PHYSICS EDUCATION RESOURCES ON THE INTERNET

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PREFACE

The intention of this thesis was to provide the faculty of Oklahoma State University's Physics Department with resources of the internet related to introductory physics instruction. Originally, the focus of this study was to research the varied misconceptions (preconceptions) about Newtonian Mechanics students bring with them to the classroom. In light of the extensive research already undertaken on this topic, the scope of this project shifted to producing a survey of the available literature germane to introductory physics education. The project then grew to be an on-line resource for those involved in physics education available to users of the internet. The resulting web page has been designed to be a dynamic resource so that it may continue to grow and remain current in the years to come

Inspiration for the Physics Education Resource Site web page is partly due to the Oklahoma chapter of CETP (Collaboratives for Excellence in Teacher Preparation). Through work done in organizing the physics course for the CETP program, motivation for developing an internet based cornerstone as a tool for science teacher preparation arose.

I wish to express my sincere appreciation to my committee advisor, Dr Bruce Ackerson, for his helpful supervision, insightful guidance, and friendship. This appreciation extends to committee members Dr. Larry Scott and Dr. Paul Westhaus, whose encouragement made this project possible. Thanks also go out to the CETP

program at Oklahoma State University for the financial support in developing the inquiry based physics course which parallels and compliments my experiences in the physics department.

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I.

INTRODUCTION

Background. Sponsored by the American Association of Physics Teachers (AAPT), a conference was held and a Steering Committee was created in 1956 as part of an effort to improve introductory physics instruction at the college level. Included as one of their resolutions was that the AAPT should encourage the implementation of experimental and non-conventional courses in physics in order to improve the effectiveness of physics instruction (AAPT, 1957). Certainly, efforts to improve the effectiveness of physics instruction did not begin at this conference; however, the Steering Committee's resolutions are indicative of the present reforms in science education. Perhaps the present day analogy is the "Physics at the Crossroads" letter created by another conference held by the AAPT in 1996. Like the aims of the 1956 meeting, this letter was sent to physicists nationwide in order to assess and address the issues relevant to introductory physics. Whereas the 1956 meeting held mainly that content and time allotted for physics instruction be adjusted, the 1996 meeting strove to deal with issues such as eliminating rote memorization, students' lack of confidence in science, demoralization among physics faculty teachers," and "revitalization of our physics courses" (Hilborn, 1996). These issues reflect the poor preparation of introductory physics students and the instructors' frustrations as a result from this.

It is clear from the change in focus of these two conferences that the issues of physics instruction are shifting. It seems today that physicists know what content they want to be taught at the introductory level but now need to change how it is presented to

better instruct their students. Work done by Lillian C. McDermott, however, indicates that regardless of the skill of the instructor or the method of instruction at the secondary level, students still perform poorly on the same controlled examinations (McDermott, 1990).

To ensure students were better prepared for future science courses, numerous inquiry based elementary physical science courses have been developed and are currently used nationwide at the elementary and secondary levels. These courses are a response to the notion that doing away with pre-conceptions early in education is not only most effective, but essential. The effects of these courses, however, have been minimal and as McDermott notes, enthusiasm of teachers implementing these courses is short lived due to a lack of both experience and knowledge of the content of the new course work (McDermott, 1976). According to McDermott, the issue at hand now seems to be the preparation of current and future teachers in the physical sciences at both the elementary and secondary levels.

In the spirit of these issues, the Physics Education Resource Site web page will provide resources for those involved in physics education. Having been registered with various internet search engines, it can be found by those seeking assistance in improving their own physics education or physics instruction methods. The web page places an emphasis on inquiry based learning and is geared toward pre-college use, although there are resources indexed that professors and graduate students may find helpful as well.

The Problem. There is no single answer or solution to the problem of poorly prepared introductory physics students at the college level. It seems that in order to prepare such

students, effort needs to go into the training of elementary through secondary teachers so that the quality of science instruction is improved at these levels. This improvement will be reflected in the preparation of physics students as they complete their high school physics courses and go on to take college level introductory physics courses.

The problem of poorly prepared introductory college physics students is a consequence of science teachers who lack the knowledge and or confidence to teach quality science at the elementary through primary levels. The Physics Education Resource Site attempts to combat this problem by acting as a tool by which students and educators may improve physics education at the elementary through secondary levels.

Having stated the above, the problem most immediate to the purposes of the Physics Education Resource Site involves the assemblage and categorization of the more useful and valuable resources on the internet.

Purpose of the Study. The purpose of this study was to survey the content of the internet pertinent to physics education and to categorize the found resources into an easily navigable web page. This was to be accomplished in the hopes that the web page could be used as a current and up to date multimedia spring board for teachers and students involved in physics education. It is hoped that teachers will find the web page helpful from developing course curricula, using and finding relevant on-line resources, to using free internet based applets specifically designed for physics education. In addition, this study also places importance on the students of physics seeking assistance or independent research.

supplemental in its own right. It has been designed to compliment physics programs that are already in existence.

Definition of Terms.

AAPT: American Association of Physics Teachers.

CETP: Collaboratives for Excellence in Teacher Preparation.

Physics Education Web Site: An active web page consisting of internet resources indexed by category on the internet resulting from this study.

Host Page: A web page that acts as a title page to various other web pages.

Web Page: An internet accessible URL that contains documents and or links to other web pages and resources.

URL: Uniform Resource Locator; a specially formatted address that an internet browser uses to locate, retrieve, and display a document.

Web Page Address / Internet Address: Synonymous with URL.

Internet: The worldwide network that is made up of cooperative sub-networks which offer a variety of personal and commercial uses.

Search Engine: A program on the internet that allows a user to search for on-line information.

On-line: The description of an item as being found on the internet.

Applet: Special internet program with a wide variety of applications.

Search String: A query made up of key words used in search engines.

Email: Electronic mail.

Link: A phrase, object, or image on a web page that is associated with a URL.

Pre-conception: An incorrect notion already strongly held by a student.

Mis-conception: An incorrect understanding of presented content strongly held by a student.

Scope and Limitations. The foremost limitation to this study is the impossibility to document all of the internet resources related to physics education. It would be absurd to suggest that the Physics Education Resource Site is a *comprehensive* index of all the resources apposite to physics education on the internet. This particular limitation is compounded by time as well as the activity of the resources indexed. As time evolves, numerous web sites are created and become defunct; this undoubtedly will effect some resources indexed on the Physics Education Resource Site. This limitation has been addressed in part by allowing the Physics Education Resource Site to be a dynamic document so that it may be adequately maintained and grow under the supervision of Oklahoma State University's physics department faculty. The web page is also subject to advice and criticism by its audience through communication by email.

