The IEEE Virtual Museum: Using Web-based Education and a Humanistic Approach to Promote Engineering at the K-12 Level

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Abstract

This paper examines ways that the humanities can be integrated into the science and technology curricula of an international audience of pre-college students. Historically, engineering curricula at the college level have ignored the humanities and liberal arts. This division has its roots in the elementary and secondary school levels where little effort is made to bring an understanding of one branch of learning into the context of the other. This results in an under appreciation of the engineering endeavor as well as decreased exposure to the possibility of engineering as a potential career. The IEEE Virtual Museum uses the history of science and technology to bridge the gap between these two disciplines at the pre-college level. The IEEE, an international organization, has chosen the World Wide Web as its medium because of its potential to reach the largest number of educators and their students worldwide. The site explores how technology works while examining the social ramifications of that technology. It is augmented by instructional materials that help educators implement the material found on the site, and which can be tailored to local conditions. In this way, science and technology teachers learn how to bring the humanities into their classrooms, while humanities teachers learn to integrate science and technology into theirs. The challenges of developing a site and supporting materials for an international audience (e.g., bandwidth, language, inclusiveness) are also addressed.

Introduction

Enriching all of our children's scientific and technical education enables them to become more fully participatory citizens in an increasingly technological world. Encouraging careers in engineering for young people will raise the number of engineering students, especially among groups, such as women, that have been traditionally underrepresented in technological fields. The IEEE, as the world's largest technical society, has been concerned, as have many others, with the state of literacy in science, technology, engineering, and mathematics (STEM).

IEEE is particularly concerned with technology and engineering, the fields of their membership and the fields that transformed the world in the 20th century. These fields have grown increasingly complex and diverse, and it is difficult for the layperson to grasp their interconnection. IEEE has therefore increasingly turned its attention to pre-college education and to technological literacy, mainly in its own fields, but not necessarily drawing strict boundaries as to what will and will not be covered.

As part of that campaign, the IEEE History Center, an organizational unit co-sponsored and housed by Rutgers, the State University of New Jersey, has constructed the IEEE Virtual Museum. The IEEE History Center is charged with preserving, researching, and promoting the history of electrical engineering and computing. The promotion has been increasingly taking the form of pre-college education. The fact that computing, electronics, and information theory—to name just three areas—are all under the rubric of IEEE is a result of the historical development of these technologies. Therefore using a historical approach to better understand and explain them makes sense. Furthermore, since the technologies have become much more complex over time, showing them as they developed makes technology easier to explain. For example, showing how Volta developed the first battery reveals the underlying principle of the battery more readily than dissecting a modern example.

The World Wide Web, largely the result of IEEE technologies, is a communication medium with a global reach that has a large and growing influence in the transfer of information and in education. The interactive and highly visual nature of the Web makes it ideal for communicating with young people. Its reach is also global, and important consideration for an international organization like IEEE. Therefore, as our major tool for approaching pre-college technological literacy, we chose to construct the IEEE Virtual Museum, or VM.

Please keep in mind that we use "museum" as metaphor. There are many differences between a virtual museum and the traditional brick-and-mortar museum (and there are many variations within each of those categories). In this paper we may alternate between museum terminology and Internet terminology. What we mean by a virtual museum is a collection of web pages that use text and historical artifacts to tell stories. These stories are about electrical technologies, how they came to be, and how they impacted society. The stories are told through words, pictures, and multimedia objects such as video, audio, and animation. An individual "walks" or navigates through these stories at their own pace, stopping and focusing on areas they find the most compelling.

Since the IEEE Virtual Museum is completely virtual—the IEEE History Center is a think tank with no collections—we are not constrained in the story we tell, as might the Web site of brick-and-mortar museum with its own holdings to promote. We can borrow iconic images from the world's museums—Volta's battery from one museum, Faraday's induction coil from another—in order to produce the best pedagological experience. We further can combine the hands-on (although in this case virtual) experience of a science and technology center with the artifact richness of a history museum, an unusual combination in the "real" world.

