MECHANICS MULTIMEDIA REVIEWS - Report and recommendations on available multimedia material

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1 Introduction

MPTL, Multimedia in Physics Teaching and Learning, is a group of physics educators and researchers that meets yearly to explore the challenges posed by the use of new multimedia learning tools for physics. Each year since 2002 an international MPTL working group has identified and evaluated multimedia resources and web sites from around the world. Each year the review group focuses on a specific branch of physics: quantum physics, optics and waves, classical mechanics, statistical and thermal physics, electricity and magnetism, and advanced topics (specifically solid state and particle physics). Summaries of the annual reports are available at the website: http://www.mptl.eu. The group has decided to revisit these core topics; this year's review topic is the second look at Mechanics.

The first part of this paper describes the review process and the results. We report new trends and tools, highly-rated resources, and best practice examples of how to apply multimedia. Multimedia is one tool, among many others, to promote learning and there are many factors that influence its effectiveness for learning. To extend our knowledge about learning with multimedia, it makes sense to use the best practice examples determined by the review process to characterize and illustrate how theoretical considerations of learning can be applied. In the second part of this paper we pursue this latter objective.

2 The review process

To start the process, a list of websites was collected by Bruce Mason (University of Oklahoma) and his students. The list was created using the 2004 MPTL review, the MERLOT [http://merlot.org] and ComPADRE [http://compadre.org] Digital Libraries, resources lists Risorse per la didattica di Fisica [http://zitogiuseppe.com/didattica.html] and Multimedia Physik [http://www.schulphysik.de/], and web searches. About 180 web sites were found, with an average of 8 to 10 learning objects per site. Only non-commercial or freely-available material was reviewed. This eliminated some materials from consideration, but the MPTL reviewers felt it was important to highlight open education resources readily available to teachers and students. Furthermore, consideration of open resources tends to reveal new ideas and approaches by instructors and researchers. Only resources in English or with English translations were peer reviewed because of the need for reviewers to understand the materials. A preliminary screening of the resources for multimedia use, accuracy, and topic reduced to 84 the number of resource collections receiving full peer reviews.

The reviewers were mostly regular attendees of the MPTL workshops. The electronic review process was hosted on ComPADRE for administrative and archival purposes. The evaluation considered three main areas with a total of 10 criteria and various rubrics in each criteria (see Table 1). Each item was assessed on a 5-point Likert-scale and, as needed, included a free-text review response. An overall score and summary assessment was also given.

A second evaluation using the MERLOT (Multimedia Educational Resource for Learning and Online) peer review criteria was also performed on these items. MERLOT rubrics used similar criteria under the categories: "Quality", "Potential Learning Impact", and "Ease of Use". There were only small differences between the two reviews for the highly recommended sites.

Those sites that were ranked highly by both groups are presented below.

3. Results

We start with some general observations about the materials reviewed.

- Most of the material is about standard topics of Mechanics (e.g. kinematics, forces, etc.) although there were several more advanced sites on modern dynamics.
- A few sites offer a complete curriculum for Mechanics. These are mostly text based (html-text books) with little interactivity or student control.
- There are some isolated simulations, interactive tutorials, video clips, and virtual labs with interesting new ideas for teaching. Because they cover isolated topics, and are not embedded into a comprehensive course, they are more difficult to use in class.
- There are some sites dealing with special topics like baseball. These sites use Physics to explain the theoretical background of the topics. A systematic learning of Physics is not the main goal of the authors.
- There is no general standard for the design of websites. Authors use their own individual styles and user interfaces.
- Similar to the 2004 report on Mechanics, only a few sites offer suggestions on how to implement the material in teaching and learning processes.
- The creation of video materials has expanded greatly. However, video collections do not yet belong to the highest ranked sites because of a lack of student interactivity and control. In most cases, videos are not embedded into an adequate learning environment. (Some of the new features for learning will be discussed in section 4).
- The highly distributed nature of these materials calls for the development of tools for collecting, discussing, sharing, and reusing them to engage learners.

Recommended resources

The following resources received “Excellent” ratings from both the MPTL and MERLOT reviews. The first two of these resources received top reviews in 2004 as well.

