Current State of Websites in Science Education – Focus on Atomic Structure

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ABSTRACT

Web-Based Learning - usage of the Web as an arena for learning - has captured the imagination and interest of science educators worldwide. 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, to communicate and to learn. The Web's advanced graphical tools and computational power allow scientists, educators and students to visualize scientific data and processes in ways that were previously impossible, allowing a deeper understanding of natural phenomena. However, it is unclear to what extent these powerful tools are practically implemented in science education. Our study, aimed at answering this question, focused on the pedagogical and technological characteristics of Websites attempting to teach the subject of atomic structure. A classification scheme was developed and implemented on 95 educational Websites, of various levels and disciplines, focusing on atomic structure. The results show that advanced communication means and graphical tools are rarely used. While the content of the majority of Websites can be considered reliable, in their structure, level of graphics, and content they resemble an online version of a textbook rather than a new, interactive, learning environment. These findings are discussed in detail.

KEY WORDS:

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

INTRODUCTION

The Internet, a newly emerging medium, offers unprecedented opportunities in, 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, to communicate and to learn. The Web's advanced graphical tools and computational power allow both scientists and educators to visualize scientific data and processes in ways that are otherwise impossible. As a result, students can gain a deeper understanding of natural phenomena. It is not surprising therefore, that, Web-Based Learning (WBL) – the usage of the Web as an arena for learning – has captured the imagination and interest of science educators worldwide.

Teachers, lecturers, and educators at all levels are showing growing interest in Web-based instruction. Lecture notes, homework assignments, online books, and complete courses in pure science topics like chemistry, physics, or 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 units to lead and support the translation of courses to the Web, with the aim of student outreach (e.g., Distributed Learning at the University of Central Florida, Stanford Online). In the effort to produce these units, scientists, educators, Web designers, information technologists and computer technicians all join forces.

History shows that whenever a new technology emerges, expectations for better educational results are aroused. Such a trend has been evident with the emergence of radio, television and the computer. AT present, many researchers, educators and politicians, speculate whether a new revolution in education could result from intelligent utilization of the World Wide Web tools. The new medium offers long-distance interaction with peers and experts; the ability to perform complex numerical calculations online; huge amounts of data in the form of databases, journals, museums and much more; and excellent graphical tools for colorful, three-dimensional and dynamic images. But to what extent do Web authors in science education utilize these features? Has a new curriculum emerged by virtue of these tools? How, if at all, did pedagogy evolve with the new trend? This paper tries to answer these questions. Let us start by a short overview of the related work in this field.

Many attempts to classify WBL environments have been made in the last several years. The main purpose of which have been to identify the added educational value of the new technology: whether such added value exists at all and how it is manifested in new didactic situations and solutions. Harasim (1993) for example, emphasized the implementation of different models of instructional process. She defined 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) suggested a set of fourteen instructional modes covering the entire complex of Computer-Mediated Communication (CMC) technology. The proposed set included modes such as mentoring, project-based instruction, lecturing, information retrieval, chat and peer reviewing, together with Web versions of traditional Computer Aided Instruction (CAI) modes (e.g., tutorials, simulations, drills). Berenfeld (1996) focused on the distant-action allowed by the Web, suggesting five modes of “tele-ing”. These modes are tele-access to information, virtual publishing, tele-presence, tele-mentoring and tele-sharing. Riel (1993) on the other hand, focused on cultural and social aspects of the Web. He proposed the engagement of Web technology within learning circles or electronic communities to achieve various types of interaction (at the local and international level) and project-based instructional tasks.

Recently, Nachmias, Mioduser, Oren, and Lahav (1999) suggested a comprehensive taxonomy for educational Website classification. The criteria have been divided into four dimensions: descriptive, pedagogical, knowledge and communication. Mioduser *et al.* (Mioduser, Nachmias, Oren, and Lahav, 1999; Mioduser, Nachmias, Lahav, and Oren, 2000) applied this taxonomy to 436 educational Websites. Their main conclusion was: "*one step ahead for the technology, two steps back for the pedagogy*". They found that most sites' main component was the information-base, built upon the hypermedia-CD model. As for interactivity features based on the implementation of new technological resources (e.g., Java applets, Shockwave), most online activities resembled the automatic-feedback (behaviorist-like) transactions of classic CAI (e.g., multiple-choice, select-correct-part).

