Taxonomy of Scientifically Oriented Educational Websites

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ABSTRACT

Web-Based Learning (WBL) – the usage of the Web as an arena for learning – has captured the imagination and interest of science educators worldwide. While many educators believe in the unprecedented opportunities and potential offered by the Internet to enhance education, others are intimidated by its somewhat chaotic and unstructured nature. To enhance our understanding of WBL, it is important to categorize the main feature of the Web as an educational medium: identify its instructional and pedagogical means, elaborate on the communication technologies and their implications, and define criteria to evaluate the content level. Following Nachmias *et al*. (1999), this paper provides a classification scheme by which scientifically oriented educational Websites can be evaluated and compared. The criteria are sorted into five dimensions: These dimensions are the (1) descriptive dimension (e.g., target population, site developers, language); (2) pedagogical dimension (e.g., instructional model, instructional means, cognitive demands); (3) representational dimension (e.g., representational structure and means, navigation tools); (4) communication dimension (e.g., links configuration, distant learning modes); and (5) scientific content dimension (e.g., content level, visualization means, historical background). Based on these criteria, we present an example of site evaluation in the field of atomic structure. Finally we discuss the potential embedded in this taxonomy to assist the Website developer, to provide the science teacher with a tool for mindful selection and evaluation of scientifically instructional sites, and to offer the researcher a conceptual framework for the formulation and study of relevant research questions.

KEY WORDS:

Internet, Taxonomy, Science education, Web-Based Learning, Atomic Structure.

INTRODUCTION

The Internet, a new emerging medium offers unprecedented opportunities and exciting avenues to science education. The accessibility to a huge, interlinked and complex network of information as well as the availability of novel communication means, offer new ways to use scientific information, communicate and learn. The Web's advanced graphic means and computational power allows both scientists and educators to visualize scientific data and processes in ways that are otherwise impossible. Students can thereby gain a deeper understanding of nature phenomena. Consequently, Web-Based Learning (WBL) – the use of the Web as an arena for learning – has captured the imagination and interest of science educators worldwide. Many of them are currently engaged in experimental projects focusing on the integration of WWW activities within science teaching and learning processes.

Let us briefly review some salient Web features, which are relevant to its role within the educational process. The first and obvious key feature of the Web is the support for sophisticated manipulation of information. Information manipulation functions (e.g., generating, transmitting, storing, processing, retrieving of information) are at the heart of educational transactions. The possibility to contribute to, or to access online libraries, databases, journals, museums, and other public information repositories on the Internet may therefore qualitatively affect science education.

The network serves more and more as a communication facilitator. Computer-Mediated Communication (CMC) constitutes a powerful interaction means (e.g., e-mail, group conferencing, IRCs) that enables students to communicate with peers, teachers, and experts, as well as to conduct collaborative work (Berge, 1995; Harasim, Hiltz, Teles, & Turoff, 1995).

The Web is also increasingly becoming a creation environment. A considerable number of user-friendly tools for the creation of Web-deliverable materials are currently available. These tools may support students' creativity and initiative, allowing them to generate and publish their own Websites without mediators and with minimal technical assistance.

Finally, the Web also serves as an instruction delivery medium. Numerous science-oriented Websites provide digital educational activities and Netcourses for all grade levels in a large number of subjects (Hackbarth, 1997; Khan, 1997). The conception of the Web as a learning environment is instantiated in varied forms, from online versions of traditional Computer Aided Instruction (CAI) to innovative individual and group virtual-learning modes.

Teachers, lecturers, and educators at all levels are showing growing interest in Web-based instruction. Lectures notes, homework assignments, online books, and complete courses in pure science topics like chemistry, physics, and biology, together with interdisciplinary topics such as environmental engineering and others, can readily be found on the Web (Berenfeld, 1996; Berge & Collins, 1998; Owston, 1997). Many academic institutions have established complete units that lead and support the translation of courses to the Web, aiming student outreach (e.g., Distributed Learning at the University of Central Florida, Stanford Online). In an effort to produce these units, scientists, educators, Web designers, information technologists and computer technicians are working cooperatively.

