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LETTERS AND COMMENTS

Report and recommendations on multimedia materials for teaching and learning electricity and magnetism

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Abstract
This paper presents the results of a peer review of multimedia materials for teaching and learning electricity and magnetism prepared as a part of the annual activities undertaken by an international group of scientists associated with Multimedia Physics in Teaching and Learning. The work promotes the use of valuable and freely accessible information technology materials for different levels of teaching, mostly higher education. The authors discuss the process of selecting resources and the rubrics used in the rating process. The reviews of high-quality learning resources are presented along with descriptions of valuable didactical features.

1. Introduction

Information technology (IT) has become ubiquitous in the lifetime of our current students, who are always connected to their peers, instructors and sources of information. Teaching and learning practices are impacted on by the expectations for connectivity and engagement of these students, and are supported by the current wide selection of multimedia teaching and

Table 1. The review topics and the Multimedia Physics in Teaching and Learning (MPTL) conference at which they were reported.

MPTL conference	Topic
17th Istambul (Turky) 2012	Electricity and magnetism
16th Ljubljana (Slovenia) 2011	Statistical and thermal physics
15th Reims (France) 2010	Mechanics
14th Udine (Italy) 2009	Optics and waves
12th Wroclaw (Poland) 2007	Solid state, nuclear and particle physics
11th Szeged (Hungry) 2006	Electricity and magnetism
10th Berlin (Germany) 2005	Statistical and thermal physics
9th Graz (Austria) 2004	Mechanics
8th Prague (Czech Republik) 2003	Optics
7th Parma (Italy) 2002	Quantum mechanics

learning resources. Many educators and researchers are developing, and using, a variety of educational materials that make use of simulations, virtual laboratories, videos of real and animated experiments and online tutorials based on well-established didactic methods [1–3]. Although there are commercial enterprises specializing in the preparation and delivery of such tools, we are fortunate in physics to have many collections of high-quality resources freely available and easily accessible via the internet.

One of the challenges that potential users of IT face is to find suitable and good quality multimedia materials. Indeed, the large number of products readily available makes it very time consuming to search and select those that are relevant and of high educational quality. Traditional internet search engines are not designed to address the combination of topical, didactical, usability and age-appropriate requirements for these resources.

This peer review is part of a continuing series of annual reviews, started in 2002. The main goals of these efforts are to identify quality media-based teaching resources and to encourage the use of them. An international group of physicists associated with the International Conference on Multimedia in Physics Teaching and Learning (MPTL, started in 1996) performs the reviews resulting in the recommendation of materials useful in preparation of activities devoted to different subject areas in physics. One topic is chosen each year for review. Table 1 presents the topics covered by year. A number of papers describing the findings of these annual reviews have been prepared [4] and are available on the web[10].

This paper presents the results of a peer review of open access/open source multimedia and technology-based learning materials devoted to topics in electricity and magnetism. Multimedia resources on this topic were previously considered in 2006. The use of multimedia resources is particularly important for this topic due to the abstract concepts involved, such as fields, charge and current. Both teachers and students can use these learning tools to explore the unfamiliar concepts introduced in electricity and magnetism courses. Of course, the features of quality learning, including student engagement, peer and student–instructor interactions, and proper didactic scaffolding, apply to these technology-based resources in the same way as for more traditional instruction.

2. Review process

The review process is similar to that used in 2002 [5] and consists of four main steps: gathering a broad list of resources, sorting out quality materials suitable for reviews, reviewing and reporting noteworthy items, and providing an overview of the review results.

[10] www.mptl.eu/evaluations.htm.

The creation of a preliminary list of resources for review took advantage of a number of tools. The search started with the list created from the 2006 MPTL review [6] and additional items were added through web searches by students at the University of Oklahoma and comparison with the online resource databases in MERLOT [7] (280 resources) and ComPADRE [8] (680 resources, many not containing multimedia). There was a significant overlap between all these sources, resulting in a preliminary list containing about 1000 items. Many of these individual items, such as simulations or media-enhanced web pages, were part of a larger resource collection. To facilitate the process, these larger resource collections were reviewed rather than creating separate reviews for individual items. The MPTL group has found that understanding the context of resources in a collection helped the review process and resulted in better recommendations for potential users.

The list of resources was then filtered in the following manner.

- Items from 2006 that could no longer be found were removed.
- Commercial (for-fee) resources were removed.
- Resources that were copies or mirrors from other web sites were removed.
- Resources with obvious physics errors were removed.
- Items with little or no multimedia were removed.

The filtering process resulted in about 240 resource collections that were suitable for potential review. One of the authors (Mason) sorted these resources into four main categories to determine which would be suitable for a full review. This streamlined the review process and focused it on the resources with the highest potential to be worthy of note. The resultant categories and the number in each were as follows.

- *Do not review* (140). These items had either (1) limited use of multimedia, (2) limited potential for student engagement or interactions, or (3) were not in English and thus were difficult to assign to multiple reviewers.
- *Low-priority review* (35). These items had some interesting aspects but were of lower potential quality. They could prove useful for some users.
- *High-priority review* (54). These items were assigned to reviewers.
- *Interesting examples* (9). A few other items were kept as interesting examples. This included examples of video collections, potentially useful but all with limited potential for student engagement, and examples of material with physics errors but ranked highly in Google searches.