Categorization of the resources indexed on the Physics Education Resource Site is the second most prominent limitation. The resources indexed had to be reduced to a finite number of subjects to make the study feasible, thereby limiting the web page's scope of related physics education resources. Once an appropriate number of categories were chosen, the tasks involved then became categorizing the resources accurately so that the users of the page could navigate it efficiently.

Organization of the Study. The subsequent chapters will consist of the following:

Chapter II: A discussion of some of the present ongoing physics education reforms and a review of the internet web pages prevalent to this study.

Chapter III: An account of the methodology, including a description of the categorization methods.

Chapter IV: A summary of the various resources categorized on the Physics Education Resource Site.

Chapter V: Presentation of the references used to complete this study

II.

REVIEW OF THE LITERATURE

Assessing Available Internet Resources by Category. Web pages and internet sources of value to students were limited to three categories: "Science News, Magazines, FAQ's, and Forums," "Organizations," "Popular / Cool Sites." These categories were chosen so that students would find the Physics Education Resource Site both useful for their own education needs, and enjoyable enough to capture their interests. The page for educators was broken down into fourteen categories: "Physics Education Research Groups," "Resources / Museums," "Some Articles," "Companies," "Pseudo-sciences," "Organizations," "A Few Classroom Web Pages," "Curricula / Lesson Resources," "Workshops / Programs," "Mis / Pre-conceptions Web Sites," "Computer Applications," "Pages of Links / Unique," "Student's Main Page," "Unsorted Sites." These categories were chosen to best represent the resources that were found for educators.

Student's Main Page Categories. The "Science News, Magazines, FAQ's, and Forums" category features reputable web page which offer information related to specific subjects. Usually, these sites simply contain an index of most commonly asked questions of a particular topic. Other sites give the user the opportunity to submit questions to a bulletin board or via email.

The Why Files, for example, has a forum designed for virtually every science subject a student will encounter in high school. In a Why Files forum, the user can submit a question or respond to any topic. The response rate to messages ranges from hours to not more than a week. Sponsored by the NSF, The Why Files has a knowledgeable staff to answer questions and monitor postings. This site also has regularly updated science images with explanations and science news articles published on-line that are archived. What helps make The Why Files such a good resource is the attention it draws from students (primary education through graduate school), faculty, and the general public.

The sci.skeptic FAQ web page is a document that addresses issues from the scientific method to pseudo-scientific claims. This web page has not been recently updated, however its content is used by those who participate in the sci.skeptic news group. Paul Johnson, the author of the sci.skeptic web page, privately maintains the web page but makes a reference to the Committee for the Scientific Investigation of Claims Of the Paranormal (CSICOP). This site is a good resource for finding out about abounding theories and defining terms that are buzzwords in the pseudo-science community.

The "Organizations" category is an index to organizations whose interests are in science and most often related to physics. The National Aeronautics and Space Administration (NASA) web page offers a wealth of information to the user and is one of

the more popular sites on the internet. Users can find out about available science related programs, space missions, science history, space science, and etc. on NASA's web page. NASA's web page also has links to related sites, links to news sites, a FAQ link, a NASA web search engine, and much more. The material on NASA's web page is presented so that it furthers science education in whatever the interests are of the user.

A link to the Society of Physics Students (SPS) was included under the "Organizations" category as a source of additional student resources. SPS is made up of student run chapters at the college level nation wide. On the SPS web site published articles can be viewed on-line, membership and program information is made available, and links to zones and chapters guide the user to SPS organizations. Currently, the SPS web page is maintained by the American Institute of Physics and has not been updated for a full year. Hopefully this web page will grow and offer even more to student users in the future.

Web pages indexed under the "Popular / Cool Sites" category consist of science related web pages that are known for their popularity. For example, here students can access the latest Martian weather reports, photos, and news posted by NASA via the Mars Missions link. Bill Nye the Science Guy's Nye Labs Online link parallels the popular television show that is popular with children. At this site, students can view and perform the demo of the day which consists of a short lab made up of household items for lab materials. Major funding for this web page comes from the NSF and the Boeing Company.

The StudyWEB link allows students to search for information on any topic offered in high school and beyond American. StudyWEB is sponsored by Computer Resources,

Inc. and is part of the TeacherNet Web Ring. Admittedly, this category most likely contains the web pages that will attract students the most.

Educator's Main Page Categories. In the Physics Education Research Groups category, some of the more recognized research groups have been indexed alphabetically for interested educators. These sites appear first on the Educator's Main Page because of their immediate value. These are established education research programs researching and addressing physics education issues specifically. For the interested person seeking information on physics education, these sites are invaluable. As an example (which is also highly recommended), the homepage of one of the most pioneering physics education groups from the University of Washington (called PEG) can be found in this category. A description of their Physics by Inquiry course (for future and pre-service elementary teachers) and their Tutorials in Introductory Physics course (for physics majors at the college level) can be found here as well as details of the respective instruction preparation workshops.

In the "Resources / Museums" category, indexed web sites range from science museums to PBS Online to science fair resources. This is more of a collection of miscellaneous resources that contained enough value in two or more category subjects that indexing them into only one category would not accurately represent them.

Although the Ontario Science Centre is located in Ontario, Canada, their web page is constructed so that users worldwide can still make virtual visits and benefit from the museum via the internet. This web page has links to other on-line resources and science web pages of interest categorized nicely for the user.

The Internet Pilot TO Physics (TIPTOP) is an excellent resource for both students and educators involved in physics education. TIPTOP is an international effort to aid physics research and education by gathering useful resources of the internet. At this web site the user can read publications, find out about science related event dates, enter various science forums, and make use of a wide variety of computer applications and simulations. Students might find this web page useful to some extent, but the genre of the web page is mostly of interest to educators and physicists.

PBS Online has a long lived reputation for promoting education and their web site reflects this with current news articles and science and technology categories that the user can browse.

The "Some Articles" category simply cites references to published articles related to physics education issues. Many of these links refer to publications of physics education research groups (as indicated in parenthesis). The National Academy of Sciences' National Science Education Standards article can be found in its entirety in this category as well as links to lists of paper published references. As an example, clicking on the Some assorted articles from periodicals link refers the user to bibliographic information organized in reverse chronological order. These articles are related to physics education, most of which were published in the American Journal of Physics periodical.

Some of the more widely known commercial companies that offer science equipment were indexed in the "Companies" category. Educator's can use this category to see what is available on-line, order on-line, or request a catalog. The convenience of this category is that it acts as an electronic address book and allows immediate access to company products. Texas Instruments has one of the more developed sites that is user

friendly for educators and students. For instance, information for class activities for the popular Computer Based Laboratory (CBL) calculator is available as well as assistance for those who own products and have questions. Downloads are also available throughout company web pages.