Introduction to Chaos and Nonlinear Dynamics:
T. Kanamaru, Kogakuin University, and J. M. T. Thompson, Cambridge University.
http://brain.cc.kogakuin.ac.jp/~kanamaru/Chaos/e/

This web site contains a wide range of simulations of non-linear systems, including applications of Chaos theory to model operation of the brain. The simulations are very professional and they include descriptions of the systems studied. There are also images and videos of non-linear systems with many links to other pages on chaos theory. This material is suitable for university students. It would be improved by having more teaching examples and problems for students.

The Pendulum Lab:
F.-J. Elmer, University of Basel.
http://www.elmer.unibas.ch/pendulum/index.html
The Pendulum lab by Franz-Josef Elmer is an extremely thorough investigation of the dynamics of a pendulum. It covers the topic from the simple pendulum to the chaotic motion of the damped and driven pendulum. It includes simulations, reference text, and exercises for the student. Virtual experiments can be performed with background information provided by an extensive set of hyperlinked notes that explains the theory of the system. This material can be used for a wide range of student levels, although much of the material is best suited for advanced undergraduate and graduate students studying dynamical systems.

PhET - Motion:
PhET Research Group, University of Colorado, Boulder.
http://phet.colorado.edu/en/simulations/category/physics/motion
The PhET resources were recommended in last year's review of Optics and Waves, and the same comments are appropriate for the materials in Mechanics. The PhET simulations are strongly grounded in research on how students interact with and learn from multimedia. These simulations are designed to create a realistic virtual environment that encourages learners to interact and explore. There is only very basic guidance on how to operate the simulations to encourage student-driven learning. The physics topics and potential learning goals for each simulation are listed and many simulations include examples of learning activities, clicker questions, and virtual labs. A new feature is a rating scheme for these teaching examples. There are 17 different simulations in mechanics covering topics from kinematics and graphing to energy conservation and torque. One drawback of these resources is that there are no indications of the physical models being used for these simulations or definitions of terms.

Open Source Physics:
Edited by W. Christian & F. Esquembre
http://www.compadre.org/osp
The OSP Collection provides curriculum resources that engage students in physics, computation, and computer modeling. The Open aspect of these materials make them suitable for a wide range of educational uses. The streamlined Easy Java Simulation (EJS) computer modeling environment provides students with new ways to explore, explain, and predict physical phenomena. Instructors can build interactive exercises either from scratch or by modifying resources in the large OSP simulation library. The open source concept means that the physical models in these simulations can always be viewed, and modified as needed.

The materials listed next received mostly "Very Good" ratings, although for some there is a disagreement between the MERLOT and MPTL reviews. These resources are grouped into two categories, Multimedia-Enabled Tutorials and General Resource Collections.

Multimedia-Enabled Tutorials:

Contextual Physics:
Department of Physics, Chinese University of Hong Kong
http://resources.edb.gov.hk/cphysics/main/main_e.html
The central content of this site are mechanics tutorials motivated by real-world problems. A rocket launch is used to introduce concepts of force and Newton's Laws. Design of highway crash barriers is used to introduce concepts of energy and energy conversion. The tutorials use student activities, videos, flash animations, and text explanations. These materials have an emphasis on contextual learning for high school students. The quality of the videos is somewhat limited. There are also restricted materials available to registered teachers that could not be reviewed.

Aeronautics Resources:
NASA Glenn Research Center
http://www.grc.nasa.gov/WWW/K-12/aerores.htm
This web site offers many tutorials on physics applications in aeronautics and aerospace research. It includes a Beginner's Guide to Aerodynamics, a Beginner's Guide to Propulsion, a Beginner's Guide to Wind Tunnels, and other topics. The breadth and depth of the material is outstanding. The range goes from basic information about operation of airplanes to interactive simulations of fluid dynamics. The site offers illustrations and activities for students of different grades. This is a comprehensive learning resource on aeronautics. The potential drawback of this site is the navigation system. A user can quickly, and unexpectedly, move from introductory to very challenging material. Also there are some of the applets and pages that look a little bit dated.

Physics Classroom:
Tom Henderson, Glenbrook South High School
http://www.physicsclassroom.com
This is an extensive tutorial website covering most topics in introductory physics. The tutorial material is easy to read and use. The available multimedia includes animations, shockwave simulations, student explorations, audio-enabled problem solving, and interactive quizzes. All of the materials are organized in a very clear format. This web site will be useful for physical science classes and algebra-based physics classes because of the emphasis on conceptual understanding. It also provides a basic supplement to calculus-based introductory physics.