The high-priority review resource collections were each assigned to two or more reviewers using an online review process hosted on ComPADRE. The review rubric used here has been described in previous reports [5]. It includes three main aspects of quality multimedia learning resources: motivation for using the resource (ease of use, attractive layout, stated purpose and stated use), quality of content (relevance, scope, accuracy), and the didactic methods and context (flexibility, targeted audience, pedagogy, feedback and documentation). Each individual rubric is rated on a five-point scale, overall ratings are given for each of the three main categories and an overall score is assigned. The evaluation form is presented in the appendix.

3. Resources of note

The following are the resource collections that were highly ranked by one or more reviewers. All of them are free of charge and do not require registration. As the recommended teaching resources cover all educational levels, information about the main target group in each case is also presented. There were some disagreements between reviewers, which are discussed further in the review comments and in section 4 below.

British Energy: electric circuits
http://resources.schoolscience.co.uk/BritishEnergy/11-14/index.html
Content: circuits Rating: excellent
Level of teaching: primary, secondary

Comments. This resource provides a focused, simple introduction to circuits suitable for primary and secondary students. The tutorial includes theory, virtual experiments and self-tests for learners. The simulation is interactive, although it is a little hard to construct circuits at times. Many exploratory 'challenge' problems are available for students to use, although one reviewer felt some problems were too scripted.

Rutgers: learning cycles on electricity and magnetism
http://paer.rutgers.edu/PT3/cycleindex.php?topicid=10
Content: charges and fields Rating: excellent/very good
Level of teaching: secondary, higher

Comments. In this set of resources, the use of videos for student exploration in a learning cycle is noteworthy. The explorations provide the learning goal, prior knowledge, and one or more predictions and follow-up questions. Simple experiments using common materials are used. Some of these videos show experiments students could do themselves, but the videos are valuable for pre-class or pre-lab purposes. The multimedia use is limited to videos, but these are well designed for the stated learning goals.

Open Source Physics: E&M modelling resources in easy Java simulations
http://www.compadre.org/osp/search/search.cfm?gs=224&b=1&qc=Modeling
Content: E&M, all topics Rating: excellent/very good
Level of teaching: secondary, higher

Comments. This is a wide collection of resources from different authors, all built on the Easy Java Simulations platform. The type and quality of the content varies, but most is quite good. Theory and student activities are embedded with many of the EJS models. One noteworthy aspect of the EJS environment is that all models can be opened, the simulation method viewed, and the model and didactic content modified as needed. This makes clear the algorithms and the approximations being made.

PhET: electricity, magnets and circuits
http://phet.colorado.edu/en/simulations/category/physics/electricity-magnets-and-circuits
Content: E&M fields and circuits, teaching ideas Rating: excellent/very good/good
Level of teaching: primary, secondary

Comments. This collection of materials provides a series of research-based interactive environments for students to explore different physics topics. Each of the simulations includes a number of lesson plans created by instructors and researchers on the PhET team. The reviewers have different opinions of the materials. All reviewers noted the open, flexible and exploratory nature of the resources, although one reviewer feels a need for more structure. Although there are questions about these simulations reinforcing student misconceptions, the reviewers noted the extensive student-use studies by the PhET researchers that address these problems. The algorithms and approximations used in the program are not given. In the E&M

materials there are four main noteworthy simulations (circuits, Faraday, E&M fields and E&M waves), with multiple versions provided for the use of different audiences.

CANU: dc circuit laboratory simulation
http://canu.ucalgary.ca/map/content/circuitbuilder/basic/simulate/practice/
Content: dc circuits Rating: excellent/good
Level of teaching: secondary, higher

Comments. This circuit simulator has a flexible design and interface so that any dc circuit can be simulated. Controls allow the change in parameters of any circuit element, although implementing changes is not always obvious. Unfortunately, the graphics and interface are somewhat dated, using abstract symbols and a square virtual circuit board for the circuit design. There are no pedagogical resources except for the noteworthy demo/tutorial at http://canu.ucalgary.ca/map/content/circuitbuilder/basic/simulate/demo/.

Amrita: electricity and magnetism virtual lab
http://amrita.vlab.co.in/?sub=1&brch=192
Content: magnetic fields and circuit elements Rating: excellent/fair
Level of teaching: higher

Comments. This is a collection of tutorials that includes theory and a simulated experiment, as well as a self-evaluation for students to test their understanding, exercises for exploring the experiment and references. One reviewer felt the combination of theory, simulation, activities and tutorials to be very noteworthy and of high quality. The second reviewer felt that the simulated experiments are too structured and 'cookbook' for effective learning.