As is evident from this group effort, the translation of a course to the Web is not simple. Students will not benefit much from online material (books or lectures) unless some kind of interaction with the site is possible, or the material contains features that a book does not (e.g., simulations). It is thus evident that a new kind of curriculum is emerging. This curriculum takes advantage of the Internet as an “information highway”, combines historical aspects with the latest research results, allows student to lead the learning process by means of synchronous or asynchronous online forums, and opens the subject matter boundary to new interdisciplinary elements by linking up to other Web pages. This type of curriculum also changes the way we think about the subject matter by allowing us to raise questions that cannot be solved using a chalk and a blackboard, but can be solved by computer simulations. The use of online interactive simulations is particularly important in science education, because it provides the means to model experiments that are otherwise too expensive, dangerous, technically complicated or long.

While many educators believe in the unprecedented opportunities and potential offered by the Internet to enhance education, others are intimidated by its somewhat chaotic and unstructured nature. The unlimited freedom, the overwhelming amount of information and the possibility for anyone to take part in the creation of knowledge, are, for many, a barrier to fulfilling the perceived potential. Furthermore, many Websites, although meant to be educational, do not take full advantage of the educational features of the Internet. It is thus necessary to carefully examine the

Internet as an educational medium and, similar to research done on science textbooks (e.g., Chiappetta, Sethna, & Fillman, 1991), define a list of criteria by which scientifically oriented educational Websites can be uniformly characterized and evaluated. Such a classification scheme may assist Web designers in designing Web activities according to educational needs and constraints, provide the science teacher with a tool for mindful selection and evaluation of scientific instructional sites, and offer the researcher a conceptual framework for the formulation and study of relevant research questions regarding the use of the Internet in science education.

Recently, Nachmias Mioduser, Oren and Lahav (1999) suggested a comprehensive taxonomy for educational Websites classification based on the division of the criteria into four dimensions: descriptive, pedagogical, knowledge and communication. This attempt provides a general tool to classify and evaluate educational sites, which are not necessarily scientific in nature. Our paper provides a revised classification scheme by which scientifically oriented educational Websites can be evaluated and compared. The addition to the four-dimensional taxonomy focuses on the scientific content level as expressed via representation of experiments and models, incorporation of mathematical descriptions of natural phenomena, and material based on interaction of science, technology and society. These categories are gathered into a new fifth dimension entitled scientific content. In addition, we have adjusted the taxonomy as a whole to the special characteristics of scientifically oriented educational Websites. Finally, to exemplify this new classification scheme, we present an example of Website evaluation in the field of atomic structure.

RELATED WORK

There are various perspective to classify Web-based learning materials. It is commonly accepted that many of the features of pre-Web computer-based learning environments evolved into or were absorbed by the new technologies (e.g., traditional tutoring modes, friendly interface features, hyperlinked information bases). Nevertheless, a frequent claim has been made that special efforts should be made to identify the added educational value of the new technologies: whether such added value exists at all and how it is manifested in new didactic situations and solutions. In search for this added value, recent research efforts have focused on specific qualities of Web technology.

Harasim (1993) for example, emphasizes the implementation of different models of instructional process, by defining seven instructional modalities that are either expert-based (e-lecture, ask-an-expert, mentorship, tutor-support) or student-based (access to information, peer interaction, structured group activity). Both Berge (1995) and Collins (1995) suggest a set of fourteen instructional modes covering the entire complex of CMC technology. The proposed set includes modes such as mentoring, project-based instruction, lecturing, information retrieval, chat, peer reviewing and others together with Web versions of traditional CAI modes (e.g., tutorials, simulations, drills).

Berenfeld (1996) focus on the distant-action allowed by the Web suggesting five modes of “teleing”. These modes are tele-access to information, virtual publishing, tele-presence, tele-mentoring and tele-sharing. Riel (1993) on the other hand, focus on cultural and social aspects of the Web. He proposes the engagement of the Web technology within learning circles or electronic communities for the achievement of varied types of interaction (at the local and international level) and project-based instructional tasks.

One last example to be mentioned is the approach of Teles (1993) that analyzes Web-based support of cognitive apprenticeship by features that embody a variety of methods (e.g., sequencing, scaffolding, exploration, reflection) in online-apprenticeship or tele-apprenticeship activities.