Having emphasized the self-learning aspect of the museum metaphor, however, early focus groups among both students and educators actually indicated that the site would be of greatest use, and would draw the greatest traffic, if it were adapted to be a tool for educators to carry out their instructional mandate, rather than just a fun reference site for students. Although the site itself would be geared for students, and teachers would direct students toward the site as a resource, we decided that the site itself must contain information that the teacher could use directly, either in preparation for class or in the classroom.

As will be seen, this realization presents a challenge to the international aspect of the VM program. However, to focus for the moment on K-12 education in the United States, in the past several years the trend has been toward curriculum content standards and student performance standards. Teachers are given specific points or areas that must be covered, with the expectation that their students will be formally tested to determine their proficiency in those areas. Although these standards are promulgated at the local (usually state) level, in most subject areas national organizations have been promoting national standards; state and local standards are often based on these.

Because of the importance of the quantitative fields previously discussed, a great deal of the standards work has been in the areas of science, mathematics, engineering, and technology. As early as 1989, the National Council for Teachers of Mathematics developed its “Curriculum and Evaluation Standards for School Mathematics.” The most ambitious effort is probably “Benchmarks for Scientific Literacy,” part of the NSF-funded *Project 2061* of the American Association for the Advancement of Science. Most recently, in 2000, the *Technology for All Americans* project of the International Technology Education Association (ITEA) has produced “Standards for Technological Literacy: Content for the Study of Technology.” Of course, the engineering and technology standards have not been as widely accepted as the science and math ones, because the former subjects are less frequently formally part of the curriculum in American schools, but they have been gaining some currency recently (see, for example, M.D. Burghardt, “Assessing Elementary School Design Portfolios,” *The Technology Teacher* 59, 2).

A difficulty of this field-based approach is that these standards tend not to be interdisciplinary and to reference one another. And if this is true within the STEM areas, how much more so when in comes to integrating STEM with the humanities and social sciences? At the collegiate level, the Accreditation Board for Engineering and In Technology (ABET), has recently become concerned with the integration of technology education with its humanist context. In 1995 ABET revised its accreditation standards and the new standards, known as Engineering Criteria 2000 (EC2000), explicitly adopt the approach that had long been advocated by the IEEE History Committee. EC2000 states that “in the interest of making engineers fully aware of their social responsibilities and better able to consider related factors in the decision-making process, institutions must require coursework in the humanities and social sciences as an integral part of the engineering program. This philosophy cannot be overemphasized.”

For pre-college education, it is the ITEA standards that are most explicit in this regard. One of the five major categories of the ITEA standards is “Technology and Society,” and this category includes four of the 20 overall standards:

1. The cultural, social, economic, and political effects of technology
2. The effects of technology on the environment

3. The role of society in the development and use of technology
4. The influence of technology on history

Although the IEEE VM's historical approach impacts most directly on this last standard, its content touches on all four. In addition, although taking a historical approach, the IEEE VM also teaches about the scientific principles and their applications, thus potentially impacting a wide range of standards of scientific and technological literacy. The existence of these and the other standards means that in order to be efficacious, the content of the IEEE VM must be accompanied by instructional material, and the instructional material must explicitly and clearly indicate to the educator how particular content on the site can be used to communicate *specific* standards.

Therefore, in the end, the site will consist of both the IEEE Virtual Museum proper, and a teacher area where instructional material can be accesses or downloaded. The museum portion will serve as both a reference site for outside-the-classroom assignments, a tool for classroom demonstrations, and, perhaps, a fun location for the self-located student to learn more about technology. The instructional material will enable teachers to "teach to the standards" as well provide teachers with assignments designed to enhance students' proficiency in the standards areas.

Anticipated short-term outcomes from this project are as follows:

Short-term Outcome

- Teachers will acquire additional knowledge and information that enhances their science, technology, and mathematics curricula.
- The addition of practical, applicable, standards-based educational content to the curricula in science, technology, and mathematics.
- A greater understanding of technical careers such as information technology, which teachers can impart to their students.
- Collaboration between industry representatives, university faculty, and pre-college educators who will be able to meet and share ideas.