The "*Pseudo*-science" category is one category of special interest and deserves separate attention. While surveying the internet for physics education resources, sites containing pseudo-scientific claims were sometimes referenced. Although these web pages can be dismissed with skepticism and a basic knowledge of physics, the targeted audience may not be able to do so with the information they have at hand. It therefore seemed worthwhile to at least recognize the potential dangers and misgivings of such web sites. Web sites in this category range from the explained to the unexplained to the "unexplainable." As the reader is warned at the beginning of the *Pseudo*-Science Main Page, all material should viewed skeptically, requiring critical thinking as an active role on the part of the reader.

An example of such is the Sympathetic Vibratory Physics web page. Throughout this web page, an aura of mystery sets the scene as the history of the intriguing "Dynasphere" is told. It is said to merge vibrations, love, and sound (music) to unity of enormous power. The specific function of the device is never made clear, but reasons are given as to why it has not been publicly demonstrated.

In addition to pseudo-scientific sites, skeptical sites such as CSICOP / Skeptical Inquirer have been placed in this category. Recognizing a potential pseudo-science is important, but the ability to investigate it through skeptical eyes is a necessary follow up. The CSICOP web page gives the user the tools that will help make this possible.

As in the Student's Main Page, the Physics Organization category contains links to various organizations of interest for the user. In the Educator's Main Page, however, the web pages indexed are of more interest to educators. That is, these organizations also are at an academic level that students will not find much interest in. The National Institute for Science Education (NISE) site describes the many educational programs and activities currently under its direction (and reports of already completed programs).

As a further example, the user can search for specific articles in Physics Today or Applied Physics Letters on the American Institute of Physics (AIP) home page. Also, both the AIP and AAPT web pages can assist educators in locating employment opportunities.

To illustrate how the internet can be used as an instructional aid for physics, the category "A Few Classroom Web Pages" have been included on the Physics Education Resource Site. At present, only a handful of these sites are in this category, but the idea of incorporating the internet into course curricula is growing in popularity among students and educators. The Cockpit Physics web page is an internet supplement to the United States Air Force Academy physics course. The intention of this site seems to be reinforcement of class lectures by making the internet lessons applicable to the students' future experiences. Using the internet as a class supplement is a novel idea since students frequently consider the act of being on the internet enjoyable.

For those educators seeking information on curricula or lesson plans, the "Curricula / Lesson Resources" category will be helpful. Whereas the "Workshops / Programs" category offers programs for the educator to become involved, this category

provides assortments of lab activities and daily lesson plans described in detail for educators.

A prime example of this is the Fundamentals of Physical Science program created by Arizona State University's chapter of CETP. The content of the course material on-line is complete and extensive on this site, with a syllabus and course description. Even if the user decides not to use the entire content of the program as originally designed, there still remains many valuable ideas and activities throughout this on-line publication he or she can capitalize on.

In the same category, the World Lecture Hall (WLH) is a web site that whose contributors are physics faculty world wide who are using the internet as a tool in the courses they instruct. The range in material in the WLH is from introductory physics to graduate level course work.

For the educator interested in course work development or new teaching techniques, the "Workshops / Programs" category will be very beneficial. Each site in this category contains information about programs with various specific goals. These web sites also offer a great number of resources and links to other regional and national on-line organizations. Among those indexed in this category are the Modeling Workshop Project of Arizona State University, the Comprehensive Conceptual Curriculum for Physics (C3P) of the University of Dallas, various CETP chapters, and Eric Mazur's (of Harvard University) Peer Instruction.

Because of the amount of attention given to misconceptions and preconceptions in science, the "Mis / Pre-conceptions Web Sites" category was created. Here, educators can investigate potential student difficulties and common problem areas in average course

curricula. For instance, the Humorous Science Mis-statements web page is a comical web page that illustrates student ingenuity and confusion among various topics. The critical user is at first entertained, but then grows alarmed as the numerous mis-statements are read. It's one thing for a student to write a humorous response intentionally, but it's quite another when a student's honest response consists of contradictions that a moment's criticism should have resolved.

The Bad Science link is a resource for instructors to refer to in hopes to address commonly held misconceptions in science. Topics range from sonic booms to molecular structure and all include detailed explanations. However informative this site may seem to be, the user needs to be critical of its content. The notion that ice skating is *not* a result of a thin layer of melted water due to the pressure of the ice skates as expressed by the web page is in opposition to many sources, including graduate level thermodynamics texts.

In the Computer Applications category, scientific software and hardware company sites can be found. Also available in this category are science related applets for use with demonstrations, homework, class activities, etc. This category will be most useful for those who have or want to gain an advanced experience with computer software and hardware applications. The Physlet Problems link offers some very useful applications of JAVA programming. Instructors can make use of interactive programs where qualitative as well as quantitative results can be obtained by the students without the need for any lab equipment. An example of such an activity includes a series of animations that depict different collision scenarios. Questions of the animations asked require students to decide what data needs to be taken. Once the data is taken the students must use their results to

verify themes such as conservation of momentum. There is great potential in this virtual hands-on technique for faculty who decide to employ it.

The TIPTOP/VLAB (TIPTOP Virtual Laboratory) link is another useful index of applets that can be used for physics instruction. JAVA based programs on this web page tackle Monte Carlo integral approximation methods, quantum mechanic wave models, the ordinary pendulum, and many other physics related subjects. The library of Applets available is extensive on this site and will hopefully be organized in the future by specific subject headings as it grows.

Web pages and resources that were unique or just contained a list of links were placed in the "Pages of Links / Unique" category. Web pages, for example, that contained an excessive amount of links which appeared to grow continually yet weren't entirely devoted to science education were indexed in this category. Such is the case for the link to Larry Martin's Bookmarks. At this web site, many interesting links related to science can be found (some of which are indexes elsewhere on the Physics Education Resource Site) in addition to several other links that are not of any interest to science education.

The Unsorted Sites category is simply a reflection of the dynamic nature of the Physics Education Resource Site. These sites are unsorted and their inclusion on the Physics Education Resource Site is pending, as well as their categorizations.

III.

METHODOLOGY

Research Methodology. Constructing the Physics Education Resource Site involved surveying the internet for web pages and resources with themes related to physics education. General search strings were used and then refined as needed to reduce the number of web pages referenced by the search engines. All relevant URL's were logged and then filtered at a later date. In many instances, web pages referenced had not been updated for years. In such cases, the links on these pages were logged, but not the host page itself. This was done in order to prevent indexed links on the Physics Education Resource Site from becoming inactive.

Once a large collection of resources were collected, they had to be categorized. Due to the number of indexed resources, it was decided that two main pages be created: the Student's Main Page and the Educator's Main Page. To reduce redundancy in URL links on both pages, a link to the Student's Main Page was placed as a category of the Educator's Main Page. The focus of the Student's Main Page became categorized resources that would interest mostly students. The philosophy behind this was that what is of interest to the students may be utilized by the educator in instruction. The Educator's Main Page evolved into a web page that would be of interest primarily to educators. This format was chosen so that students would not have to browse through subjects they most likely would have little interest in. The format for the Educator's Main Page was also based on the assumption that educators may be in search of content that students have no knowledge of.

