Report and Recommendations on Multimedia Materials for Teaching and Learning Electricity and Magnetism

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1. Introduction

Information technology 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 by the current wide selection of multimedia 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. Although there are commercial enterprises specializing in the preparation such tools, we are fortunate in physics to have many collections of high-quality resources freely available and easily accessible via the internet.

This report 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. 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 quality didactic scaffolding, apply to these technology-based resources as well as more traditional instruction.

This peer review is part of a continuing series of annual reviews, started in 2002, carried out by an international group of physicists. Each year, one topic is chosen for review. The goals of these review processes are to identify quality media-based teaching resources and to encourage use of them. Multimedia resources on the topic of electricity and magnetism were previously reviewed in 2006.

2. Process

The evaluation process in this year's review consisted 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.

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 review and additional items were added through web searches by students at the University of Oklahoma and comparison with

the online resource databases in MERLOT (280 resources) and ComPADRE (680 resources, many not containing multimedia). There was significant overlap between all of these sources, resulting in a preliminary list containing about 1,000 items. Many of these were individual resources that are part of a larger collection. In the next step of the collection and review process, these individual resources are gathered into a single item for consideration for review.

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

- Items 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 very obvious physics errors were removed
- Items with little or no multimedia were removed
- Multiple items from the same source were consolidated into a single collection to be reviewed as a whole. This consolidation was done because previous reviews have found that understanding the context of resources in a collection helped the review process.

The filtering process described above resulted in about 240 resource collections that were suitable for potential review. One of us (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:

- 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 in some cases.
- 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 with limited potential for student engagement, and examples of materials 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. 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 area is rated on a 5-point scale, and overall ratings in each category and for the total review are given. The evaluation form is presented in the Appendix 1.

3. Resources of Note:

The fallowing are the resource collections that were highly ranked by one or more reviewers. There were disagreements between reviews which are discussed further in the Conclusions section below.

British Energy: Electric Circuits
http://resources.schoolscience.co.uk/BritishEnergy/11-14/index.html
Content: Circuits Ratings: Excellent

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 Ratings: Excellent/Very Good

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 prediction and follow-up questions. Simple experiments using common materials are used. Some of these are experiments students could do although the videos can be used for pre-class or pre-lab purposes. The multimedia use is limited to videos but these are well designed for the learning goals.

Open Source Physics: E&M Modeling Resources in Easy Java Simulations
http://www.compadre.org/osp/search/search.cfm?qs=224&b=1&qc=Modeling
Content: E&M, all topics Ratings: Excellent/Very Good

Comments: This is a collection of different resources from different authors all using the Easy Java Simulations platform. The type and quality of the content varies, but most are quite good. Theory and student activities are embedded with many, but not all, of the EJS models. One noteworthy aspect of the EJS environment is that all models can be opened and modified as needed. This also makes clear the algorithms and 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

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 had different opinions of the materials. All reviewers noted the open, flexible, and exploratory nature of the resources, although one reviewer felt a need for more structure. The concern was expressed that inaccurate student understandings could be reinforced by the models, although the PhET researchers study the student use of the simulations to avoid this problem. 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, E&M Waves) with multiple versions of some of these 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 Ratings: Excellent/Good

Comments: This circuit simulator is flexible so that any DC circuit can be simulated. Controls allow the change in parameters of any circuit element, although implementing changes is note always obvious. Unfortunately, the graphics and interface are somewhat dated using abstract symbols and a square virtual circuit board for the circuits 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 Ratings: Excellent/Fair

Comments: This is a collection of tutorials that include theory and a simulated experiment, as well as a self-evaluation for students test their understanding, exercises for exploring the experiment, and references. One reviewer felt the combination of theory, simulation, activities, and tutorials are very noteworthy and 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 Ratings: Very Good

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 many of the illustrations there is little or no interactivity for the learner, but other simulations allow more exploration. Also of note, this is part of an Open Courseware course with all activities, labs, etc. (http://ocw.mit.edu/courses/physics/8-02-physics-ii-electricity-and-magnetism-spring-2007/index.htm) providing a complete didactic context for the multimedia resources.

Boston University: Easy Java Simulations
http://physics.bu.edu/~duffy/Ejs/
Content: E&M, DC & AC Circuits Ratings: Very Good

Comments: This is a collection of physics explorations based on interactive simulations. The simulations are easy to run using the intuitive interface. The recommended explorations will help learners focus on the important physics the topics covered. The use of Easy Java Simulations provides users with the capabilities of viewing and modifying the source.

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.

- 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-centered learning resulted in a strong preference for materials based on simulations and electronic models.
- The discrepancies between reviews were mostly the result of the different didactic expectations of the reviewers. These differences were usually based in different views of the proper balance between student-controlled explorations and more teacher-scaffolded learning exercises.
- Few new examples 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 be 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 materials.
- 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. 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.

Appendix 1: 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 (incl. 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?		