Web-Based Pre-lectures:
Illinois Physics Education Research Group
http://research.physics.illinois.edu/PER/prelectures.html
HippoCampus: Monterey Institute for Technology and Education
http://www.hippocampus.org/Physics
These are two very similar web sites using Flash media as pre-lecture resources for introductory physics classes. The goal of this work is to provide new approaches to help students prepare for classes in addition to textbook reading. The topics from the course are broken into 5 or 10 minute presentations available for the students to use as needed. Questions are embedded with the presentations for the students to assess their understanding. These web sites are not particularly interactive or student-controlled, but they can provide important background information in a more engaging format.

General Resource Collections:

In past reviews, several broad resource collections of interactive learning objects have been highly recommended. Three of these were also recommended this year, although not as highly as in the past. Reviewers seem to prefer learning environments that contain a more complete development of topics, from general information and background to theoretical development and applications.

NTNUJAVA Virtual Physics Laboratory:
Fu-Kwun Hwang, National Taiwan Normal University
http://www.phy.ntnu.edu.tw/ntnujava/
This is an extensive web collection of interactive java simulations, each available with a short explanation and description of the physics background. This site has a unique bulletin board interface to encourage comments and suggestions from users.

Java Applets on Physics:
Walter Fendt
http://www.walter-fendt.de/ph14e/
This applet collection includes about 20 resources on topics in mechanics. Each applet includes controls to change all of the physical parameters in a system. Each of them is part of a web page with a clear explanation of the operation and physics of the applet.

Dynamical Systems JAVA Applets:
Robert Devaney, Boston University
http://math.bu.edu/DYSYS/applets/
This collection of applets supports courses on chaos, fractals, and non-linear systems, as a supplement to a series of textbooks with learning on dynamical systems. The applets are aimed at undergraduate and graduate students studying differential equations and dynamical systems. It includes activities to engage the students in exploration.

4. Special features and perspectives for learning

Using examples from the peer review process, we will now explore theoretical considerations of multimedia use and connect to findings from the psychology of learning. It is certainly true that multimedia is only one tool to promote learning and there are many factors that are important in its effectiveness. It makes sense to focus on the most relevant aspects that characterize the strength of multimedia learning. According to Weidenmann (2002), multicoding, interactivity, and multimodality describe special features of information and communication structures available through use of multimedia. These open up new approaches to teaching and learning. We will first provide examples of these three features.

Multicoding is the use different kinds of representations, for example using different methods for describing motion (see Figures 1 and 2).

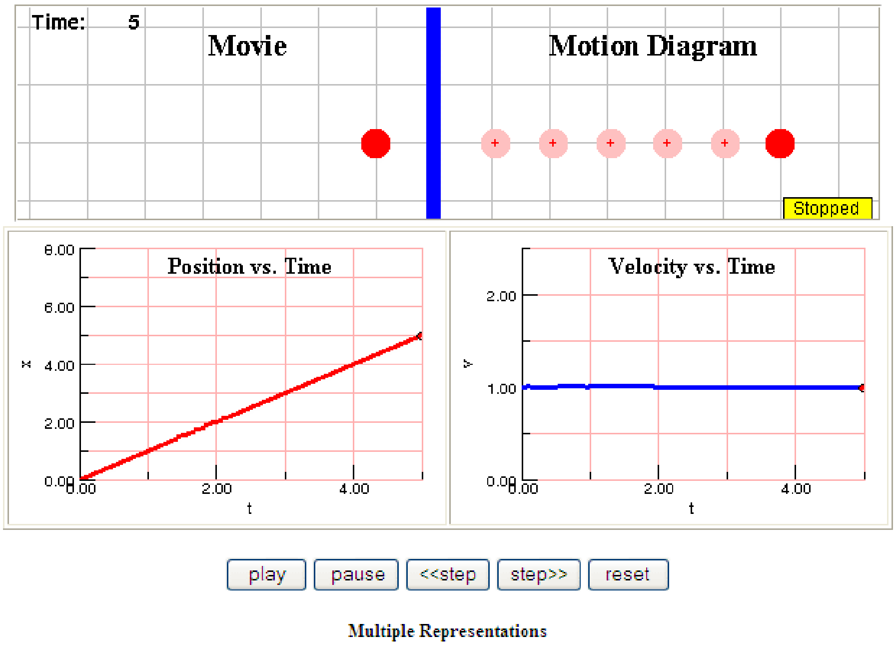

Figure 1: Different ways to describe the same motion
http://buphy.bu.edu/~duffy/semester1/c02_multiple.html (20.8.2010)

Using various representations that focus on different aspects of a problem can help improve cognitive flexibility. "Cognitive flexibility" includes the ability to restructure existing knowledge according to the demands of a given situation (Spiro & Jehng, 1990). Thus, a knowledge ensemble can be constructed and tailored to meet the needs of a specific problem-solving situation, or support learning and linking of new concepts (Spiro, Feltovich, Jacobson, & Coulson, 1992). Cognitive flexibility helps to apply knowledge under various conditions in an effective way.