Examples:

1) A student may be in search of physics organizations, but will not likely find interest in the AAPT web page.

2) If both a student and an educator are seeking information on the pendulum, the student may be seeking a basic understanding while the educator is seeking alternative laboratory activities or materials.

IV.

FINDINGS

General. The most useful web pages to those involved in physics education are the web pages set up and maintained by professional and educational institutions. Such web pages are generally sponsored and funded by large agencies like the National Science Foundation, or NASA. These web pages are professionally constructed, updated frequently, and are staffed so that they continue to improve. The emphasis of these sites is primarily in offering users information and resources free of charge.

Commercial web pages also offer resources and information to the user, but focus mainly on drawing monetary business to the company. These web pages do, however, offer some free materials and further resources to the user. What is not lacking on the internet is the quantity of free materials. Users can request free catalogues from on-line companies they may never have gotten a hold of otherwise, and educational software (demonstrations and full versions) is available in abundance for free in the form of

downloads. Some software may even be used remotely (run on distant servers) for educational purposes.

The disadvantage of the available information on the internet is the volume of sites containing misleading information. Lycos' very popular search engine, for example, has resources for paranormal web pages on their Space/Sci-Fi host page (which is only one "click" away from Lycos' home page). Additionally, endless web pages devoted to such things as aliens, psychics, and cover-ups by the government are growing exponentially in popularity. Hence, without discretion or critical thinking on the part of the user, much invalid and false information can become confused with science education.

V.

RECOMMENDATIONS AND CONCLUDING COMMENTS

Recommendations. Because new web pages and on-line resources are created and vanish daily, the Physics Education Resource Site should be monitored regularly. To keep the web page current and accurate, the Physics Education Resource Site should be appended and searched for links to pages that are new, no longer operate, or whose URL's have changed several times each year.

It is recommended that whoever maintains the Physics Education Resource Site in the future should feel free to make adjustments to category headings and listings as time warrants. However, much effort has been placed on creating a web page so that it is easily browsed. Therefore, should the listings grow in numbers such that acceptable

loading times on average internet connections are jeopardized, then the pages may need to be broken up into several pages linked by category name.

As an alternative, future additions to the web site might best include resources by regions. This would be especially helpful for the Workshops/Programs category. This sub-categorization could also be extended to the Student's Main Page so that specific age groups of students could divide student resources more effectively.

It is also advised that graphics and animations are kept to a minimum, if used at all in the future. With the exception of the Student's Main Page, there should not be a need to add graphics to the web page. Not only do the graphics require space on the server storing the page, they impede use of the web site by increasing the load time for the general user. If graphics were to be used, they would be most beneficial to the Student's Main Page to promote more traffic and frequent use by students. Currently, many useful science images can be found via the links on the Physics Education Resource Site, not on the page itself.

Concluding Comments. The task of searching the internet for various subjects of the Physics Education Resource Site web page has proven to be challenging, fully encompassing, but enjoyable. Limiting search strings to key words that will yield web page URL's pertinent to a specific category requires a certain degree of finesse if non-relevant web sites are to be avoided. Once the desired subject has been searched, one must filter out the various resources and web pages that have already been logged under a different search string. In addition, the links of web pages that contain useful resources but are no longer maintained must be logged instead of the host page in order to avoid the

host page becoming inactive without warning. As an example, twelve links originally placed on the Physics Education Resource Site had to be removed or appended only two weeks after they were added due to cancellation or a change URL addresses. Once the logged web pages and resources are filtered and sifted, it is their worth to the author that determines whether or not it is to be indexed. As the number of these indexed resources grows, one begins to admire the wealth of information available on the internet and gains an appreciation for web pages that are able to present the selected areas of interest with quality references effectively.

BIBLIOGRAPHY

Clement, John, "Students' Preconceptions in Introductory Mechanics," Am. J. Phys. 50 (1), 66 (1982).

Dutch, Steven Ian, "The Standard Model for Reform in Science Education Does Not Work," Journal of Geoscience Education 44, 245 (1996).

Grayson, D.J. and L.C. McDermott, "Use of the computer for research on student thinking in physics," Am. J. Phys. 64 (5) 557 (1996).

Halloun, Ibrahim Abou, and Hestenes, David, "Common Sense Concepts About Motion," Am. J. Phys. 53 (11), 1056 (1985).

Halloun, Ibrahim Abou, and Hestenes, David, "The Initial State of College Physics Students," Am. J. Phys. 53 (11), 1043 (1985).

Hammer, David, "Misconceptions or P-Prims: How May Alternative Perspectives of Cognitive Structure Influence Instructional Perceptions and Intentions?," The Journal of the Learning Sciences 5 (2), 97 (1996).

Hestenes, David, "Modeling Methodology for Physic Teachers," Proceedings of the International Conference on Undergraduate Physics Education (College Park, August 1996).

Hestenes, David, "Toward a Modeling Theory of Physics Instruction," Am. J. Phys. 55 (5), 440 (1987).

Hestenes, David, "Wherefore a Science Teacher?," Phys. Teach. April, 235 (1979)

Hestenes, David and Wells, Malcolm, "A Mechanics Baseline Test," The Phys. Teach. 30, 159 (1992).

Hestenes, David, Wells, Malcolm, and Swackhamer, Gregg, "Force Concept Inventory," The Phys. Teach. 30, 141 (1992).

Laws, Priscilla W., "Calculus-Based Physics Without Lectures," The Phys. Teach., 24 (1991).

Laws, Priscilla W., "Millikan Lecture 1996: Promoting Active Learning Based on Physics Education Research in Introductory Physics Courses," Am. J. Phys. 65 (1), 14 (1997).

McDermott, L.C., "A perspective on teacher preparation in physics and other sciences: the need for special courses for teachers," Am. J. Phys. 58 (8), 734 (1990).

McDermott, L.C., "A view from physics," in Toward a Scientific Practice of Science Education, M. Gardner, J. Greeno, F. Reif, and A. Schoenfeld (Eds.), Hillsdale, NJ: Lawrence Erlbaum, Inc., p. 3-30 (1989).

McDermott, L.C., "Combined Physics Course for Future Elementary and Secondary School Teachers," Am J. Phys. 42, 668 (1974).

McDermott, L.C., "Guest Comment: How we teach and how students learn -- A mismatch?," Am. J. Phys. 60 (4) 295 (1993).

McDermott, L.C., "Improving high school physics teacher preparation," Phys. Teach. 13 (12), 523 (1975).

