REPORT AND RECOMMENDATIONS ON AVAILABLE MULTIMEDIA MATERIAL FOR OPTICS AND WAVES

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Abstract
In the tradition of previous MPTL meetings, thispaper reports the findings of a joint evaluation of multimedia educational resources for waves and optics by the European working group “Multimedia in Physics Teaching and Learning” and the MERLOT/Physics Editorial Board. This year, a list of 140 web collections, each with many individual multimedia learning items, was compiled by the MERLOT group, the ComPADRE digital library, and Dr. Robert Wagenbrunn. Each review group distributed the web sites on this list among their members. Each reviewer, using established rubrics, selected high quality items, performed a detailed review, and reported their results for comparison between reviewers.
This paper presents a discussion of characteristics of the top rated resources and the suitability of the use of multimedia, comparisons of the findings of different reviewers, and general comments on the current review process and future directions for this effort.

1. Introduction and Background
Multimedia-enriched learning resources, such as interactive simulations, videos, online tutorials, and virtual lab environments, have an increasingly important role in physics education. Well developed multimedia can engage students in the learning process in ways that expand the topics covered, the activities pursued, the depth of content, and where and when learning occurs. These resources can support the development of conceptual understanding of physics and allow more complex, and real-world, physical systems to be studied and modeled.
Developers from around the world are engaged in creating multimedia for physics education and, in many cases, delivering it free of charge to anyone with a network connection. This creates challenges for teachers. As the use of these materials increases, and our students become more experienced in using technology and the web for all aspects of their lives, the expectation for teachers to use these resources increases. However, the large amount, diverse nature, and scant organization of the multimedia available on the web makes finding the proper resources difficult. An instructor must be confident that the resources used are scientifically correct, help rather than hinder students' learning, and fit into courses in an organic, rather than “bolted on”, manner.
This review is part of an ongoing effort to help instructors meet the challenges listed above. It is the eighth annual review of Multimedia educational materials by an international group of physicists. The goals of this continuing effort are to survey the existing available resources and to identify those that have the potential to significantly improve physics learning. Each year a broad physics topic is selected for review, a search for existing resources is performed, and the highest quality items are identified through peer review. The reports of the review results have been presented at MPTL workshops since 2002. This initiative had been started by members of a working group within the EUPEN network (European Physics Education Network), who presented reviews and analysis of materials on quantum mechanics in 2002 and on optics in 2003. Since 2004, the EUPEN working group has collaborated with the MERLOT/Physics peer review board in this process. The topics covered have been classical mechanics in 2004, thermodynamics and statistical physics in 2005, electricity and magnetism in 2006, particle and solid state physics in 2007, and a repeat review of quantum mechanics in 2008. The reports are available on-line (MPTL 2010).

As a continuation of the cycle of reviews, revisiting topics to find changes in the available material, the reviews in 2009 covered the topics of optics and waves. These topics were reviewed in 2003 and 2004, with waves included as part of the previous classical mechanics reviews. These topics lend themselves to multimedia presentations because of the many of the models used are unfamiliar to students.

2. Process

The process followed in this review process has been described in previous reports and publications (MPTL 2010). One notable addition this year was the use of an online review form to collect individual reviews. Below we briefly outline the steps in the 2009 review process. The steps are: the discovery of materials, the initial selection of materials to be reviewed, the detailed evaluation of selected materials, the comparison between reviews, and the determination of exemplary materials.

2.1. Collection of Links

The search for optics and waves resources was performed by both students and faculty at the University of Oklahoma and by Robert Wagenbrunn from Graz, Austria. The search included materials available in MERLOT (MERLOT 2010), existing link lists, and through general web searches. The two independent searches were performed to improve the discovery of materials.
The total number of resources found in the initial searches was 469. This included a broad range of resource types, from broad collections of materials covering many topics to single web pages or java applets. Past experience has shown that the review process is improved when collections of related resources are evaluated together if possible. Reviewers can better judge the pedagogical impact of the materials if considered as a group. After consolidation of the resources into collections and the elimination of sites that did not operate correctly, had incorrect physics, or were merely lists and links to other web sites, there were 169 individual resources to evaluate.