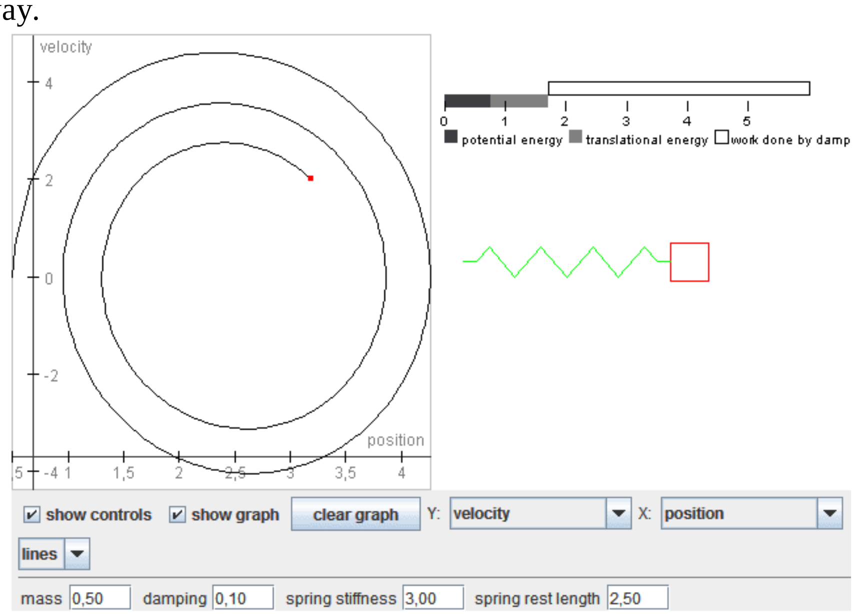

Figure 2: Different graphical ways to represent the movement of a harmonic oscillator.
http://www.myphysicslab.com (20.8.2010).

Interactivity has two main aspects important for learning: activation and feedback. Activation calls for the right challenge and engaging tasks. In the example shown in Figure 3, the student must perform the task of matching a representation of motion by controlling the position of a virtual car. The motion of the student's mouse provides a kinesthetic connection to the data represented in the graph.

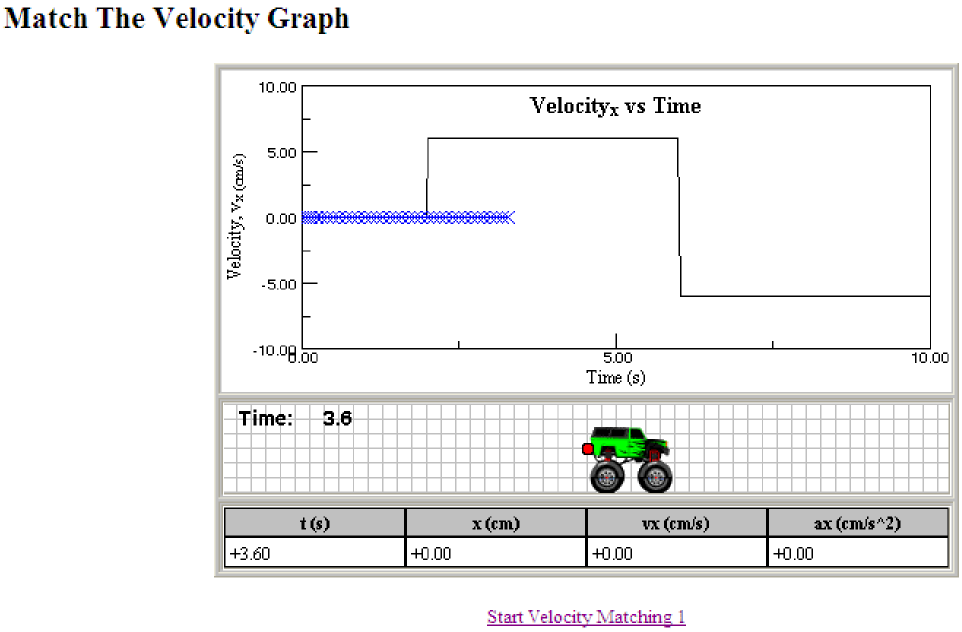

Figure 3: This requires students to move the car according to the given velocity graph http://webphysics.davidson.edu/physlet_resources/kinematics_tutorial/default.htm (20.8.2010).