Mioduser *et al.* (1999; 2000) also showed that educational sites rarely employ advanced features of the Web, such as videoconference and Moo/mud, which were included in the taxonomy. On the other hand, the taxonomy did not address central issues related to science education (e.g., experimental and theoretical nature of science, level of mathematics). Therefore, we have constructed a modified classification scheme for Websites that focus on science education (Nachmias & Tuvi, 2001). The modified taxonomy has as scientific content an additional dimension. This dimension includes parameters such as scientific discipline, historical aspects, mathematical level, graphical representation of science and more.

In this study, we have applied the modified classification scheme to 95 sites that teach atomic structure in a variety of levels and disciplines. In the following sections we will briefly describe our classification scheme, present the study and its findings, discuss our results and suggest directions for the further development of WBL environments.

TAXONOMY OF SCIENTIFICALLY ORIENTED EDUCATIONAL WEBSITES

For the purpose of this study we developed a practical tool to describe the complexity and variety of Web based instruction materials. Our tool continues a research line focusing on the systematic analysis and evaluation of technology-based learning materials, from the early years of computer-based instruction (e.g., Blease, 1986; Shuell, & Shueckler, 1989) to more recent work on Web-based instruction (e.g., Berenfeld, 1996; Khan, 1998; December, 1998), as well as on the accumulated experience and knowledge in the field of instructional design (e.g., Gagne, Briggs & Wagner, 1992; Dick, 1996). In addition, we have integrated criteria introduced by science textbook researchers (Niaz, 1998; Chiappetta, Sethna, and Fillman 1991; Chiappetta, Sethna, and Fillman 1993). The taxonomy is a classification scheme aimed at reflecting the developers' educational philosophies as well as their actual manifestations, by revealing how different functionalities are configured, how the knowledge is structured and represented, and how communication features are implemented (see detailed description of related work in Nachmias & Tuvi, 2001).

Our taxonomy characterizes an educational Website by reference to five main dimensions: basic descriptive information, pedagogical and educational considerations, representational features, communicational means and scientific content. In what follows, we elaborate on each dimension.

The Descriptive Dimension

This dimension includes basic information regarding a site’s location, authors, target population and relevant technical data. The information is organized under 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(s)* used on the site; *target population* and *size*, the last indicated by the number of html pages.

The Pedagogical Dimension

The variables in this dimension reveal the developers' stance regarding the type of instruction offered 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, games); *interaction type* (e.g., browsing, answering questions, performing simple or complex activities, interacting with experts or peers); *cognitive process* activated (e.g., information retrieval, problem-solving); *locus of control* over the learning process; *feedback* (e.g., automatic, human expert's response); *help functions* offered on the site; *learning resources* either embedded in the site's design or external, physical and human resources; and *evaluation* (e.g., standardized tests, alternative evaluation).

The Representational Dimension

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

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, 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, some categories may be less important for some topics, and other categories, not mentioned here, may emerge for other subjects. This dimension consists of eight categories: *discipline*, defined by the primary discipline (e.g., physics, chemistry, biology) and the subtopic within that discipline; *reliability of information*, measured by the existence or absence of scientific mistakes; *mathematical level* (i.e., elementary, high, academic); *interaction of science, technology and society* (e.g., ethical problems, usefulness to society, environmental issues); *experimental nature of science* (e.g., number of experiments mentioned in the text, take home experiments); *theoretical models*, measured by the number of models mentioned in the text; *graphic representation* (e.g., simulations, photos, figures of data, illustrations) and *historical and current trends* (e.g., timeline, latest research described).

Auxiliary Tables

In addition to the classification scheme described above, we constructed auxiliary tables that list the important experiments and theoretical models related to research on atomic structure. The items listed were chosen according to several general chemistry textbooks (Mcquarrie & Rock, 1991; Petrucci & Harwood, 1997; Whitten Davis & Peck, 1996) in addition to books about the history of science (Cobb & Goldwhite, 1995; Encyclopedia Britannica, 1970; Idhe, 1984; Nye, 1996) and Atkins' (1998) physical chemistry textbook. These tables are designed to give better insight into the experimental and theoretical nature of science as presented by educational Websites in the field of atomic structure.

METHOD

Site Selection

For the purpose of this research, 95 Websites teaching atomic structure were chosen, using mainly search engines on the Internet (e.g., Yahoo, http://www.yahoo.com, Google: http://www.google.com) in addition to browsing. Chemical engineering students at NACE (Negev Academic College of Engineering, Israel), were given a task to find three sites that teach atomic structure, as part of their assignments in a course on technical writing. The students initially found about 20% of the sites. The sites were then selected and reviewed by one of the authors, who also located the rest of the sites. The common search terms used were "Atomic Structure", "Structure of the Atom" or "Atom". All URLs were compared to avoid double counting and mirror sites.