2.2. Reviews

Each of the items identified from the search and consolidation process was reviewed by one member from the EUPEN group and one from the MERLOT group. These reviews were performed independently and used somewhat different rubrics. This provided different views of the materials that were compared to identify the highest quality.
This year the EUPEN group submitted reviews online using the review tools from the ComPADRE digital library. Each item was assigned to one reviewer who made a preliminary judgment of the quality of the resource and entered an overall score and comments at the top of the form. For those resources that ranked in the top 20-40% of items in the preliminary review, the reviewer entered a complete evaluation using the review criteria accepted by participants at the MPTL workshops in Parma and Prague. These criteria have been published (Altherr 2004). The three main review categories are **Motivation**, **Content**, and **Method**. Each of these areas includes sub-criteria that are rated on a Likert scale from -2 to 2, with a space for comments for each. When complete, the reviewers submitted their reviews for consideration by those running the review process. The use of the online review forms improved this process because reviewers' comments were available for all items in a consistent format available for later consideration.
The MERLOT group used the two-step review process similar to that used for all MERLOT peer reviews, aided by the MERLOT online peer review workflow. A preliminary triage process is used to select items for full peer review. The full MERLOT peer review uses three main categories: **Quality of Content**, **Potential Effectiveness for Teaching and Learning**, and **Ease of Use**, each defined by 4 or 5 questions used to rate the materials. Resources are scored on a 1 to 5 scale for each of the three categories and an overall score is given. Details of the MERLOT/Physics review process and the rubric are available (MERLOT Physics Editorial board 2010).
Once completed, the EUPEN and MERLOT reviews were compared to identify high quality materials and common comments about the reviewed materials. The next section contains detailed information and recommendations for the highest quality resources found in the topics of optics and waves.

3. Recommended Resources and Websites for Optics and Waves

The following are the recommendations and comments for the Excellent and Very Good resources identified in this review.

Excellent Materials:

The following resources received excellent ratings from members of both groups and are recommended for instructors and students studying these topics.

ActivPhysics Online: Alan Van Heuvelen, Rutgers, Paul D'Alessandris, Monroe Community College

http://wps.aw.com/aw_young_physics_11/13/3510/898586.cw/index.html

This is a web-based tutorial for all of introductory physics that combines interactive java and flash applets with student explorations and activities. Each tutorial starts with a learning goal and proceeds with guided questions or activities that help the students explore a topic using the simulations. Most activities include an “Advisor” button that provides more information about that particular physical concept. The interactive simulations allow learners to change physical parameters and observe the results while video and audio are used to provide explanations. In most cases the simulations include multiple representations related to the problem, such as graphs, equations, values of physical quantities along with the simulation modeling an experiment. This web site contains materials from all topics in an introductory physics course. The Waves topics include the properties of mechanical waves, standing waves, superposition and beats, and the Doppler Effect. The Optics topics include reflection and refraction, geometric optics of lenses and mirrors, interference, and polarization.

Javaoptics Course: Grup d'Innovació Docent en Òptica Física i Fotònica, Universitat de Barcelona

http://www.ub.es/javaoptics/index-en.html

The Javaoptics Course is a collection of Open Source Physics [OSP] simulations that cover important topics in optics. The simulations include ray tracing, refraction and optical fibers, several forms on interference effects, and Fourier optics. Because this material is designed for both physics and optometry studies, there is also a simulation of the eye and the physics of poor vision. Many parameters in the simulations can be adjusted, and a write-up of the theoretical background of the physics simulated is available for most applets. The resources are available under the creative commons license and are appropriate for use from high school to intermediate university-level physics, depending on the simulation. The material can be accessed as either a single large package, individual web-start java applets, or through a browser.

PhET - Sound & Waves, Light & Radiation: PhET Research Group, University of Colorado, Boulder

http://phet.colorado.edu/simulations/index.php?cat=Sound_and_Waves

http://phet.colorado.edu/simulations/index.php?cat=Light_and_Radiation

The simulations developed by the PhET research group at the University of Colorado 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. The PhET research also helps avoid possible misconceptions that students might create due to the simulations as well as the non-physical preconceptions that the simulations address. The physics topics and potential learning goals for each simulation are listed. Many simulations also include example learning activities uploaded by teachers. The materials on Sound and Waves include interference simulations and Fourier series. The topics covered under Light and Radiation include geometric optics, color, interference, and the quantum mechanical nature of light.