McDermott, L.C., "Practice Teaching Program in Physics for Future Elementary School Teachers," Am J. Phys. 42, 737 (1974).

McDermott, L.C., "Research and computer-based instruction: opportunity for interaction," Am. J. Phys. 58 (5), 452 (1990).

McDermott, L.C., "Research on conceptual understanding in mechanics," Physics Today 37, 24 (July 1984).

McDermott, L.C., "Teacher education and the implementation of elementary science curricula," Am. J. Phys. 44 (5), 434 (1976).

McDermott, L.C., "What we teach and what is learned: Closing the gap," Am. J. Phys. 59 (4), 301 (1991).

McDermott, L.C., M.L. Rosenquist, and E.H. van Zee, "Instructional strategies to improve the performance of minority students in the sciences," New Directions for Teaching and Learning 16, 59 (1983).

McDermott, L.C., P. Shaffer and M. Somers, "Research as a guide for curriculum development: An illustration in the context of the Atwood's machine," Am. J. Phys. 62 (1) 46-55 (1994).

Redish, Edward F., "Implications of Cognitive Studies for Teaching Physics," Am. J. Phys. 62 (9), 796 (1994).

Schroeder, Charles C., "New Students-New Learning Styles," Change 25 (4), 21 (1993).

Shea, James H., ed., "Constructivism in Science Education," Journal of Geoscience Education 44, 244 (1996).

Slattery, William A., "A Course for Training Preservice Elementary Teachers in the Content and Processes of Earth Science," Journal of Geoscience Education 44, 259 (1996).

Smith, John P. III, diSessa, Andrea A., and Roschelle, Jeremy, "Misconceptions Reconceived: A Constructivist Analysis of Knowledge in Transition," The Journal of the Learning Sciences 3 (2), 115 (1993).

Strike, Kenneth A., and Posner, George J., "A Revisionist Theory of Conceptual Change,"

Trowbridge, D.E. and L. C. McDermott, "Investigation of student understanding of the concept of acceleration in one dimension," Am. J. Phys. 49 (3), 242 (1981).

Van Heuvelen, Alan, "Overview, Case Study Physics," Am. J. Phys. 59 (10), 898 (1991).

Vosniadou, Stella, "Capturing and Modeling the Process of Conceptual Change," Learning and Instruction 6, 45 (1994).

Wilson, Jack M., "The CUPLE Physics Studio," The Phys. Teach. 32, 518 (1994).

APPENDIX A

Physics Education Resource Site

(With an emphasis on Inquiry Based Learning)

Student's **Main Page** ***Educator's*** **Main Page**

This site is intended to be a dynamic "publication" of resources for those involved in Physics Education. In that spirit, if you find a URL on any of the Physics Education Resource Site pages that no longer works or if you know of other URL's that may be appropriate for this web page, please contact me at maier@mail.provalue.net (you may also send your questions and comments regarding this site to this address).

This site was originally created by Steven Maier of Oklahoma State University. This project was

sponsored by OSU's Physics Department as part of a Professional Masters degree in Physics (PMP) program in 1998 under the direction of committee members Dr. Bruce Ackerson (committee advisor), Dr. Larry Scott , and Dr. Paul Westhaus .

Created January 20th, 1998. There have been  *visitors since February of 1998.*

APPENDIX B

Physics Education Resource Site

Student's
Main Page

Science News, Magazines, FAQ's, and Forums	Organizations	Popular / Cool Sites	Physics Education Resource Site Main Page

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Popular / Cool Sites: *(back to table)*

- Mars Missions
- Seeing, Hearing and Smelling the World (The science of your senses!)
- www.4Kids.org
- Storm Chaser Homepage
- NSSDC Photo Gallery (Lots of space pics!)
- Landscape of Mars
- Bill Nye the Science Guy ('Nye Labs On-line)
- Seaborgium (Seaborgium and Flubber. . .)
- Science Fair
- Quest: NASA K-12 Internet Initiative
- The Franklin Institute Science Museum

- Study WEB (Educational search engine)
- The Physics Connexion
- Just for Kids
- Physics Resource Site
- Physics Education Resources
- grad_teach. Resources on the WWW
- BluePoint - Carl Sagan
- NASA's Learning Technologies Project

Organizations: *(back to table)*

- NASA
- Society of Physics Students (SPS)
- SETI

Science News, Magazines, FAQ's, and Forums: *(back to table)*

- Links to Other Science Sites for Kids!
- Cyberbee.com
- inScight Science Magazine
- Question and Answer Exchange Index, Science Central
- PopSci.com
- Astronomy Net
- The Why Files
- National Geographic
- Physics and Networking Newsletters
- Sky and Telescope Magazine
- Physics News
- Quantum
- American Institute of Physics - Physics Information NetSite
- Helios Science News
- Web Quiz / WebTest
- A.I.P. Physics News
- PhysLINK's PHYSICS NEWS Home Page
- Search A.I.P Physics News
- What's New in Physics?

- Bob Park's What's New?
- Physics Today
- Nature
- New Scientist
- Popular Science
- US News Mysteries of Science
- Hot Topics (NASA)
- American Institute of Physics (AIP)
- PhysicsWorld, Volume 11, No 04
- The American Journal of Physics Home Page
- TIPTOP: Physics Forum
- Barbara's World Tour
- JASON Student Zone
- The Resource Guide
- sci.skeptic FAQ
- The Usenet Physics FAQ and Relativity FAQ

Last updated April 5th , 1998

APPENDIX C

Physics Education Resource Site

Educator's

Main Page

Physics Education Research Groups	Resources / Museums	Some Articles	Companies
Pseudo-sciences	Organizations	A Few Classroom Web Pages	Curricula / Lesson Resources
Workshops / Programs	Mis / Pre-conception Web Sites	Computer Applications	Pages of Links / Unique
Student's Main Page			Unsorted Sites

Physics Education Research Groups: *back to table*

- Arkansas Precision Education Group
- Center for Innovation in Learning (CIL)
- Indiana University

- Kansas State University Physics Education Group (home of the Physics InfoMall)
- Michigan State University College of Education
- Montana State University Conceptual Physics Research Group
- North Carolina State University Physics Education Research
- Ohio State University
- Rensselaer Polytechnic Institute
- San Diego State University Center for Research in Mathematics & Science Education
- University of California, Berkeley
- University of Maine Laboratory for Research in Physics Education (LRPE)
- University of Maryland Physics Education Research
- University of Massachusetts Physics Education Research Group
- University of Minnesota Physics Education Research and Development
- University of Nebraska Research in Physics Education Group (RPEG)
- University of Oldenburg
- University of Utrecht Centre for Science and Mathematics Education (The Netherlands)
- University of Washington Physics Education Group