Atomic structure is a subtopic of many major topics (e.g., general chemistry, radioactivity, particle physics). Therefore, a site was chosen according to the following criteria:

1. The site was deliberately developed for educational purposes;
2. The site included any sort of explanation (or definition) of the atom concept. Alternatively, the site included instruction for a demonstration aimed at explaining atomic structure.

The first criterion means that although any site on the Web can be used as a resource for learning, only sites explicitly defined by their developers as pursuing educational goals were selected for this study. The second criterion was defined to avoid the selection of “mega-sites”, i.e., Websites that are in fact "umbrella-sites", or general-access-sites to conglomerates of educational projects or Web pages. In addition, it came to avoid sites that included course syllabus only, with no explanations. Although a site’s language was not a criterion, all sites, except for one written in French, were written in English. The site’s size, target population and level of explanation were not selection criteria.

Characterization of the Selected Websites

All sites were evaluated according to the taxonomy discussed above (Nachmias and Tuvi, 2001). The evaluation process was carried out from November 1999 until April 2000. During May 2000, each site was visited again, and its evaluation was revised. A list of all Websites can be found at http://muse.tau.ac.il/wbl/wbl_atom.html.

RESULTS

In what follows, we present the results of the evaluation of 95 Websites on atomic structure, according to the five dimensions of our taxonomy.

The Descriptive Dimension

Table I presents basic descriptive information about the Websites included in the study. Academic institutions were the main contributors of educational Websites in our sample (two thirds of the sites). Public organizations, private companies, schools and other educational agents had generated the remaining third. It should be noted that these figures do not necessarily reflect the actual distribution of Websites by their originators, but the biased distribution resulting from our sampling procedure.

Our results show that 75% of the sites were aimed at the college/university level and 25% at the high school level. A cross tabulation of authors and target population presented in Table II clearly shows that academic authors write for academic students and school authors write for school students, while other authors write for both groups ($\chi^2 = 26.27$, $p = 0.00$).

A site's size, in terms of number of html pages, was not trivial. Many of the sites were not dedicated to atomic structure only, and discussed other topics as well. Furthermore, many authors devoted several sections to atomic structure, not necessarily in consecutive order. This was particularly evident in many online courses in general chemistry, and is similar to the section order found in many chemistry textbooks (e.g., Whitten *et al.* 1996). In our study, the site's size was thus defined as the size of the whole site, regardless of what part of it was devoted to atomic structure. The size of 39% of the sites was less than 10 pages. About half of those sites (18% of the total) comprised only one page, and the other 61% covered more than 10 html pages.

The Websites' evolution was traced by the year of the last update. When an update date was absent, the creation date was used. About 12% of the sites did not have any date available. Among the rest of the sites, 40% were updated in 1998 or before, 24% in 1999, and another 24% were updated in the year 2000.

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The Pedagogical Dimension

Table III focuses on the pedagogical features of the Websites. All 95 sites were aimed at individual work. None of them supported online collaborative work or classroom collaborative work. Furthermore, on all sites, a directed instruction mode was employed. As expected within a Web environment, all sites supported user's control over the learning process.

Web technology offers a wide range of possibilities regarding instructional means. Our data show that the most frequent means implemented are information-bases (98%). Only 5% of the sites utilized online tools, and 3% of the sites implemented structured activities. Open-ended activities, virtual environments and online adaptive mechanisms were not used in any site under study.

Interactivity can be considered one of the major potential contributions of digital technology to educational instruction. The data shows that all sites (100%) used the lowest level of interaction according to our scale, namely browsing. In 20% of the sites question-answer tasks were included; simple interactions, in which clicking or dragging objects on the screen activates a predetermined script, appeared on only 8% of the sites.

Cognitive processes elicited by the activities, in order of frequency, only, were memorizing (99%), and Information retrieval 21% . 8% of the sites supported activities such as data analysis or problem solving. None of the 95 sites were included the cognitive processes of creation and invention.

Feedback features (either automatic or human) were included in less than 20% of the sites, far below their presence in pre-Web digital learning materials (e.g., Azevedo & Bernard, 1995; Cohen, 1985; Cyboran, 1995). Help features of the sites (either technical or content related) were included in only 18% of the sites.