WebTOP: Mississippi State University

http://webtop.msstate.edu/

WebTOP is a collection of 13 3D simulations of optical systems. The materials cover a broad range of topics from the basic properties of waves to diffraction and interference effects, to lasers. The simulation views are very detailed and can be explored through panning, zooming, and rotating the scene. Physical parameters in each of the simulations can be adjusted. Each simulation includes detailed instructions on how to operate the simulation and the physical theory behind the display. The simulations also include example parameter choices that illustrate important physical properties of the systems simulated. There are also exercises that will help students explore the simulation. We should note that the MERLOT reviewer rated this item excellent while the initial

EUPEN reviewer did not rate it highly because of difficulty downloading and running the applets. A reconsideration of this item by the EUPEN team made them feel that it should be recommended.

Very Good materials:
These materials received either excellent or very good ratings from reviewers, often with a slight disagreement between the MERLOT and EUPEN reviewers.
A-Level Resources, Interference of Light Waves: Claire McIntyre, Paul Berry, Andrew Green, University of Liverpool
http://www.matter.org.uk/schools/Content/Interference/Default.htm
This series of web pages is designed as an interactive tutorial for High School level students. It provides an introduction to a very specific topic, double slit interference, through text and interactive java applets. The textual material includes definitions of important physical parameters in the problem and hyperlinks to derivations, data worksheets and calculators, and more in-depth discussions. The interactive applets simulate an optical experiment observing interference fringes for differing wavelengths, number of interference slits, and slit width and separation. This material is noteworthy for its detail exploration of a topic and the integration of explanations, activities, and simulations.
Physlets, Semester 1 & 2: Andrew Duffy, Boston University
http://buphy.bu.edu/~duffy/semester1/,
http://buphy.bu.edu/~duffy/semester2/
This collection of Physlet-based physics illustrations provides an example of the power of Physlets for adoption by instructors. The Davidson Physlets, which have been recognized in previous multimedia reviews, are used here by an instructor at Boston University to build a wide range of simple applet-based demonstrations of physical properties. The topics in this collection cover most of introductory physics, with waves and interference in “Semester 1” and optics in “Semester 2”. All of these applet pages include questions, discussions, or activities about the physics being illustrated. The Second Semester materials on optics received higher ratings than the First Semester from our reviewers.

4. General Results and Discussion

There are several general observations that can be made from this overview of available multimedia materials for optics and waves:

- There are many simulations available illustrating Geometrical Optics. Teaching resources showing ray tracing for lenses, mirrors, and interfaces between materials of with different indices of refraction are widely available for adoption of teachers.
- There are many resources available that illustrate wave interference. Most of these materials focus on double-slit and multi-slit interference. Resources for teaching single-slit diffraction and thin-film interference are also available.
- There are few resources that directly connect the wave model of light and the ray model of light. This is a connection that can be conceptually difficult for students to make.
- There are many mirror sites that link to original resources on the web.

In addition to these general perceptions of the optics and waves resources available on the web, there are several other results from the review process of interest.
We found that the resources ranked highest in this review are different from the 2003 review. Most of the excellent materials from this review were not available or have been significantly updated in the past six years. Most of the highly-rated 2003 materials received good and very good reviews, but were not the highest rated. In several cases this was due to a feeling that the resource display or the media seemed somewhat outdated. This indicates the changing nature of the multimedia educational resources available on the web.
There is also an increasing emphasis on the part of the reviewers of the importance of didactical information and context with multimedia illustrations and simulations. This includes student activities, examples and reports of classroom usage, and research on learning outcomes. Such contextual information is extremely rare, and should be encouraged. This is likely to be an increasingly important consideration in future review cycles.
Finally, as in past years, the materials that received full reviews were in English or had English translations. This is a limitation of this review effort caused by the importance of fluency of the reviewers in the language of the learning resource.

5. Future Reviews

The results of this review indicate the importance of continuing surveys and reviews of the learning materials available through the web. We will be considering materials in Classical Mechanics in 2010 as the next in the sequence of topics started in 2002. The result of this review is scheduled to be reported at the joint MPTL/GIREP conference in August of 2010.

References

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

MERLOT, http://www.merlot.org, accessed January 2010

Altherr S., Wagner A., Eckert B., Jodl H.J., “Multimedia material for teaching physics (search, evaluation and examples)", European Journal of Physics 25 (2004)

MERLOT/Physics peer review outline and rubrics, http://portals.merlot.org/physics/PeerReviewOverview.html