Interactive simulations can also give inherent feedback if they are motivated by a guiding task. In the example shown in Figure 4, the task is to create standing waves. This exercise reinforces the concept that a standing wave is the superposition of a wave travelling to the left with one going to the right. If the correct settings for the boundaries and the correct excitation are chosen, a standing wave is created. The feedback is "success" or "failure".

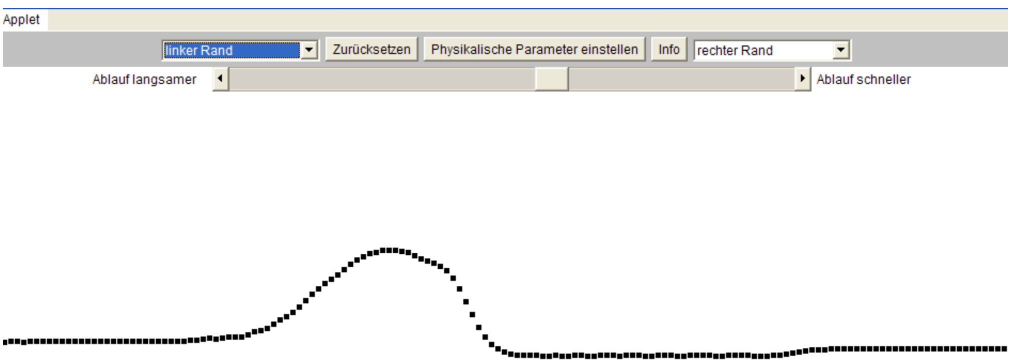

Figure 4: An interactive wave machine. Excitations are created by mouse movements. http://www.physikonline.net/spezial/wellen/programm_1d/wellenapp_jare.html (20.8.2010).

Multimodality is the use of several cognitive input channels during learning. A multimedia application employing both aural and visual information activates different senses and provides a more realistic and authentic experience. Mayer (1997) described the combined presentation of verbal and visual information as specifically helpful for inexperienced learners. Mayer and Moreno (1998) outlined a split-attention-effect. Better learning results are possible when verbal and visual information are combined. The arrangement of verbal and visual components may lead to a better processing in limited working memory (Moreno & Mayer, 1999).

Strictly speaking, multicoding, multimodality and interactivity describe only superficial characteristics of a user interface. They set up the general framework and environment of a student activity, but in the actual process of learning they can have both positive and negative effects. For example, multicoding can be helpful in opening different problem-solving approaches for students. On the other hand, too many representations can be confusing. Therefore further considerations are necessary to determine optimal conditions for learning.

The next sections will consider further examples of learning resources and discuss their potential for particular instructional intentions. Examples of video, games, and information structuring will be presented. These resources are designed for: A) extending visual perception, B) connecting abstract concepts to real-world examples, C) assisting cognitive apprenticeship, D) structuring knowledge, E) illustrating process oriented explanations, and F) playing games with rules that are derived from laws of Physics.

A) Extending visual perception using video or animations

An interesting application of multimedia is to extend our perception and illustrate what cannot be easily seen. At http://www.physikonline.net/filme/mpg_m3_scheinkr/foucault13.mpg is a video of a pendulum taken with a rotating camera, representing a rotating frame of reference. Viewers can get an understanding of Coriolis Acceleration and “fictitious” forces.

Figure 5 gives another video example of an unusual point of view, as viewers "take a seat on a basketball" and fly with the ball on a trajectory into the basket.

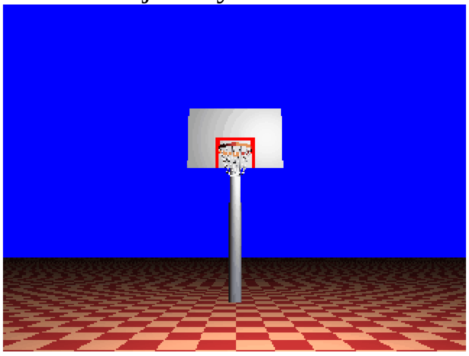

Figure 5: Animation to show what could be seen flying along the trajectory of a basketball http://fearofphysics.com/Proj/betheball.html (20.8.2010).

