TemaClave=1073)

In the transformation of printed-support to digital-support representations, some warnings and limitations must be also taken into account:

- The design of representations should follow the guidelines that come from Multimedia Processing Theory (Mayer 1997, Austin 2009) such as spatial and temporal contiguity, coherence and simplicity and non-redundancy of codes (Cook 2006).

- Considering the simplicity principle, the multimedia codes should convey the idea to be highlighted (colour, sound, movement, etc), and use dynamic pictures uniquely when it gives some meaningful and necessary information. It is important to avoid the multimedia information classified as noisy, such as unnecessary movement, overly artistic pictures, music, etc.

- Representations should incorporate necessary scaffolding: Reading of images is not a trivial process and students sometimes wholly or partly mistake. So it is important to provide the necessary scaffolding when introducing educational representations (Ametller & Pintó 2002), such as captions, explanatory text (visual or auditory) or complementary images. It is also important to scaffold the translation between different languages (de Jong 2010).

- Extremely simplistic or incorrect representations should be avoided. They may lead to alternative conceptions or misconceptions.
Colour is one of the multimedia codes that can be dynamic in digital-support documents. Considering Kress & Van Leeuwen (2002), changing colour can contribute organizational communication, facing Physics’ density of ideas and reducing cognitive overload (Mayer 2001). Different colours can be used to highlight different concepts, such as in figure 11, where an interactive picture shows different physical magnitudes using different colours. However, in figure 12 colours are intended to communicate an ideational linguistic function (i.e., colour=temperature), and it can lead to a conceptual mistake: if particles change their colour when they are heated, it means that temperature is a molecular property. It can be a pitfall for understanding the concept of temperature.

Figure 11: Available at [http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html](http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html)

Figure 12: Available at [http://www.librosvivos.net/smtc/homeTC.asp?TemaClave=1062](http://www.librosvivos.net/smtc/homeTC.asp?TemaClave=1062)

Finally, another issue that must be faced when transforming printed-support documents into digital-support documents is the differentiation between virtual realistic and real representations. Since Physics usually deal with ideal objects (Besson 2009), it is important to make explicit the nature of virtuality. The lack of distinction between real and realistic representations could lead us to think that virtual realistic representations can be used to demonstrate Physics principles or laws (Pintó & Gutiérrez 2004). Instead of making this error, it is important to help students to make clear distinction between real phenomena and simulations or animations.

4.3. From problem statements to interactive applications

Classic documents usually include statements of problems, questions, exercises, experiences, etc. Obviously, the pedagogical approach of these required activities strongly depends on the educational context. However, when transforming printed-support into digital-support, interactive applications can be embedded into documents, and it could seem that they become “modern” educational tools only because they are digital and interactive, even if they maintain a traditional educational approach (Pintó et al. 2010).
Many web pages and digital textbooks are filled with a wide range of educational applications. In these cases, what is more important is to understand the underlying pedagogical approach in each of these resources. In order to avoid a misuse of digital interfaces and to optimize the use of interactive applications as learning tools it is important to consider some specific conditions:

- A weak integration of interactive tools in hypermedia documents can cause that they are used as isolated games. It is important to carefully place these interactive tools in a learning sequence to support knowledge building (Hennessy et al. 2007).
- Some interactive tools only promote “linear behaviourist assessment”, without helping students to understand why they are right or wrong (Faletič 2010). We should assure a rich variety of constructivist activities to promote cognitive challenge and high order skills, involving student thinking and doing (Pintó et al. 2010).
- The use of simulations does not assure any learning success, it depends on the scaffolding. When using simulations as an interactive tool, they are mostly effective when they are used as supplements, incorporate high-quality support structures, encourage students’ reflection and promote cognitive dissonance (Smetana et al. 2011).

An example of interactive application with a traditional approach is shown in figure 13. It is shown a problem statement that asks students to give the numeric result of the equation of the uniformly accelerated motion, and students receive a right/wrong assessment. Activities like this can be a useful tool for some specific learning activities (calculus training, developing memory, etc.), but if we only fill our hypermedia documents with these kind of activities, we will misuse the potential of interactive interfaces. Otherwise, in figure 13 it is shown an interactive application where students are asked to make a prediction. This application is integrated in a learning sequence, and the interactive interface can save students’ predictions in order to show them later and promote conceptual discussion.

Figure 13: Available at http://perso.wanadoo.es/cpalacio/acelera2.htm
5. Summary

Any transformation from printed-support to digital-support documents will not improve *per se* the educational quality of materials, and it is necessary to give some guidelines about how to carry out this process. We have identified a set of recommendations for these transformations, and we have grouped them into three main itineraries, which are related to hypertextuality, multimodality and interactivity, which occur in these digital-support documents.

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7. References:


Bramón, A. (2000). *Física per a tothom*. Barcelona: Servei de Publicacions de la UAB.