These studies represent a very complex picture regarding the multiple dimensions of the Web as an educational resource. The variety of facets mentioned above, such as instructional modes, models of tele-activity, support for cognitive functions, or types of representational structures, is only a partial list of the components of the intricate fabric of the Web. All this suggests that any attempt to offer researchers and developers a comprehensive tool for understanding and/or building educational Websites, namely, a classification scheme, presents a major challenge. Albeit the difficulties involved in its development, such a tool should satisfy at least three main demands:

1. **Mapping power:** The classification scheme should include and integrate a large variety of properties in the different dimensions (e.g., content, pedagogy, communications) of educational Websites. It should capture the rich complexity, as well as the limitations and drawbacks, of these novel learning environments.
2. **Generic nature**: The tool should be sufficiently comprehensive to cover many possible configurations of variables in different dimensions, suitable for the continuously growing population of educational Websites. But at the same time, it

should be flexible enough to undergo changes and additions, as new technological or pedagogical features and Website models appear.

3. **Clear-cut definition:** To reasonably support analytic and synthetic processes, and to ensure portability of the data collected with or defined within the tool, it should offer a sound structure, precise terminology, and definite scaling and classing schemes.

The comprehensive taxonomy suggested by Nachmias *et al.* (1999) satisfies the above demands by introducing about 100 variables in four main dimensions. These dimensions are the descriptive dimension (e.g., target population, site developers, language), pedagogical dimension (e.g., instructional model, instructional means, cognitive demands), knowledge dimension (e.g., representational structure and means, navigation tools), communication dimension (e.g., links configuration, distant learning modes). Upon applying this taxonomy to educational Websites, it was found that several features of the Web, included in the taxonomy, are not employed by educational sites, (e.g. video conference and Moo/mud) (see detailed description in Mioduser, Nachmias, Oren & Lahav, 1999, and Mioduser, Nachmias, Lahav & Oren, in press). In addition, this taxonomy is general in nature, and does not deal with central issues related to science education. Therefore, our main purpose in this work is to revise and extend the original taxonomy to the needs and special characteristics of the science education community.

When evaluating scientific educational material, special attention should be devoted to the content of the material. In their work on high-school chemistry and biology textbooks, Chiappetta and his colleagues (Chiappetta *et al.* 1991, 1993) point out four main categories related to the content of these textbooks: science as a body of knowledge (e.g., presentation of facts, concepts, hypotheses, memorizing instructions), science as a way of investigating (e.g., requiring students to answer questions and make calculations), science as a way of thinking (e.g., description of scientific experiments, emphasize of empirical nature of science, discussion of evidence and proof) and interaction of science, technology and society (e.g., description of usefulness of science and technology to society, discussion of social issues related to science and technology).

The approach suggested by Niaz (1998) is more specific, in its comparison of chemistry textbooks at the freshman college level from viewpoint of history and philosophy of science. He discusses the work of three important scientists who contributed to the research on atomic structure (Thomson, Rutherford and Bohr) and presents eight categories related to the implications of their experiments on the scientific knowledge evolution. The categories emphasize both the correct and mistaken conclusions of each scientist. In addition, Niaz raises other categories, such as number of pages per subject, level of mathematical detail and existence of graphic illustrations of models or experiments.

While both Niaz (1998) and Chiappetta *et al*. (1991, 1993) originally designed their list of criteria for specific scientific discipline textbooks (e.g., chemistry, biology), their ideas can be implemented in other scientific disciplines and/or media, particularly, to Internet-based scientific educational material. Categories such as level of mathematical derivations, description of models and experiments whether graphically or verbally, in addition to historical treatment of science and interaction of science technology and society, represent important issues that should be examined when evaluating scientific educational Websites.

On the basis of the previous work described here, and especially on the taxonomy suggested by Nachmias *et al.* (1999), we would like to propose our model as a tool for describing the complexity of the educational kaleidoscope currently evolving in the Web. Since our main interest is science education, we focus on the fifth dimension - "**the scientific content dimension**". This dimension, rooted in the criteria suggested by Chiappetta *et al.* (1991, 1993) and Niaz (1998), is comprised of eight categories including parameters such as representation of experiments and models, level of mathematical description and interaction of science, technology and society. All the parameters are discussed in detail below.

TAXONOMY OF SCIENTIFICALLY ORIENTED EDUCATIONAL WEBSITES

Our proposed classification scheme consists of five dimensions. The first four dimensions are a revised version of the taxonomy of Nachmias *et al.* (1999) and are therefore presented briefly. The fifth dimension that focuses on scientific content is new, thus elaborated in detail. A form-like summary of the taxonomy is given in Appendix A.