Anticipated long-term outcomes from this project include:

Long-term outcomes

- The level of technological literacy of the participating pre-college educators will be positively impacted and they will, in turn, impact the technological literacy level of their students for many years.
- Industry, university personnel, and pre-college educators will be given opportunities to meet and develop future collaborative relationships.
- Active integration of technology in the classroom using on-line instructional modules.
- A wide diversity of students, including females and minorities, will be exposed to information technology, engineering, and other technical professions.

Structure of the IEEE Virtual Museum

The IEEE History Center contracted with ScienCentral, Inc., of New York to develop the structure of the IEEE Virtual Museum. The VM is designed to be a database-driven site. Information entered into the database is assigned to one of four categories: “People Page,” “Event Page,” “Technology Page” or “Story Page.” The main core of the database is the People, Event, and Technology, or “PET” pages. People pages have text relating the lives and works of key people in the history of engineering. Events pages describe specific events in the history of technology, most often the societal impact of a technology. Technology pages explain how a technology actually works. Each of these pages also has other information associated with it, for example time and place. Furthermore, each of these pages can be imbedded with multimedia objects, such as images, audio clips, video clips, and interactive scripts. For example, each People Page will contain a picture of the person, most Technology Pages will contain an interactive explaining the technology, and many Event Pages will contain an audio or video clip.

Most importantly, these pages are not connected to other pages in any serial, ordered sense, but each is linked to any other relevant page. This distinguishes them from the fourth category of page, the Story Page. Story pages are linked to the other Story pages within an exhibit, thus providing narrative threads that convey the main point to the audience. Story pages are produced in serial groups that make up an exhibit. As mentioned above, an exhibit can itself be about a technology, an event, or a person, or even a place in time or space. Story pages can also have imbedded multimedia materials, although these tend to be on the PET pages. Story pages are also linked to all other relevant pages in the database, but in addition they are linked to each other in a serial fashion (that is there is a first page, second page, etc., with forward and back buttons). At the time that a page of any sort is created, it is automatically linked to all the relevant pages that are already in the database. Note, however, that there are no hot links within a page.

When a user calls up a page, it appears along with one or two navigation bars (depending on the layout of the particular kind of page). If the user is on a Story page the layout indicates which exhibit one is in and where within the exhibit one is. Attached to that Story page are relevant PET pages relevant story pages from other exhibits, and any relevant external sites that we recommend. These external URLs are also in the database and also linked to each other and all other pages. All of these navigation lists are hot links.

This arrangement allows the visitor to design their own museum experience. At each step along the preset path of an exhibit, they have an opportunity to “Dig Deeper.” For example, in reading a brief history of television in “Socket To Me,” a visitor may choose to click on a Technology Page to learn how television works, or to click on David Sarnoff to learn more about him. When the visitor is done, he or she can return to the exhibit path, but it is just as easy while on the Sarnoff page to see that Guiglielmo Marconi is mentioned and to note that he has a People Page. If the visitor clicks on that, there is still a link back to Sarnoff (and, as always, back to the story page they departed), but suddenly the visitor is met with a whole new set of links to a different technology (radio) and to engineers of an earlier generation (Sarnoff worked for Marconi, but Marconi worked with or competed against Fessenden, Bose, and so forth).

As has been said, one of the strengths of Internet technology and of the Virtual Museum metaphor is that advantage can be taken of collections that exist elsewhere on the World Wide Web. Therefore, the links to other sites, particularly the Web sites of brick-and-mortar science museums with relevant material. As mentioned, the structure of the site encourages the visitor to design their own experience. However, it is also important that users who wants to be guided through the experience do not lose their way. Therefore, when navigating throughout the site, the user sees a single browser window. If they choose to follow an external link, on the other hand, a fresh window is opened up for them. In this way when they eventually shut down the tangential path, they are right back where they were when they “left” the IEEE VM.