There are now many more video resources available than in 2004. Videos are much easier to produce and share because of new technologies (non-interlaced video), simpler video editor programs, and free providers for video-sharing. In this multimedia review with an emphasis on the context of learning, collections of video resources, such as movies or Flash animations, did not tend to receive “Excellent” or “Very Good’ ratings. In general, these sites do not provide ideally designed learning environments, lacking interactivity, student control, and feedback. However, there are many web sites with videos on mechanics that can be used successfully by teachers in their classes. Some of the most notable video collections are:

http://pen.physik.uni-kl.de/medien/MM_Videos/index_eng.html	High quality video and special topics

http://livephoto.rit.edu/	Focus on video analysis for mechanics
http://www.iwf.de/iwf/default_en.htm	Large collection on many topics
http://groups.physics.umn.edu/demo/	Lecture Demonstration videos
http://www.upscale.utoronto.ca/GeneralInterest/Harrison/Flash/	Short Flash tutorials and animations
http://phys23p.sl.psu.edu/phys_anim/mech/indexer_mech.html	Database of Flash animations of physical systems and experiments

B) Connecting to real phenomena

Realistic videos can help students connect abstract physics concepts and representations to real scenarios. The example in Figure 6 shows the motion of a harmonic oscillator using different methods. With similar goals as the example in Figure 2, this animation adds video of a real experiment to the abstract representations of harmonic motion.

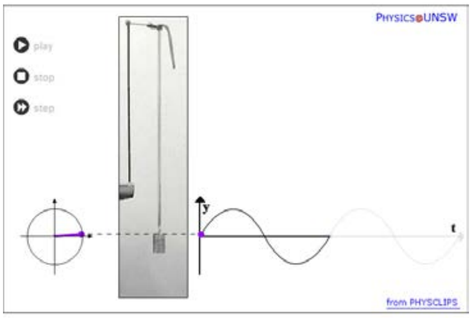

Figure 6: Combination of realistic and abstract representations of a harmonic oscillation. http://www.animations.physics.unsw.edu.au/jw/SHM.htm#yva (20.8.2010)

C) Assisting cognitive apprenticeship, from observation to conceptual understanding

Figure 7: A picture out of a video showing effects of perpendicular pokes on a rolling ball http://paer.rutgers.edu/pt3/movies/bowlingball.mov (20.8.2010)

Video clips can play a role in guiding students from observation to conceptual understanding. Step-by-step, well-directed observations on video can be reviewed multiple times and additional visual and aural information can help students develop physical interpretations of phenomena. The site from Rutgers shown in Figure 7 contains many videos that help train students use physically correct descriptions of the real world. Instruction methods that follow the concepts of cognitive apprenticeship are described.

D) Structuring knowledge using physics concept maps

A structured knowledge base is important for problem solving and should be developed by students from the start of their study of physics. The Hyperphysics web site has organized physics in clickable maps that provide pictorial representations and topical connections.