The descriptive dimension

This dimension includes basic information regarding the location, creators, target population and relevant technical data of a site. The information is organized in five categories: *Site identification* (e.g., name, URL, authors' affiliation - academic, public organization, commercial, school or other); *site evolution* (e.g., creation date or last updating, development status); *language* or languages used in the site; *target population* and *size*, the last indicated by the number of html pages.

The pedagogical dimension

The variables in this dimension unveil the developers' stance regarding the type of instruction elicited by their site (e.g., target learning processes, instructional configuration and means, collaborative work, feedback, assessment). The variables in this dimension are organized in ten categories: *instructional configuration*, (e.g., individualized, collaborative); *instructional model* (e.g., directed and hierarchically organized, inquiry-oriented); *instructional means* (e.g., hypermedia databases, virtual 3D environments, online student-modeling and adaptive mechanisms, games); *interaction type* (e.g., browsing, answering questions, performing simple or complex activities, using online tools, interacting with experts or peers); *cognitive process* activated (e.g., plain information retrieval, complex processing of varied types of information, problem-solving, creative activity or invention); *locus of control* over the learning process; *feedback* (e.g., automatic evaluation answers, human expert's response either synchronic or asynchronic); *help functions* offered in the site; *learning resources* either embedded in the site's design or external physical and human resources; and *evaluation* (e.g., from standardized tests to alternative evaluation).

The representational dimension

Information can be retrieved from any Website, especially educational Websites. It is of great importance, however, to note in what format information and knowledge are presented. This dimension comprises two categories of variables: *representational structure*, which identifies the organizational template underlying the knowledge stratum, (e.g., linear, branching, or Web structure); and *representational means* (e.g., text, image, sound, animation, and the frequencies of their respective uses in a site).

The communication dimension

Networking, by definition, implies communication, or people's interaction with knowledge and/or with other people. The fourth dimension of the taxonomy relates to communication features through three categories: *navigation tools* (e.g., thematic indexes, internal navigation tools); *links* (e.g., external or internal links and the frequencies of their usage, the purpose of links - external databases, activities, human communication); and communication *means* (e.g., electronic mail, discussion group with or without moderators, chat facilities).

The scientific content dimension

Beyond the general parameters described above, there are more specific parameters that apply to science education Websites. The parameters in this dimension were chosen so as to allow classification of sites that focus on specific subtopics (e.g., “atomic structure”, rather than “chemistry”; “fusion” rather than “physics”). Therefore, it is possible that some categories will be less important for some topics, and that other categories, not mentioned here, will emerge for other subjects. This dimension consists of eight categories:

- *Discipline* - Science can be taught from many different angles. As opposed to a book that is chosen by a reader, mainly according to its title, a Website can be reached by various search queries relating to its content rather than its title alone. Because of the hypertext nature of Websites, one does not necessarily reach the home page of a site by direct search for a specific topic. For example, one can look for "atomic structure" and find sites dealing with fusion (physics), general chemistry (chemistry), astrophysics, quantum mechanics, etc. While the search results may lead to satisfactory educational material, the main topics can vary significantly within the list of sites. We therefore define two parameters: the primary discipline (e.g., physics, chemistry, biology) and the subtopic within that discipline.

· *Reliability of information* - Books and journal articles are published only after experts referee them. Internet Websites, on the other hand, are not necessarily reviewed. The reader must decide whether the information provided by the Website is reliable and to what extent can it be used further. We thus propose a scale of 1 to 5, where 1 is unreliable and 5 is very reliable, to test the reliability of the sites.

· *Mathematical Level* - Scientific ideas can be explained using different levels of mathematics. The mathematical level is an important factor that specifies what audience will benefit from the site. While providing a deeper insight into the subject to some readers, mathematical treatment of scientific problems can make the text unreadable to others. We chose to distinguish between the five levels of mathematics used by the site as follows: (a) none, (b) elementary school, (c) high school, (d) undergraduate, and (e) higher.

- *Interaction of Science, Technology and Society* - This category distinguishes three issues that relate science, technology and society: ethical problems (e.g., as those that arise in subjects like atomic bombs, animal cloning); usefulness to society (e.g., patents based on basic scientific principles such as the Polaroid camera) and environmental issues (e.g., certain gases released from chimneys of chemical factories can contribute to the increasing ozone hole, production of acid rain and more).