Some Articles: **(see also Physics Education Group homepages)** *back to table*

- "Digging into Science"
- National Science Education Standards - Contents
- Some assorted articles from periodicals
- High School Science Effectiveness Report (Apple)
- Middle School Science and Math Effectiveness Report (Apple)
- Research (from Arizona State University)
- Publications (from Center for Innovation in Learning)
- Physics Education research (from Indiana University)
- Physics Education Group On-line Publications (from Kansas State University)
- Research Group on Higher Education (from Oldenburg)
- Research Papers and Such (from Tufts University)
- Description of Research (from University of Maine)
- Papers in Physics Education Research (from University of Maryland)
- Physics Education Research Papers on the Web (from University of Maryland)
- Publications and Reports (from University of Massachusetts)

- Physics Education Group Publications (from University of Washington)

Companies: *back to table*

- Archipelago Productions
- Central Scientific Company (CENCO)
- Delta Education
- Edmund Scientific
- Education Development Center, Inc. (EDC)
- Educational Innovations, Inc.
- Frey Scientific (Not Frey's actual homepage)
- Knowledge Revolution
- NASCO
- PASCO scientific
- RadioShack
- Rainwise, Inc. Weather Instruments
- Science Kit & Boreal Laboratories
- SciTech International
- Texas Instruments
- Vernier Products for the CBL
- Scientific Products for Science Education (VWR)
- Ztek® Co.
- Wiley Publishing
- Analog Press
- Prentice Hall
- Princeton University Press
- Research Books, Inc.

Organizations: *back to table*

- American Association of Physics Teachers (AAPT)
- American Institute of Physics (AIP)
- American Mathematical Society
- American Physical Society (APS)
- Chicago Area Physics Organizations (CAPO)
- Institute for Research on Learning (IRL)

- Institute of Physics (IoP)
- Knowledge Science Institute (KSI)
- National Academy of Sciences (NAS)
- National Institute for Science Education (NISE)
- National Institute of Standards and Technology (NIST)
- National Science Foundation (NSF)
- National Science Teachers Association (NSTA)
- U.S. Department of Education

A Few Classroom Web Pages: *back to table*

- Oklahoma State University: Physics 1114
- Hartsfield School's Home page
- Cockpit Physics
- Web K-12+
- Home Page

Curricula / Lesson Resources: *back to table*

- Cassini Teacher Guide
- Fundamentals of Physical Science
- Comprehensive Curriculum for Middle School Physical Science
- The Mechanical Universe...and Beyond
- World Lecture Hall - Physics (WLH)
- Welcome to the GASEF Web Site!
- Physics Education - Elementary School (K-4)
- Physics Education - Middle School
- Apple K-12 Curriculum
- The Apple Education Series: Science Tools Introduction
- Interdisciplinary Integrated Thematic Unit on Theme Park (Apple)
- Introduction to Physics (Apple)
- Problem Solving Techniques (Apple)
- Apple Curricular Resources
- SCIENCE HOBBYIST
- SCIENCE HOBBYIST: Science Museums
- Museum of Physics Department

Workshops / Programs: *back to table*

- The JASON Project
- Modeling Workshop Project
- Show, Don't Tell
- Toward a Science of Consciousness 1998 (T3)
- Family.Com: Seattle's Child - Oh, I Just Love Science!
- Comprehensive Conceptual Curriculum for Physics (C3P)
- Lousiana Collaboration for Excellence in Preparation of Teachers (LaCEPT)
- Southwest Educational Development Laboratory (SEDL)
- Oklahoma Teacher Education Collaborative (O-TEC)
- Summer Science Workshop (Northeastern Oklahoma) (SSW)
- Education (Harvard University)
- Peer Instruction
- Private Universe Teacher Workshops
- CAPSI Home Page Caltech Precollege Science Initiative
- Harvard-Smithsonian Center for Astrophysics Science Education Department
- NSF Collaboratives for Excellence in Teacher Preparation (CETP)
- Regional Technology in Education Consortia (R-TEK main homepage)
- Dickinson College Physics and Astronomy
- Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT)
- Student and Scientist Partnerships
- International Netcourse Teacher Enhancement Coalition (INTEC)
- The Annenberg / CPB Projects Learner Online
- Tufts University Center for Science and Mathematics Teaching
- CyberProf

Mis / Pre-conception Sites: *back to table*

- Humorous Science Mis-statements
- Science Hobbyist: Misconceptions (a lot of info here, including database of K-6 textbook errors)
- Bad Astronomy
- Bad Science

Resources / Museums: *back to table*

- Minnesota K-12 Science Curriculum Framework
- Antoine: Tawes Science Network Services
- Physical Sciences Resource Center
- SciWeb - The Life Science Home Page
- Physics Around the World: Education and Online Material
- Carnegie Science Center
- PBS Online
- The World-Wide Web Virtual Library: Education
- Science
- WEB RESOURCES
- Hands on Science Centers Worldwide
- Theater of Electricity
- Science First Hand
- The Smithsonian Institution
- The Internet Pilot to Physics (TIPTOP -- excellent resource)
- Demonstration Schematics (University of California at Berkeley)
- Helpful Education Links
- PhysicsEd: Physics Education Resources
- Science Learning Network
- Discover the Science Museum
- Physics Education Resources
- Resources for Physics Education
- University of Oregon Physics Distance Education and K12 Resources
- Physics
- Resources for Teachers
- AstroEd: Astronomy Education Resources
- Science Planet - Internet Resources for Science Education
- Education Resources
- Physics Resources
- Ontario Science Centre
- The Physics Museum at the University of Queensland (Australia)
- The Natural History Museum in London
- The Israel National Museum of Science
- Educator Resources (Apple)
- Getting Started with Technology (Apple)
- Blue Web'n

- Museum of Physics (Italy)
- *Smithsonian- Air and Space Museum
- Physics InfoMall

Computer Applications: *back to table*

- Physics Academic Software
- Front Desk at the OAK Repository (oak.oakland.edu)
- Physlet Problems
- WWWAssign
- Vernier Software
- Mathsoft, Inc.
- Lahey Computer Systems, Inc. (Fortran)
- Windows Dressing for your Fortran Programs
- SPSS Science
- JMP Discovery Software
- UNISTAT 4.5
- PEP Registry, Educational Software Publishers
- JAVA Physics Resource Mailing List/JAVA resources
- DSP Development Corporation
- Physics Software Possibilities (Apple)
- TIPTOP/VLAB (excellent)

Pages of Links / Unique: *back to table*

- Using Novels for Interdisciplinary Technology Education (UNITES)
- Related Web Links
- Larry Martin's Bookmarks (*many* assorted links)
- Physics Servers on the Web
- resource center: physics
- Physics Education - College/University Inclass Resources
- CTI-Physics, External Links
- SciEd: Science and Mathematics Education Resources
- Classroom Resources (Apple)
- Links to Physics Information

- Fermilab Education Office

Unsorted sites: *back to table*

Astro Resources
Chuck Niederriter
classroom and home
Education-World
APS News

Last updated April 5th, 1998

APPENDIX D

(Educator's Resource Page)

Physics Education Resource Site

Pseudo-science*

Main Page

******NOTICE!* **Special care needs to be taken when using these sites for instructional purposes!** Most of these sites contain perspectives, theories, and content that are not widely accepted in the scientific community. As with most material *you*, the reader, are left to decide whether or not to accept what is being presented.