Educational Websites can be considered as a group of varied representational and pedagogical resources. In this category of the taxonomy we looked for the different types of resources in the sites, and whether these were constrained to Web resources or they were complemented with classroom resources. We found that 98% of the sites relied on within-the-site resources; 41% provided links to other Web resources, and 40% referred the learners to additional external resources. None of the sites referred the readers to expert consultations, and only 3% of the sites used peer consultation. With regards to evaluation means, 20% of the sites used standardized test evaluation, but none applied alternative evaluation.

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The Representational Dimension

In our analysis of the representational dimension of Websites dedicated to atomic structure we looked at two major features: *representational structure* and *representational means*. The representational structure of knowledge can be of various types: isolated unit (18% of one-page sites), linear sequence of Web pages (2%), branching structure (14%), or Web structure (66%). These figures show that, apart from the one-page sites, most of the sites utilized the intrinsic structure of the Web, and provided links for random navigation within the site, regardless of the didactical order of the specific content. This result is in accordance with the finding that all 95 sites allowed user control of the learning process.

Table IV presents the frequency distribution of representational means in the Websites. As could be expected, text is the dominant information conveyor in the Web. Visual means (e.g., images, photos, and illustrations) are less frequent, although 60% of the sites used images extensively; 16% of the sites used animation at least once, mainly in the form of visual image loops. Sound and interactive images were far less frequent, and used altogether on less than 10% of the sites.

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The Communication Dimension

Unique features of Web technology such as those related to distance communication with distant knowledge and people (e.g., peers, experts) may contribute the most to learning processes. Table V shows the frequency of inclusion of varied communication means. Internal links, in the form of navigation tools, or other links, were included extensively in 73% of the sites. External links were relatively rare to find:. 53% of the sites had not even one external link (regardless of link content), 32% of the sites had only one external link. In 22% of the sites, there was an organized external link list, which could be accessed, usually, through the home page.

An important feature of the communication dimension is the communication means. In our study we distinguished between email, forum (with or without moderator), chat and others. However, apart from email (72%), all other tools were found in negligible percentages.

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The Scientific Content Dimension

Table VI presents parameters of the scientific content dimension, cross tabulation of these parameters with target population and χ^2 statistical test results. While atomic structure is related to both chemistry and physics, our results show that the primary discipline of about two thirds of the sites is chemistry. Physics was the primary discipline of 24% of the sites. There was only one site with biology as the primary discipline, and several other sites of various disciplines, including mixed disciplines. No significant difference was found between target population groups for this parameter.

To our surprise, most of the sites (83%) were found to be reliable with respect to their content. The reliability was tested with regards to the parts of the text that discussed atomic structure, while disregarding the rest of the content. A site was called “questionable” if there were misleading statements, wrong equations, or problematic interpretations of scientific data, as compared with the information presented in general chemistry textbooks (e.g., Whitten *et al.* 1996). Minor inaccuracies with regard to dates of scientific findings and discoveries were not considered mistakes, nor did simplified, though inaccurate, models of the atom that are common in elementary explanations of atomic structure. Again, there was no significant difference between target population groups.

The mathematical level required to understand a site's content was divided into three categories: *Elementary* - when no equations or mathematical notations were presented; *High* - when the content included negative numbers, numbers written in scientific format (e.g., as in the electron mass: 9.1×10^{-31} kg) or simple equations (without the use of Greek letters); *Academic* - when more complex equations were introduced (e.g., the Schrödinger equation). Our results show that only 23% of the sites did not use mathematics at all. About 50% used high level of mathematics and 27% used academic level mathematics. Furthermore, a significant difference ($p \le 0.01$) was found between target population groups. A higher percentage of sites (42%) for high school students avoided using math than sites for college students (17%). In addition, none of the high school sites used academic level mathematics.

Interaction of Science Technology and Society (STS) was barely mentioned on the Websites of our study, regardless of target population group. Less than 10% of the sites discussed either ethical problems, usefulness to society or environmental issues related to atomic structure.

The treatment of the subject matter as an experimental science was measured by the number of experiments mentioned in the text. Forty percent of the sites did not mention any experimental detail; 30% mentioned only one or two experiments, and another 30% mentioned three or more experiments. On the other hand, theoretical models were discussed more frequently. Only 13% of the sites did not mention any model, 37% of the sites mentioned one or two models and 51% of the sites mentioned three or more models. Theoretical models mentioned in the text but not explicitly by name (e.g., a description of the atom using Bohr's terminology, without calling it the Bohr model) were counted. No significant difference was found between target population groups in this case.