- *Experimental nature of science* - Chemistry, physics and biology, in addition to some aspects of mathematics, are experimental in nature. When teaching these topics in class, one has the ability to perform live demonstrations, or to allow the students to perform laboratory experiments. The Internet as a medium has the ability to describe experiments as text, present photos and figures related to experimental apparatuses and results, provide links to scientific laboratory Websites, and perform simulations to important experiments. These issues are related to the *graphic representation of science* category (see below). However, here we focus on two issues: the number of experiments mentioned in the site, regardless of the format in which they are presented; and take-home experiments instructions provided by the site. A more comprehensive analysis of the experimental nature of Websites can be performed using an auxiliary table that specifies the experiments relevant to the subtopic. An example of such a table is presented in the next section.

- *Theoretical models* - These are the theories used to explain and predict experimental results. As with experiments, the Internet as a medium can provide descriptions, derivations, simulations and links that will explain and elaborate relevant theoretical models. Again, we seek here only the number of models mentioned. An auxiliary table listing the specific models relevant to the subtopic can assist in performing a more comprehensive analysis.

- *Graphic representation* - The use of extensive graphics is one of the major advantages the Internet has to offer. In this category, we specify, on a yes/no basis, what kinds of graphics are used in the site: dynamic, interactive and 3-dimensional simulations; photos (e.g., of people or laboratory equipment); figures of data (e.g., experimental results); illustrations (e.g., experimental setup); and video movies. The number of images and simulations used in the site is described in the representational dimension, and therefore need not be repeated here.

- *Historical and current trends* - The last category deals with the weight given by the site to historical developments in the field and to current, ongoing research in the subject. We measure these issues by two parameters: historical timeline - if present, how many events are mentioned, and the year from which the latest research update is described.

EXAMPLE - THE STRUCTURE OF THE ATOM

As an example of the use of our taxonomy, we applied it to the subtopic "structure of the atom". From the point of view of undergraduate general chemistry courses, we constructed two auxiliary tables (see below) that list the important experiments and theoretical models that have emerged throughout history. The question we asked as we examined the educational Websites teaching the structure of the atom pertains to what extent these models are discussed (explained, mathematically derived, illustrated by figures). In the case of experiments, we distinguished between descriptions of the way these experiments were performed at the time (about a hundred years ago) and modern techniques to perform the same experiments which are based on the scientific knowledge accumulated through the years. Collecting and analyzing these data from different Websites provides deeper insight to the categories: “the experimental nature of science” and “the theoretical nature of science”, which are part of the scientific content dimension discussed above.

The experiments and models listed were chosen according to several general chemistry textbooks (Whitten Davis & Peck,1996; Mcquarrie & Rock, 1991; Petrucci & Harwood, 1997) in addition to books about the history of science (Nye, 1996, Idhe, 1984, Cobb & Goldwhite, 1995 and Encyclopedia Britannica, 1970) and Atkins’ physical chemistry textbook (Atkins, 1998). A brief summary of the experiments and models is given in our following paper (Tuvi and Nachmias, in preparation).

The example chosen to describe the usage of the taxonomy is entitled: *“The Particle Adventure”* at: http://ParticleAdventure.org/. This site has won many awards over the years from various Web and other media publishers such as the Discovery channel, Alchemist's WebPick, USA Today, Education World, Class Web and the National Academy Press Coolest Science Sites among others. It should be noted, however, that our evaluation refers to the content related to the structure of the atom only, not beyond it.

The Descriptive Dimension

Site identification: URL: http://ParticleAdventure.org/, Site name: The Particle Adventure, Root site: The Adventure WebRing at: http://www.realkids.com/webring.htm as well as Particle Data Group at http://pdg.lbl.gov/. Authors are academic, the site is constantly updated although it appears complete. The language of the site is English, although it exists in Spanish, French, Polish and Slovenian as well. The target population is high school students. The site size is over 100 html pages.

The Pedagogical Dimension

The instructional configuration of the site is individualized instruction, the model is directed and the instructional means are mainly information base. The interaction type is browsing, the cognitive process is memorizing. Navigation in the site is student controlled; there is no feedback on user activities. Contextualized help, technical help and didactic help are provided through the site's main page. The site relies on external Websites in addition to other Learning resources. There is no evaluation of the user activity in the site.