One of the greatest strengths of this database design of the IEEE VM is that learning exists not just in the pages, but in the interconnections of the pages. A small number of pages can have a large number of interconnections, meaning that exhibits can be prepared on a modest scale that will have a major impact. Furthermore, as new exhibits are built they can take advantage of existing PET pages. Once the database is well populated, it is easy to imagine producing an exhibit with hundreds of connections and an infinity of possible visitor paths with the insertion of a single story page. Another strength with the Virtual Museum concept in general is that it is relatively easy—compared to the brick-and-mortar case—to add, subtract, or modify exhibits.

Content of the IEEE Virtual Museum

To begin the Museum, the decision was made to produce a “main” exhibit that is a survey of the history of electrical science and technologies. In this way, the visitor with no previous knowledge of the subject can become oriented. Steering first-time visitors toward this introductory exhibit also affords the possibility to make the case of the historical and social importance of technology, and of the interconnection of the apparently (to the layperson) disparate technologies of interest to IEEE. Furthermore, since this exhibit touches at least briefly on all of the technologies that will eventually populate the museum, it serves as a “backbone” to the rest of the content. A visitor traveling along any meandering path will most likely frequently “cross” (that is, be given an opportunity to link to a story page on) this exhibit. This exhibit has been named “Socket to Me: How Electricity Came to Be.”

In addition the first thematic exhibit was chosen to be “The Beat Goes On: The Story of Sound Recording,” a subject of interest to young people and which affords various opportunities for multimedia content. In developing this content it was learned that the ideal length for an exhibit is 5 – 7 story pages with perhaps 50-60 associated PET pages. Of course, in future exhibits the nature of the content will determine the actual size, but this seems a good ballpark. The backbone exhibit, on the other hand, is twice the size of a “standard” exhibit.

Instructional Material

The instructional material to accompany the first two exhibits is under development, as are processes so that future instructional material can be produced in parallel with exhibit content. The material will take the form of modules, several modules per exhibit. These modules will provide practical teaching activities connected to the technical content of the exhibit and will be aligned with the national standards for technology. Each module addresses one standard or a small narrow group of standards. The material is being developed in conjunction with both pedagogy experts and actual classroom teachers and their students. Instructional material includes lesson plans that incorporate the site, further explanations of activities that can be carried out on-line, and instructions for activities that can be carried out in the classroom.

The Future: International Considerations

As mentioned, content and instructional material development will be continuous activities at the IEEE Virtual Museum. Exhibits are in the pipeline to cover microwave theory and techniques, women and engineering, and the career of Thomas Alva Edison. Under consideration are exhibits on the personal computer and on the Internet. The instructional material will also be expanded (by producing more modules) to include science and mathematics standards.

Thanks to the power of the World Wide Web, and the prevalence of English as an international on-line language, the IEEE Virtual Museum will be a resource available through the world. To reach IEEE's intended global audience, however, will create additional challenges, the first of which is language. Fortunately, in most cases language can be easily overcome with sufficient financial resources. The museum has been designed so that if translation can be supplied, a parallel meta-site can be set up so that the non-English-speaking visitor has the same experience. The robust nature of the unique database-drive structure means that translating only some of the PET pages when an exhibit is translated would still allow a reasonable visitor experience.

Another challenge is the possibility that there may bandwidth issues outside of North America and Europe, or even in certain areas within those regions. One solution would be to reproduce portions of the museum on CD-ROM. This could be done in conjunction with translation.

The final, and most difficult, challenge will be in developing instructional material that will make the IEEE VM viable internationally. Technologically, it would be easy to establish parallel teachers' areas, or to bundle the country-specific instructional material on the language-specific CD-ROM. But countries outside of the United States may have different curriculum standards or none at all. We will need to slowly, over time, utilizing IEEE's global reach, identify individuals in other countries who will work with us to produce versions of the IEEE Virtual Museum and its instructional material appropriate for their societies.