Graphical representation of science was followed using five parameters: simulations, photos, figures of data, illustrations and video movies. Images intended for decoration and without scientific importance were not included in this count; 19% of the sites used simulations, 18% - photographs, 17% - figures of data and 72% - illustrations. None of the sites used video movies. Clearly, illustrations are the preferred way of graphically representing science by the Web authors we studied. A significant difference at the 0.05 level was found between the usage of photographs in high school sites and higher education sites, with more photographs within the first group.

Historical aspects of science were traced using two parameters: historical timeline and the year of the latest research results discussed in the text. Only 12% of the sites included a timeline. A significant difference at the 0.05 level was found between population target groups in this case, with more sites targeted at high school drawing a timeline of events. Fifty-five percent of the sites did not put the text in any time frame, and did not mention any dates. 37% of the sites mentioned research undertaken in the first half of the 20^{th} century and only 8% of the sites mentioned up-to-date research related to atomic structure. In accordance with the timeline results, here too, a significant difference at the 0.05 level was found between target population groups. Sites designed for high school students mentioned dates more frequently: 25% of the high school sites mentioned research results from the last 60 years as opposed to 3% of the higher education sites.

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Table VII presents the distribution of sites by important experiments and theoretical models in the field of atomic structure. As the numbers indicate, and in accordance with our earlier mentioned results, experiments were described much less frequently than theoretical models. The most frequently mentioned experiments were Rutherford's experiments with α particles (32%) and Thomson's discovery of the electron and measurement of the e/m ratio (20%). On the other hand, the Bohr-Sommerfeld model of the atom was described in 56% of the sites. Thirty-eight percent of the sites described Rutherford's model of the atom, and 34% discussed atomic orbitals. Dalton's atomic theory was described on 28% of the sites. Planck's and De-Broglie's contributions to the understanding of atomic structure were each discussed on 26% of the sites. Heisenberg's uncertainty principle was discussed on 21% of the sites. Other models and experiments were mentioned on less than 20% of the sites.

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DISCUSSION

The Web offers unprecedented opportunities for science education. It has the ability to integrate many different tools and thus change the nature of educational processes with respect to pedagogy, communication and curriculum. Many educators and researchers have considerable expectations from this new medium. Conversely, there are many skeptics. In what follows, we shall discuss our results in light of the taxonomy's five dimensions.

Sites' Population

Our study included 95 different Websites that focused on teaching the structure of the atom. The number of sites found, their size and year of update all indicate that the new medium is extensively used in this particular subtopic. Nevertheless, there is no significant attempt among educators at different levels to share knowledge and experience when constructing educational Websites. Most of the sites were similar to each other in their content, structure, format and target population. These findings demonstrate the redundant aspect of the World Wide Web.

Pedagogy

On most of the sites, the user activity was similar to those required by textbooks, i.e., browsing and memorizing, on an individual basis. The sites rarely provided interactive tools. Websites in our study were mainly used as additional sources of information, without help, feedback, or a significant number of quality links to other resources (whether WWW resources, or textbooks). These results are in accordance with the results of Mioduser *et al.* (2000) who claimed: "One step ahead for the technology, two steps back for the pedagogy".

Representation

Out of 95 sites in our study, 66% used the natural structure of the Web and constructed their sites as a network of information that could be accessed in different ways. This result should be compared with the result of Mioduser *et al.* (2000) in which only 30% of the sites had a network structure. From a technical point of view, including one button that directs all pages back to the home page suffices to create a network structure for a Website. Furthermore, many of the sites were made with some sort of slide presentation software in which navigation buttons are created automatically. Thus, the 66% network structure could be a result of software tool templates rather than authorial intentions.

Nevertheless, this result can be considered encouraging in the sense that information was not restricted to a certain line of thought. A network structure not only uses the inherent structure of the Web. It also provides equal opportunities for students of various background or learning pace to benefit from the site.

On the other hand, the usage of interactive images, sound clips or dynamic images was extremely rare. All sites used text, and 60% of the sites made extensive use of static images. This form of representation resembles a textbook more than a new educational medium.