The Representational Dimension

The site is linearly organized; however, a permanent frame-index helps navigating between topics. Therefore, the knowledge representational structure can be considered as Web structure. On a scale of 1 to 5 (see Appendix A), the representational means can be said to be: text - 5, images - 4, interactive images -1, animation - 2, sound - 1, real-time updating - 1. In other words - the representational means are basically text, images and some animation.

The Communication Dimension

The site has both an index in the home page, and internal navigation tools in the form of arrows and buttons on each page in addition to a permanent frame-index. All internal links are constantly available; on a scale of 1 to 5, internal links: 5, external links: 2. The external links are present mainly in the home page in the form of an organized external link list. There are links to external activities in the form of student and teacher worksheets - in Spanish only. This can be accessed through the welcome page. The only communication means available are the email addresses of the site's authors.

The Scientific Content Dimension

The content point of view is physics; the subtopic is particle physics. The site's content is very reliable and no mathematics are used within the site. As far as interaction of science, technology and society is concerned, no mention is made of either ethical problems, usefulness to society or environmental issues.

The experimental nature of science is well established in this site, which mentions many experiments in the particle physics field, but describes few of them in detail. On a scale of 1 to 5 (see Appendix A), the score is 5 (i.e., more than 6 experiments are mentioned). It should be noted, however, that these experiments are not necessarily the ones listed in our auxiliary tables. Take-home experiments are not provided by the site. The theoretical nature of science is not emphasized as opposed to its experimental nature, and practically no theoretical models are presented as such; instead, these are generally presented as facts. Many models though, are mentioned through the historical timeline. Nevertheless, the timeline can be reached only from the welcome page. On a scale of 1 to 5 (see Appendix A), the score is 5 (more than 6 models).

Graphic representation of science - The site provides few dynamical simulations but no interactive or 3-dimensional simulations. There are very few photos, no figures, but many illustrations. There are no video movies.

A historical timeline is included in the site with more than 40 events mentioned (on a scale of 1 to 5, the score is 5). The latest research described is from 1999 - the Nobel prize in physics, which is was awarded in the field of particle physics (5 on the scale of 1 to 5).

The relevant experiments and theoretical models are presented in Table I.

The site was evaluated on October 24, 1999.

CONCLUDING REMARKS

The discussion on emergent trends in Web-based learning should be considered against the background of a continuum beginning from the very first CAI applications (Venezky & Osin, 1991), towards current and future networked synthetic environments for learning (Dede, 1996). One developmental path along this continuum deals with the philosophies, objectives, means and modes that evolved as consequence of the implementation of interactive digital technology in education (e.g., principles for learning software design, Stern, 2000). The second developmental path deals with knowledge representation and manipulation, which has become increasingly significant since the emergence of advanced information storage and handling tools (e.g., hypertext, search engines, networked databases). The third path focuses on communication features, which due to recent technological developments have qualitatively affected the opportunities for people to interact with peers, colleagues and experts.

The combination of these three key elements is what confers Web-based learning its educational potential. But the realization of this promise potential should not be taken for granted. A substantial research effort is required to assess the qualities of existing learning sites, to support the development of new sites, and to provide educators with evaluation and pedagogic decision-making information. The proposed taxonomy aims to contribute to this research effort by providing an organizing scheme and mapping tool for defining the features of educational Websites. Along these lines, Mioduser *et al.* (in press), conducted a systematic study of about 500 educational Websites for science and technology education, using the general taxonomy as their main data collection tool. A second study, that is now in progress focuses on about 100 educational Websites on atomic structure, using the taxonomy presented in this paper (Tuvi & Nachmias, in preparation).

The initiation behind the proposed taxonomy is to create a common language among all science educators, researchers, developers, and practitioners, who are interested in Web-based learning. We see it as an evolving rather than a fixed instrument. Therefore, we would welcome and appreciate any remarks and suggestions that may contribute to its improvement. We would also be pleased to provide the research tool and related information to any colleague interested in its use and further development.