Too often, material is accepted without sufficient critical thought or skepticism on the part of the reader. For this reason, students should have an understanding of what "good" science is before venturing through these sites. (Or perhaps, sites like these could be used as part of an exercise to help students understand what "good" and "bad" science is.)

? Confused as to what *good* and *bad* science is? Never heard of the word "***Pseudo*science**?" Then you'll want to read "Fallacies and Telltale Signs of a Pseudoscience," an adaptation of published work by Stephen S. Carey.

Pseudo-sciences / The "Unexplained":

- Sympathetic Vibratory Physics - John W. Keely, bio, work,...
- NOVA Online/Pyramids/Who Built the Pyramids?
- Foreword to The Tenacious Mars Effect
- Astrology 101
- Trio Takes Aim Against Spread of Pseudo-Science
- FORCES CANADA - BENZO(A)PYRENE AND THE PSEUDO-SCIENCE OF
- Pseudo-intellectual ram-blings
- The First Online Church of "Bob"

Debunking of Pseuso-science Sites:

- The James Randi Educational Foundation Homepage
- Skepticism and Pseudoscience
- Skeptical Information

more sites to come. . .

APPENDIX E

(Pseudoscience page)
(Educator's Resource Page)

Adapted from: Carey, Stephen S. A Beginner's Guide to Scientific Method ; California: Wadsworth
Publishing Company, 1994.

Fallacies in Scientific Reasoning

(click the terms for examples)

Fallacies Involving Initial Observations

Anecdotal evidence: basing a general claim on a few anecdotal reports.

Omitting facts: creating an air of mystery by leaving out facts that might account for the mystery.

Distorting the facts: altering the facts to create the impression that something is mysterious.

Fallacies Involving Rival Explanations

Fallacious argument by elimination: arguing for a given explanation by

attempting to show that rival explanations are wrong.

Fallacious inference to a causal link: inferring a causal link on the basis of a correlation, concomitant variation, or the fact that the suspected cause occurred before its effect. Possible rival explanations are coincidence, fudging of data, and third factors.

Fallacies in Proposing and Testing Explanations

Exploiting analogies and similarities: treating explanations for well-understood phenomena as though they were evidence for a similar explanation for something not so well understood.

Proposing unfalsifiable claims: (1) advancing a claim, explanatory or otherwise, that is consistent with everything that could happen; (2) working with predictions that cannot be falsified; (3) explaining away all conceivable experimental results that might suggest that a claim is false; or (4) treating initiating facts as confirming facts.

Illicit ad hoc rescues: advancing auxiliary assumptions that cannot be independently verified as a means of saving an explanation or extraordinary claim.

The Telltale Signs of Pseudoscience

1. Pseudoscientific claims often involve fallacious scientific reasoning of the sort exemplified by the preceding fallacies.

2. Pseudoscience can occur within the bounds of legitimate scientific disciplines. (Cold Fusion)

3. Pseudoscience tends not to be self-correcting. (Astrology)

4. Pseudoscience produces very little explanatory theory. (How *do* those aliens get away with violating the laws of physics with their crafts?)

5. Rarely do pseudoscientific claims change much over time.

6. Pseudoscientists tend to view skepticism as a sign of narrow-mindedness. (Mental telepathy)

Examples

Anecdotal evidence: (Back to top)

"Aliens exist and perform abductions because I've heard of such instances."

Omitting facts. (Back to top)

Describing how impossible it would have been for the ancient Egyptians to create the Great Pyramids (concluding it must have been aliens) during their era ***without*** : acknowledging that, in many ways, the Egyptians were expert engineers (marvels of their time); or informing the audience of the thousands of slaves Egyptians used for hard labor.

Distorting the facts: (Back to top)

The assertion: "How do you explain the ability of a telepath with a near 100% accuracy?"-- exaggerating the telepath's 60% accuracy (taking 60% = 0.60 and rounding up to "near 100%").

Fallacious argument by elimination: (Back to top)

Instead of proving or disproving his claim, a pseudoscientist sets out only to ***dis***prove rival explanations.

Fallacious inference to a causal link: (Back to top)

Many great athletes were born when Mars occupied a certain position in its orbit, therefore the celestial bodies do predict/control our destinies. There is also a high correlation between drowning and ice cream sales -- so does ice cream cause drowning?

Exploiting analogies and similarities: (Back to top)

The argument: "Just as gravitational and magnetic fields can cause objects to move, "Water seekers" are sensitive to similar fields of under water reservoirs and are thus caused to indicate them by uncontrollable motions."

Proposing unfalsifiable claims: (Back to top)

(1) Check the horoscope readings, pretend you're a Scorpion and try to convince yourself that the reading is ***in no way*** similar to current or anticipated events. You can do this with outdated horoscopes, too.

(2) " _____ is an effect of a "force" that can in no way be detected by scientific instruments."

(3) Unconditionally discrediting all of the work done that is in opposition to the proposed claim.

(4) Cutting research short to avoid unsupportive data, and then asserting the theory based merely on the initial findings.

Illicit ad hoc rescues: (Back to top)

Conspiracy theories are notorious for this: ". . . then it must be some kind of government cover-up!" Another example is the elusive and all encompassing "ether" or "aether" (disbanded as a result of Einstein's publication in 1905).

APPENDIX F

Some Published Articles

(by date)

Wosilait, K., P.R.L. Heron, P. Shaffer, and L.C. McDermott, "Research as a guide for the development and assesment of curriculum: An example from Light and Shadow," to be submitted to Am. J. Phys. (1997).

O'Brien Pride, T., S. Vokos, and L.C. McDermott, "The challenge of matching learning assesments to teaching goals: an example from the work-energy and impulse-momentum theorems," accepted for publication in Am. J. Phys. (1997).

Laws, Priscilla W., "Millikan Lecture 1996: Promoting Active Learning Based on Physics Education Research in Introductory Physics Courses", Am. J. Phys. 65 (1), 14 (1997).

(Steinberg, R., G. Oberem and L.C. McDermott, "Development of a computer-based tutorial on the photoelectric effect,"Am. J. Phys. 64 (11) 1370 (1996).

(Grayson, D.J. and L.C. McDermott, "Use of the computer for research on student thinking in physics," Am. J. Phys. 64 (5) 557 (1996).