Communication

While most sites (73%) were internally linked, via hot links and navigation tools (content bars, page indices, navigation buttons), external links were rarely found. Only 22% of the sites had an organized external link list, and 28% of the sites did not provide an email address. These results are in accordance with the results of Mioduser *et al.* (2000). One can thus conclude that Web authors mainly construct independent units for the use of their own students. They normally ignore similar, existing Websites, overlooking one of the main benefits of the Internet - collaboration among users, developers and experts - that has been shown to increase students' motivation (Mistelr-Jackson & Songer, 2000).

Scientific Content

Atomic structure was originally explored by physicists (e.g., Röntgen, Thomson, Rutherford, Planck, Bohr, De-Broglie, Heisenberg, Schrödinger and more). Nevertheless, the principal discipline of 66% of the sites in our study is chemistry, while physics is the discipline of only 24%. This may be due to the fact that atoms are at the center of any chemical activity, while atomic physics is only one aspect of a wide variety of physical phenomena.

Many educators are suspicious about the reliability of scientific data presented on the Web. Notwithstanding, our results are encouraging - most of the sites (83%) were scientifically reliable. On the other hand, not all of the information was scientifically up-to-date. For example, the Bohr model of the atom is the most prevalent one in educational Websites. Today we know that Bohr's model of the atom does not provide an accurate picture of the nature of atomic structure. Even so, this model is widely used in high-school chemistry curricula, because of its simplified nature. Therefore, we can claim that most of the educational Websites are as accurate as high-school chemistry textbooks.

On most of the sites, the content is represented at a relatively high math level, in the form of known facts, rather than evolving research topics. Experiments are rarely described in detail - the discovery of the electron is mentioned in only 20% of the sites. There is no serious discussion of environmental or ethical issues related to the topic, and historical aspects are usually ignored, especially by academic authors. In other words, the information is provided in a relatively shallow mode that serves the cognitive process of memorizing facts and figures. We can thus conclude, that there is no apparent change in the curricular nature of educational processes in the field of atomic structure.

CONCLUSIONS

An enormous amount of information can be found on the Web. Nevertheless, it was surprising to find 95 different educational Websites that focus on atomic structure. We used our specially designed taxonomy of educational Websites to examine these sites. Our main question was whether the advanced learning technologies are supported by any novel pedagogical or curricular paradigms such as constructivism, inquiry based learning or alternative evaluation. Our results, supported by those of Mioduser *et al.* (2000), show that this is not the case. While the information may be considered reliable and the natural structure of the Web is used, true pedagogical and/or curricular change remains an ideal, rather than proven practice. At the content level, science is represented as a collection of facts. The experimental nature of scientific research is mostly ignored. Links to special databases or interactive expert consultation are not applied. Moreover, links to similar sites are rare. Considering the redundant nature of the Web, cooperation between Web-authors could be beneficial. However, our data show that attempts to collaborate over the Web are uncommon. In addition, technology is implemented in its most simple form (i.e., linked text and static images) and advanced technology is rare (e.g., dynamic images, interactive simulations). To summarize, the overall format of these Websites resembles a textbook rather than a new educational environment.

In light of these results, one can adopt the skeptics' perspective and argue that Web technology has little to offer to education. However, several fascinating high pedagogical-quality sites that focus on atomic structure do exist on the Web (Tuvi & Nachmias, submitted). Adopting a more thoughtful perspective, one may claim that WBL is currently at a transitional stage. The vast usage of the new technology, even in its simplest form, is a major development in its own right, and a necessary step on the way to a revolution. More research and extensive development of innovative educational models are thus required.

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Table I: Selected parameters of the descriptive dimension (% out of 95 sites).

Category	Parameter	%
Authors' affiliation	Academic	67.4
	School	10.5
	Other	22.1
Target population	High school	25.3
	Higher education	74.7
Site size (# of html pages)	≤ 10 pages	38.9
	> 10 pages	61.1
Last update	2000	24.2
	1999	24.2
	≤ 1998	40.0
	Unknown	11.6

Table II: Cross tabulation between authors and target population. The numbers represent % of sites within each group of authors.

Target → Authors ↓	High school	Higher education
Academic (N = 64)	10.9	89.1
School (N = 10)	80.0	20.0
Other (N = 21)	42.9	57.1

Table III: Parameters of the pedagogical dimension (% out of 95 sites).