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Table I: The Structure of the Atom -Auxiliary Tables

a. Experimental Mode

	Experiment	Description of old experiments	Figure or photo	Description of related up-to-date experiments
One.	Early experiments related to existence of atoms	NO	NO	NO
Two.	Discharge tubes, cathode rays and canal rays	NO	NO	NO
Three.	Black body radiation and the ultraviolet catastrophe	NO	NO	NO
Four.	The photoelectric effect	NO	NO	NO
Five.	Discovery of X-ray (Röntgen)	YES	YES	NO
Six.	Discovery of radioactive isotopes (uranium, radium, polonium)	YES	YES	NO
Seven.	Discovery of the electron (Thomson)	NO	NO	NO
Eight.	Measurements of the electron's charge (Milikan)	NO	NO	NO
Nine.	Rutherford's experiments with α particles	YES	YES	YES
Ten.	Isotopes and mass spectrometry	NO	NO	NO
Eleven.	Spectroscopy of the hydrogen atom	NO	NO	NO
Twelve	Identification of the proton	NO	NO	NO
hirteen	Identification of the neutron	YES	NO	NO
ourteen	Other (particle accelerators)	YES	YES	YES

b. Theoretical Mode

	Model	General Description	Mathematical Description	Figure/Photo
One.	Democritus' philosophy on the existence of atoms	YES	NO	NO
Two.	Dalton's atomic theory	NO	NO	NO
Three.	Avogadro's hypothesis	NO	NO	NO
Four.	Thomson's "plum pudding" model of the atom	YES	NO	NO
Five.	Rutherford's model of the atom	YES	YES	NO
Six.	Rydberg's empirical equation	NO	NO	NO
Seven.	Planck's theory on the quantization of light	YES	NO	NO
Eight.	Einstein's theory on photon-electron collisions	YES	NO	NO
Nine.	Bohr-Sommerfeld model of the atom	YES	NO	NO
Ten.	De-Broglie's and the wave particle duality of matter	YES	NO	NO
Eleven.	Heisenberg's uncertainty principle	YES	NO	NO
Twelve	The Schrödinger equation	YES	NO	NO
hirteen	Atomic orbitals	NO	NO	NO
ourteen	Other (Pauli, Dirac and others)	YES	NO	NO

Table I. Auxiliary tables used to evaluate the site: *"The Particle Adventure"* at: http://ParticleAdventure.org/.

APPENDIX: SUMMERY FORM OF THE CLASSIFICATION SCHEME

A. The Descriptive Dimension

Site Identification
1. URL________________________
2. Site name ___________________
3. Root site ____________________

Authors
4. Authors and their affiliation
   One. ☐ Academic
   Two. ☐ Public organization
   Three. ☐ Commercial
   Four. ☐ School
   Five. ☐ Other __________________

Site Evolution
5. Year of creation/update ______
6. Completion yes/no

Language
7. Language(s)
   One. ☐ Hebrew
   Two. ☐ English
   Three. ☐ Other _______

Target Population
8. Target Population
   One. ☐ Elementary
   Two. ☐ High school
   Three. ☐ Higher Education

Site Size
9. Number of html pages

1	2	3	4	5
≤ 3	4-10	11-30	30-100	>100

B. The Pedagogical Dimension

Instructional Configuration
10. Individualized instruction yes/no
11. Classroom collaborative learning yes/no
12. Web collaborative learning yes/no

Instructional Model
13. Directed yes/no
14. Inquiry-based yes/no

Instructional Means
15. Information-Base yes/no
16. Tools yes/no
17. Structured activity yes/no
18. Open-ended activity yes/no
19. Virtual environment yes/no
20. Student modeling / Adaptive mechanism yes/no
21. Games yes/no

Interaction Type
22. Browsing yes/no
23. Information gathering yes/no
24. Simple activity yes/no
25. Complex activity yes/no
26. Online tool yes/no

Cognitive Process
27. Information retrieval yes/no
28. Memorizing yes/no
29. Data analysis yes/no
30. Problem solving yes/no
31. Creation and invention yes/no

Locus of Control
32. Student controlled yes/no
33. Software controlled yes/no

Feedback
34. Automatic yes/no
35. Human asynchronous yes/no
36. Human synchronous yes/no

Help Functions
37. Technical help yes/no
38. Contextualized content-help yes/no
39. Didactic help yes/no

Learning Resources
40. Within Website resources yes/no
41. Linked WWW resources yes/no
42. External resources yes/no
43. Real-time data collection yes/no
44. Ask and expert yes/no
45. Ask a peer yes/no

Evaluation
46. Standardized test yes/no
47. Alternative evaluation yes/no

C. The Representational Dimension

Representational Structure
48. Knowledge Representational Structure
   One. ☐ One page only
   Two. ☐ Linear structure
   Three. ☐ Branching structure
   Four. ☐ Web structure