MIT: TEAL E&M simulations
http://web.mit.edu/8.02t/www/802TEAL3D/index.html
Content: all of E&M Rating: very good
Level of teaching: higher

Comments. This is a series of high-quality simulations and illustrations of all E&M topics. There is a particular focus on visualization of fields. In some of the illustrations there is little or no interactivity for the learner, but other simulations allow exploration. This is part of an MIT Open Courseware course collection that provided activities, homework and labs (http://ocw.mit.edu/courses/physics/8-02-physics-ii-electricity-and-magnetism-spring-2007/index.htm), creating a complete didactic context for the multimedia resources.

Boston University: Easy Java simulations
http://physics.bu.edu/~duffy/Ejs/
Content: E&M, dc and ac circuits Rating: very good
Level of teaching: secondary, higher

Comments. This is a collection of physics explorations based on interactive simulations. The simulations are easy to run using an intuitive interface. These explorations will help learners focus on the important physics of the topics covered. The use of Easy Java simulations provides users with the capabilities of viewing and modifying the source as described above. This is an example of a single author using the Easy Java simulations modelling environment to build a collection of resources sharing a similar look and pedagogical approach.

4. Conclusions and further efforts

The following are general comments and reflections on the materials reviewed and the review process itself.

- This review process found items of significant value for educational purposes at different educational levels, mostly pre-university and university.
- The review rubrics and the reviewers' expectations together set a high bar for recognition as high-quality multimedia resources. The requirements for effective and significant use of multimedia and quality student-centred learning resulted in a strong preference for materials based on simulations and virtual models.
- The discrepancies between reviews were mostly the result of the different didactic expectations of the reviewers. These differences were usually based on different views of the proper balance between student-controlled explorations and more teacher-scaffolded learning exercises.
- Few new examples, not considered in previous years, of simulation-based multimedia learning resources for physics were discovered in this review. The reason might arise from flaws in the search process or too-restrictive views on quality, interactive multimedia. It might also mean that the materials available from the existing developers are meeting instructors' needs. This might be a mature field with little motivation for new developers to create more material.
- Currently, a great deal of work is going into the creation of videos and online course material based around videos. Few such video collections were included in this review because most are simply filmed lectures or demos. They are online examples of face-to-face pedagogies with limited effectiveness. Videos such as these have their uses but require a great deal of context that is not immediately obvious from the video collections themselves. As is always true with the review of these materials, the context and use of materials will determine their ultimate value for learning.
- A search was made for mobile applications (tablet and phone-based), but the review process found very few good examples for E&M. Most were simply vocabulary lessons and other lower level learning activities.
- Some of the electricity and magnetism learning resources at the top of a Google search were of questionable quality. There were several plug-and-chug 'calculators' that provide students with answers to typical homework problems without any need to understand the physics. There were also materials with physics errors, such as a tutorial on computing equivalent resistance with an image of a short-circuit.

The annual review effort will be continued next year and presented at the MPTL 2013 meeting in Madrid. The topic of the next review is still to be determined. Following the sequence of topics from the first round of reviews, 2002–2007, the next review would cover the topics of solid state, nuclear and particle physics. However, as mentioned above, this review may consider new developments in the use of video and mobile devices (phones and tablets) for all topics in physics.

In this paper, we have presented the results of a peer review of multimedia-based learning resources in electricity and magnetism. Our goal was to bring this work and the recommended materials to the attention of readers. Most importantly, the aim of this continuing effort is to promote the use of high-quality IT materials by physics and science educators and to assist in maintaining and improving the standard of physics teaching at universities and other institutes of secondary and higher education.

Appendix. Review rubric

URL
Overall rating:
Comment:
Recommendation:

User-friendliness:	**Rating**	**Comments**
Is it easy to start using the MM?		
Are the design comprehensible and the image quality satisfactory?		
Is the function of control elements evident?		
Are the software requirements clear and of adequate proportion?		
Attractiveness:		
Is the layout appealing?		
Is there a motivating introduction?		
Are there interactive components?		
Is the topic interesting (reference to everyday life, applications, explaining a phenomenon)?		
Is the MM up-to-date/innovative?		
Clear description of purpose and work assignment:		
Is the intention of the MM evident?		
Does the user know what is expected from him?		
Is there a problem to solve or a context to understand?		
Relevance:		
Is the topic important?		
Does it make sense to use the MM (e.g. problems in understanding, dynamic process)?		
Scope:		
Is there a profoundness of content?		
Is there a broadness of content (special case, general overview)?		
Correctness:		
Is the content of the MM correct?		
Are simplifications indicated?		
Flexibility:		
Is the MM appropriate for a broad target group (including self-learning)?		
Is it possible to use the MM in different teaching and learning situations?		
Does the MM allow for the same topic to be approached in different ways?		
Matching to target group:		
Is a reasonable didactical reduction implemented?		
Are technical terms explained?		
Are the objectives appropriate?		
Realization:		
Is the general approach suitable to present the subject and realize aims of the given MM?		
Is the type of MM chosen reasonable (video, simulation, animation)?		
Documentation:		
Is the operation obvious or explained?		
Is the material self-evident or explained by additional text?		
Is there a reference to material for further studies?		
Are there any suggestions for implementation into the teaching process?		

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[8] comPADRE Recources for physics and astronomy communities http://www.compadre.org