Hestenes, David, "Modeling Methodology for Physic Teachers", Proceedings of the International Conference on Undergraduate Physics Education (College Park, August 1996).

Hammer, David, "Misconceptions or P-Prims: How May Alternative Perspectives of

Cognitive Structure Influence Instructional Perceptions and Intentions?", The Journal of the Learning Sciences 5 (2), 97 (1996).

Slattery, William A., "A Course for Training Preservice Elementary Teachers in the

Content and Processes of Earth Science", Journal of Geoscience Education 44, 259 (1996).

Dutch, Steven Ian, "The Standard Model for Reform in Science Education Does Not
Work", Journal of Geoscience Education 44, 245 (1996).

Shea, James H., ed., "Constructivism in Science Education", Journal of Geoscience Education 44, 244 (1996).

Hilborn, Robert C., "Physics at the Crossroads", March 12, 1996.

Hestenes, David, and Halloun, Ibrahim, "Interpreting the Force Concept Inventory A
Response to March 1995 Critique by Huffman and Heller", The Phys. Teach. 33, 502 (1995).

Wilson, Jack M., "The CUPLE Physics Studio", The Phys. Teach. 32, 518 (1994).

Vosniadou, Stella, "Capturing and Modeling the Process of Conceptual Change", Learing
and Instruction 6, 45 (1994).

Redish, Edward F., "Implications of Cognitive Studies for Teaching Physics", Am. J.
Phys. 62 (9), 796 (1994).

McDermott, L.C., P. Shaffer and M. Somers, "Research as a guide for curriculum development: An illustration in the context of the Atwood's machine," Am. J. Phys.

62 (1) 46-55 (1994).

Schroeder, Charles C., "New Students-New Learning Styles", Change 25 (4), 21 (1993).

Smith, John P. III, diSessa, Andrea A., and Roschelle, Jeremy, "Misconceptions Reconceived: A Constructivist Analysis of Knowledge in Transition", The Journal

of the Learning Sciences 3 (2), 115 (1993).

McDermott, L.C., Guest Comment: "How we teach and how students learn -- A mismatch?" Am. J. Phys. 60 (4) 295 (1993).

McDermott, L.C. and P. Shaffer, "Research as a guide for curriculum development: an example from introductory electricity, Part I: Investigation of student understanding." Am. J. Phys. 60 (11), 994 (1992); Erratum to Part I, Am. J. Phys. 61 (1), 81 (1993).

Hestenes, David, "Modeling Games in the Newtonian World", Am. J. Phys. 60 (8), 732 (1992).

Shaffer, P. and L.C. McDermott, "Research as a guide for curriculum development: an example from introductory electricity, Part II: Design of instructional strategies." Am. J. Phys. 60 (11), 1003 (1992).

Strike, Kenneth A., and Posner, George J., "A Revisionist Theory of Conceptual Change",

Hestenes, David and Wells, Malcolm, "A Mechanics Baseline Test", The Phys. Teach. 30, 159 (1992).

Hestenes, David, Wells, Malcolm, and Swackhamer, Gregg, "Force Concept Inventory", The Phys. Teach. 30, 141 (1992).

Laws, Priscilla W., "Calculus-Based Physics Wihtout Lectures", The Phys. Teach., 24 (1991).

Van Heuvelen, Alan, "Overview, Case Study Physics", Am. J. Phys. 59 (10), 898 (1991).

McDermott, L.C., "What we teach and what is learned: Closing the gap," Am. J Phys. 59 (4), 301 (1991).

(McDermott, L.C., "A perspective on teacher preparation in physics and other sciences:
the need for special courses for teachers," Am. J. Phys. 58 (8), 734 (1990).

(McDermott, L.C., "Research and computer-based instruction: opportunity for interaction," Am. J. Phys. 58 (5), 452 (1990).

(McDermott, L.C., "A view from physics," in Toward a Scientific Practice of Science
Education, M. Gardner, J. Greeno, F. Reif, and A. Schoenfeld (Eds.), Hillsdale, NJ: Lawrence Erlbaum, Inc., p. 3-30 (1989).

Lawson, R.A. and L.C. McDermott, "Student understanding of the work-energy and

impulse-momentum theorems," Am. J. Phys. 55 (9), 811 (1987).

(McDermott, L.C., M.L. Rosenquist, and E.H. van Zee, "Student difficulties in connecting graphs and physics: examples from kinematics," Am. J. Phys. 55 (6), 503 (1987).

Hestenes, David, "Toward a Modeling Theory of Physics Instruction", Am. J. Phys. 55
(5), 440 (1987).

(Rosenquist, M.L. and L.C. McDermott, "A conceptual approach to teaching kinematics,"
Am. J. Phys. 55 (5), 407 (1987).

Goldberg, F.M. and L.C. McDermott, "An investigation of student understanding of the
real image formed by a converging lens or concave mirror," Am. J. Phys. 55 (2), 108 (1987).

(Goldberg, F.M. and L.C. McDermott, "Student difficulties in understanding image

formation by a plane mirror," The Phys. Teach. 24, 472 (1986).

Halloun, Ibrahim Abou, and Hestenes, David, "Common Sense Concepts About Motion",
Am. J. Phys. 53 (11), 1056 (1985).

Halloun, Ibrahim Abou, and Hestenes, David, "The Initial State of College Physics

Students", Am. J. Phys. 53 (11), 1043 (1985).

McDermott, L.C., "Research on conceptual understanding in mechanics," Physics Today
37, 24 (July 1984).

(McDermott, L.C., M.L. Rosenquist, and E.H. van Zee, "Instructional strategies to improve the performance of minority students in the sciences," New Directions for Teaching and Learning 16, 59 (1983).

Clement, John, "Students' Preconceptions in Introductory Mechanics", Am. J. Phys. 50
(1), 66 (1982).

Trowbridge, D.E. and L. C. McDermott, "Investigation of student understanding of the
concept of acceleration in one dimension", Am. J. Phys. 49 (3), 242 (1981).

(Trowbridge, D.E. and L. C. McDermott, "Investigation of student understanding of the
concept of velocity in one dimension", Am. J. Phys. 48 (12), 1020 (1980).

Hestenes, David, "Wherefore a Science Teacher?", Phys. Teach. April, 235 (1979).

(McDermott, L.C., "Teacher education and the implementation of elementary science
curricula", Am. J. Phys. 44 (5), 434 (1976).

(McDermott, L.C., "Improving high school physics teacher preparation", Phys. Teach. 13
(12), 523 (1975).

(McDermott, L.C., "Practice Teaching Program in Physics for Future Elementary School
Teachers", Am J. Phys. 42, 737 (1974).

(McDermott, L.C., "Combined Physics Course for Future Elementary and Secondary
School Teachers", Am J Phys 42, 668 (1974).

VITA

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