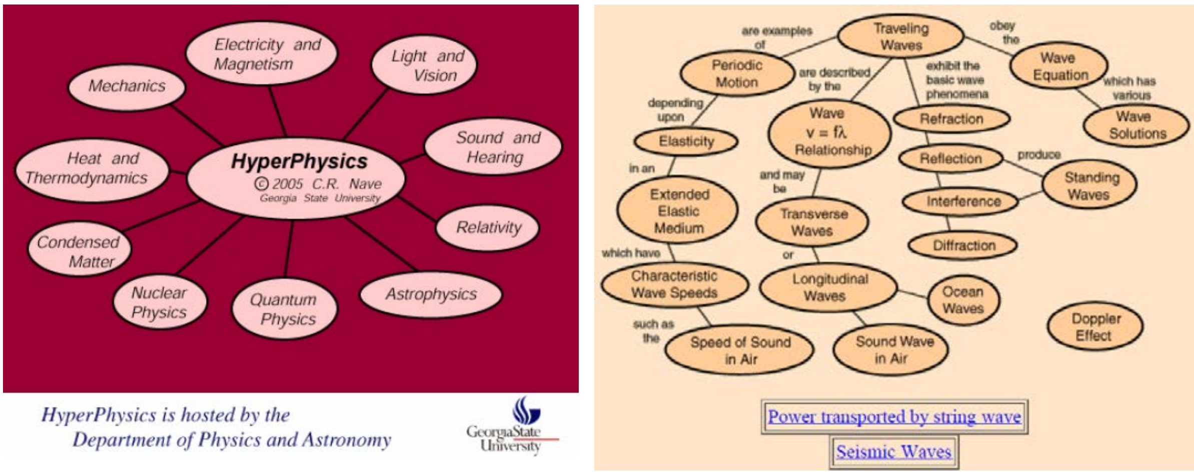

Figure 8: Maps to illustrate knowledge domains
http://hyperphysics.phy-astr.gsu.edu/hbase/hph.html (20.8.2010)

De Jong & Njoo (1992) emphasized that structuring of knowledge and linking it to prior knowledge are two important components of any learning process. Well structured and properly organized knowledge improves its accessibility and facilitates problem-solving (Reif, 1981). Charts, mind maps, and diagrams illustrate relations, help the analysis of content domains, and improves recognition of useful information (Beisser, Jonassen, & Grabowski 1994). Interactive ("clickable") concept maps, such as the example in Figure 8, are of interest in helping students structure their understanding.

E) Illustrating process oriented explanations with video and text

Animated illustrations can help students understand dynamic processes. Multimedia makes it possible to combine these animations with written or spoken text, meeting the criteria of spatial and temporal contiguity that is important for learning (Mayer, 2002). Figure 9 shows an example of this sort of multi-media presentation, combining animations, text, and interactive controls.

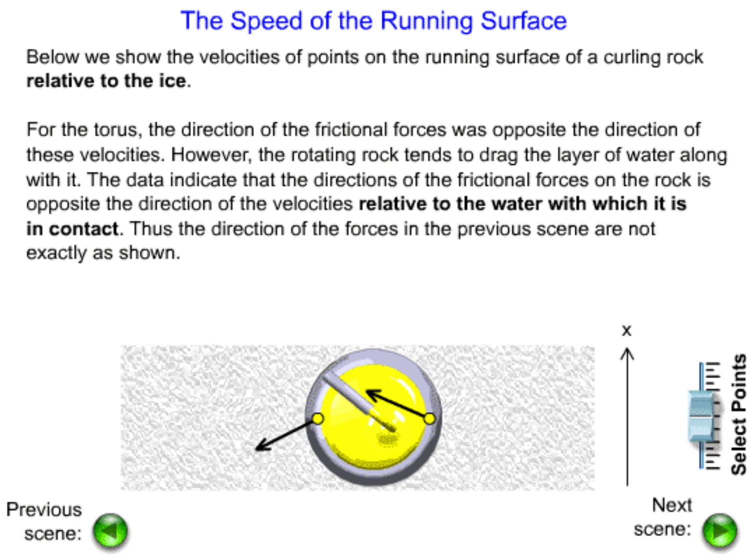

Figure 9: An internet site with animations and simulations about curling
http://faraday.physics.utoronto.ca/GeneralInterest/Harrison/
Flash/ClassMechanics/Curling/Curling.html (20.8.2010)

F) Playing games with rules derived from physical laws

Incorporating the laws of physics into a game environment can employ the attractiveness of games to mediate an understanding of consequences of these laws. A standard example are "Lunar Lander" games that have existed since the early years of computer programming. Chabotspace had an introduction to a lunar lander game with clearly defined rules - Newton's laws. Only after a completed presentation of these rules was the game started. http://www.chabotspace.org/vsc/exhibits/lunarlander/lunarlander.asp (20.8.2010)
Unfortunately, this website was rebuilt since a recent review and the introduction is now skipped and only the game is available.

5. Conclusion

On the internet there are many creative and inspiring materials for multimedia learning. However, careful research and connections to learning theory are necessary to determine best practices for using these resources. Thus, the review of high quality examples has a double purpose: discovery of tools that are ready to be used, and as concrete examples of theoretical considerations for helping students succeed.

References

Beisser, K. L., Jonassen, D. H., & Grabowski, B. L. (1994). Using and selecting graphic techniques to acquire structural knowledge. Performance Improvement Quarterly, 7(4), 20-38.