Representation Means

1	2	3	4	5
none	≥1	50%	1 per page	many

49. Text 1---2---3---4---5
50. Image 1---2---3---4---5
51. Interactive image 1---2---3---4---5
52. Animation 1---2---3---4---5
53. Sound 1---2---3---4---5
54. Real-time updating 1---2---3---4---5

D. The Communication Dimension

Navigation Tools

55. Index in home page yes/no
56. Internal navigation tools yes/no

Links

1	2	3	4	5
none	≥1	50%	1 per page	many

57. Within the site 1---2---3---4---5
58. External sites 1---2---3---4---5
59. Organized external link list yes/no
60. To external databases yes/no
61. To external activitiesyes/no
62. To virtual reality devices yes/no
63. To human communication yes/no

Communication Means

64. E-mail yes/no
65. Forum (no moderator) yes/no
66. Forum (with moderator) yes/no
67. Chat yes/no
68. Other yes/no

E. The Scientific Content Dimension

Discipline

69. Primary discipline
    One. ☐ Biology
    Two. ☐ Chemistry
    Three. ☐ Mathematics
    Four. ☐ Physics
    Five. ☐ Other ________________
70. Subtopic _____________

Reliability

71. Scientific Reliability of Information

1	2	3	4	5
none	questionable	50%	reliable	very

Mathematical Level Used

72. Mathematical Level
    One. ☐ None
    Two. ☐ Elementary school
    Three. ☐ High school
    Four. ☐ Undergraduate
    Five. ☐ Higher

Interaction of Science, Technology and Society

73. Ethical problems mentioned yes/no
74. Usefulness to societyyes/no
75. Environmental issues yes/no

Experimental Nature of Science

76. Number of experiments mentioned

1	2	3	4	5
0	1	2-3	4-5	≥6

77. Take home experiments yes/no

Theoretical Models

78. Number of models mentioned

1	2	3	4	5
0	1	2-3	4-5	≥6

Graphical Representation of Science

79. Simulations:
    One. Dynamical yes/no
    Two. Interactive yes/no
    Three. 3D yes/no
80. Photos yes/no
81. Figures of data yes/no
82. Illustrations yes/no
83. Video movies yes/no

Historical and Current Trends

84. Historical timeline included yes/no
    One. Number of events

1	2	3	4	5
≤5	6-10	11-20	21-40	>40

85. Latest researches/results described:

1	2	3	4	5
<1900	1900-20	1921-70	1971-90	1991-99

F. The Structure of the Atom -Auxiliary tables

Experimental Mode

86. Description of known experiments: (yes/no)

	Experiment	Description of old experiments	Figure or photo	Description of related up-to-date experiments
One.	Early experiments related to existence of atoms			
Two.	Discharge tubes, cathode rays and canal rays			
Three.	Black body radiation and the ultraviolet catastrophe			
Four.	The photoelectric effect			
Five.	Discovery of X-ray (Röntgen)			
Six.	Discovery of radioactive isotopes (uranium, radium, polonium)			
Seven.	Discovery of the electron (Thomson)			
Eight.	Measurements of the electron's charge (Milikan)			
Nine.	Rutherford’s experiments with α particles			
Ten.	Isotopes and mass spectrometry			
Eleven.	Spectroscopy of the hydrogen atom			
Twelve	Identification of the proton			
hirteen	Identification of the neutron			
ourteen	Other			

Theoretical Mode

87. Theoretical models related to the structure of the atom (yes/no)

	Model	General Description	Mathematical Description	Figure/Photo
One.	Democritus’ philosophy on the existence of atoms			
Two.	Dalton’s atomic theory			
Three.	Avogadro’s hypothesis			
Four.	Thomson’s "plum pudding" model of the atom			
Five.	Rutherford’s model of the atom			
Six.	Rydberg’s empirical equation			
Seven.	Planck’s theory on the quantization of light			
Eight.	Einstein’s theory on photon-electron collisions			
Nine.	Bohr-Sommerfeld model of the atom			
Ten.	De-Broglie’s and the wave particle duality of matter			
Eleven.	Heisenberg’s uncertainty principle			
Twelve	The Schrödinger equation			
hirteen	Atomic orbitals			
ourteen	Other			

Date of evaluation :________________