Category	Parameter	%
Instructional configuration	Individualized instruction	100.0
	Classroom/Web collaborative learning	0.0
Instructional model	Directed	100.0
	Inquiry-based	0.0
Locus of control	Student controlled	100.0
	Software controlled	0.0
Instructional means	Information base	97.9
	Tools	5.3
	Structured activity	3.2
Interaction type	Browsing	100.0
	Information gathering	20.0
	Simple activity	8.4
Cognitive process	Memorizing	98.9
	Information retrieval	21.1
	Data analysis/Problem solving	8.4
	Creation and invention	0.0
Feedback	Automatic or human feedback	16.8
Help functions	Technical or content based help	17.9
Learning resources	Within Website resources	97.9
	Linked WWW resources	41.1
	External resources	40.0
	Ask a peer	3.2
	Ask an expert	0.0
Evaluation	Standardized test	20.0
	Alternative evaluation	0.0

Table IV: Distribution of sites by representational means (% out of 95 sites).

	Not at all (%)	One per site (%)	More than one per site (%)
Text	0.0	0.0	100.0
Image	21.1	18.9	60.0
Interactive image	91.6	3.2	5.4
Animation	84.2	13.7	2.2
Sound	96.8	2.1	1.1

Table V: Link usage in the Websites (% out of 95 sites).

Category	Details	%
Links within the site	Not at all	12.6
	One per site	14.7
	More than one per site	72.7
Links to external sites	Not at all	52.6
	One per site	31.6
	More than one per site	15.9
Special links	Organized external link list	22.1
	E-mail	71.6

Table VI: Parameters of the scientific content dimension and cross tabulation with target population (the numbers represent % of sites within each group of target population).

Category	Details	All sites (%, N = 95)	High school (%, N = 24)	Higher education (%, N = 71)	χ^2
Discipline	Chemistry	66.3	62.5	67.6	0.44
	Physics	24.2	29.2	22.5	
	Other	9.5	8.3	9.9	
Reliability	Reliable	83.2	75.0	85.9	1.53
Mathematical level	Elementary	23.2	41.7	16.9	14.05^{**}
	High	49.5	58.3	46.5	
	Academic	27.4	0.0	36.6	
Interaction of science, technology and society	Ethical, environmental or usefulness issues	9.5	16.7	7.0	1.94
Number of experiments mentioned	None	40.0	37.5	40.8	4.30
	1-2	29.5	16.7	33.8	
	≥ 3	30.5	45.8	25.4	
Number of theoretical models mentioned	None	12.6	25.0	8.5	4.97
	1-2	36.8	37.5	36.6	
	≥ 3	50.5	37.5	54.9	
Graphical representation	Simulations	18.9	29.2	15.5	2.19
	Photographs	17.9	33.3	12.7	5.21^{*}
	Figures of data	16.8	8.3	19.7	1.66
	Illustrations	71.6	83.3	67.6	2.18
Historical & current trends	Timeline included	11.6	29.2	5.6	9.70^{*}

Table VI - continued

Category	Details	All sites (%, N = 95)	High school (%, N = 24)	Higher education (%, N = 71)	χ^2
Latest research results	None	54.7	41.7	59.2	11.59^{*}
	≤ 1940	36.8	33.3	38.0	
	1941 - present	8.4	25.0	2.8	

$^{*}\ p \leq 0.05$; $^{**}\ p \leq 0.01$

Table VII: Distribution of sites by important experiments and theoretical models (% out of 95 sites).

Experiment	%	Theoretical model	%
Rutherford's gold foil experiment	31.6	Bohr's model of the atom	55.8
Thomson's discovery of the electron	20.0	Rutherford's model of the atom	37.9
Spectroscopy of the hydrogen atom	16.8	Atomic orbitals	33.7
Discharge tubes, cathode/canal rays	15.8	Dalton's atomic theory	28.4
The photoelectric effect	14.7	Planck's theory on the quantization of light	26.3
Milikan's oil drop experiment	11.6	De-Broglie theory on the wave-particle duality of matter	26.3
Black body radiation	10.5	Heisenberg's uncertainty principle	21.1
Identification of the neutron	10.5	Thomson's "plum pudding" model	18.9
Röntgen discovery of X-ray	6.3	Einstein's theory on photon-electron collisions	18.9
Discovery of radioactive isotopes - U, Ra, Po	6.3	Rydberg's empirical equation	16.8
Identification of the proton	5.3	The Schrödinger equation	16.8
Early experiments related to existence of atoms	3.2	Democritus' philosophy	13.7
Isotopes and mass spectrometry	3.2	Avogadro's hypothesis	3.2