ComPADRE, http://www.compadre.org (accessed 8/10/2010)

De Jong, T., & Njoo, M. (1992). Learning and Instruction with Computer Simulations: Learning Processes Involved. In E. De Corte, M. C. Linn, H. Mandl and L. Verschaffel (Eds.), Computer-Based Learning Environments and Problem Solving (NATO ASI Series. Series F: Computer and Systems Sciences; 84) (pp. 411-427). Berlin: Springer.

Didattica, http://www.ba.infn.it/didattica.html (accessed 8/10/2010)

EUPEN Working Group 3, http://www.eupen.ugent.be/wg/wg3_results_multi.php, accessed January 2010

Mayer, R. E. (1997). Multimedia learning: are we asking the right question? Educational Psychologist, 32, 1-19.

Mayer, R. E. (2001). Multimedia learning. New York, NY, US: Cambridge University Press.

Mayer, R. E. (2002) Multimedia Learning. The Psychology of Learning and Motivation, 41, 85-139.

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. Journal of Educational Psychology, 90(2), 312-320.

MERLOT website, http://www.merlot.org, (accessed 8/10/2010)

MERLOT-Physics peer review outline and rubrics, http://physics.merlot.org/PeerReviewOverview.html (accessed 8/10/2010)

Moreno, R., & Mayer, R. E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity effects. Journal of Educational Psychology, 91, 1-11.

MPTL Reports, Multimedia in Physics Teaching and Learning (MPTL), Reports & Recommendations, http://www.mptl.eu/reports.htm, accessed January 2010

Multimedia Physik, http://www.schulphysik.de/ (accessed 8/10/2010)

Physical Science Resource Center: http://www.compadre.org/psrc/ (8/29/2010)

Reif, F. (1981). Teaching problem solving – A scientific approach. Physics Teacher, 19, 310-316.

Spiro, R. J., & Jehng, J. (1990). Cognitive flexibility and hypertext: Theory and technology for the non-linear and multidimensional traversal of complex subject matter. In D. Nix and R. Spiro (Eds.), Cognition, Education, and Multimedia. (pp. 163-205). Hillsdale, NJ: Erlbaum.

Spiro, R. J., Feltovich, P. J., Jacobson, M. J., & Coulson, R. L. (1992). Cognitive Flexibility, Constructivism, and Hypertext: Random Access Instruction for Advanced Knowledge Acquisition in Ill-Structured Domains. In: T. Duffy and D. Jonassen (Eds.), Constructivism and the Technology of Instruction: A Conversation. (57-75). Hillsdale N. J.: Lawrence Erlbaum.

Weidenmann, B. (2002). Multicodierung und Multimodalität im Lernprozess [Multicoding and Multimodality in Learning Processes]. In L. J. Issing, und P. Klimsa (Hrsg.), Information und Lernen mit Multimedia. (S. 45-62) Weinheim: Psychologie Verlagsunion.

Table 1: MPTL Review Rubric.

Motivation	**User-friendliness**	Is it easy to start using the resource?
		Is the design comprehensible and is the image quality satisfactory?
		Is the function of control elements evident?
		Are the software requirements clear and adequate to run the MM?
	Attractiveness	Are the layout and graphics appealing?
		Is there a motivating introduction?
		Are there interactive components?
		Is the topic interesting (application, interesting phenomenon)?
		Is the MM up-to-date and/or innovative?
	Clear description of purpose and work assignment	Is the goal of the MM evident?
		Does the user know what is expected?
		Is there a problem to solve or a context to understand?

Content	**Relevance**	Is the topic important, fundamental, or a difficult concept?
		Is the MM useful (e.g. a dynamic process)?
	Scope	Is the content covered in depth?
		Is the content presentation broad (special case, general overview)?
	Correctness	Is the content correct (equations, text, units, etc.)?
		Are simplifications or approximations described?

Method	**Flexibility**	Is the MM appropriate for a broad target group (incl. self-learning)?
		Is it possible to use the MM in different teaching and learning situations?
		Does the MM allow for different didactic approaches to the topic?
	Matching to target group	Is a reasonable didactical reduction implemented (key ideas, focus)?
		Are technical terms explained?
		Are the learning objectives understandable and appropriate?
	Realization	Is the general approach suitable to realize the aims of the given MM?
		Is the type of MM reasonable (video, simulation, animation)?
	Documen-tation	Is the operation obvious or explained?
		Is the material self-evident or explained (glossary, etc.)?
		Is there a reference to material for further studies?
		Are there suggestions for implementation in the teaching process?