Software Solutions for Science e-Education: A Case Study from the VISIT Project

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Abstract
e-Education, using the web as virtual schools or classrooms and Internet as primary delivery mechanism, has increasingly captured the enthusiasm and fantasy of entrepreneurs, educators and students. Many e-Education software systems have been franchised. However, few of them have successfully taken advantage of current available online resources and Internet technologies, such as, easy access to a huge and interlinked network of scientific data, advanced graphical tools and computational power enabling educators and students to visualize scientific data and processes in ways that were previously impossible.
This study focuses on the technological and pedagogical challenges to science e-Education, based on the lessons learnt in designing and implementing an online collaboratory - VISIT – Virtual Immersion in Science Inquiry for Teachers, sponsored by a grant from US National Science Foundation Teacher Enhancement Program. The paper examines weak spots of current e-Education software packages. The paper discusses key characteristics of successful e-Education for science educators. The paper presents new designs for enhancing science e-Education, including, vertical (in-depth) exploration of time-series data, horizontal (geographic) exploration of time-series data, user-collected data integration tool, and knowledge database construction tool. The paper also discusses future directions of enhancing science e-Education software design.

Key words: e-Education, science inquiry, GIS, online collaboratory, software design
1. Introduction

e-Education has increasingly become popular to educators and students, as well as to researchers, technologists and entrepreneurs of information technology (IT). However there are many challenges in designing and developing winning e-Education systems that aim at enhancing science education. For instance, the predetermined non-human and simulated learning environments of most e-Education software packages cannot adequately address the challenges, such as, the inquiry based learning supported by increasingly large volume online scientific data, full utilization of online technologies, and a collaborative / creative learning environment that is essential to the success of e-Education. This paper will focuses on the technological and pedagogical challenges to science e-Education, based on the lessons learnt in designing and implementing an online collaboratory - VISIT – Virtual Immersion in Science Inquiry for Teachers, sponsored by a grant from US National Science Foundation Teacher Enhancement Program. The paper will start with an examination of weak spots of current e-Education software packages. The paper will proceed to discuss key characteristics of a successful e-Education from the point of view of science educators. The paper will then present new designs to address these considerations, and finally discuss directions and needs for future research.

2. Analysis of current e-Education software packages and science-oriented e-Education sites

With the advent of technological advances, there are hundreds e-Educational software packages across the U.S. and around the world. Among them, a number of commercialized packages are getting broader attention, such as, The e-College (http://www.ecollege.com), The WebCT (http://www.webct.com), The Blackboard e-Education Suite of Enterprise Software (http://www.blackboard.com), and The Class.Com (http://www.class.com). The general features of these e-Education tools are presented in Fig. 1 and Fig. 2.

Fig. 1 Common elements of current e-Education software

<table>
<thead>
<tr>
<th>Course syllabus</th>
<th>Instructor biosketch</th>
<th>Assignments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textbooks</td>
<td>Readings</td>
<td>Grade report</td>
</tr>
<tr>
<td>Discussion forums</td>
<td>Chat room</td>
<td>Email server</td>
</tr>
<tr>
<td>External links</td>
<td>Course map</td>
<td>Tools panel</td>
</tr>
</tbody>
</table>
Fig. 2 Course management tools of current e-Education software

<table>
<thead>
<tr>
<th>Registration tool</th>
<th>Group manage tool</th>
<th>Assignment tool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calendar</td>
<td>Course setting tool</td>
<td>Communication tool</td>
</tr>
<tr>
<td>Resource link tool</td>
<td>Drawing tool</td>
<td>Grading tool</td>
</tr>
<tr>
<td>Assessment tool</td>
<td>Survey tool</td>
<td>Sys admin tool</td>
</tr>
</tbody>
</table>

Most of current e-Education software packages simulate traditional classroom settings in online environment with addition of online communication tools (such as discussion forums, chat rooms, and email list servers). The software packages also provide a suite tools to maintain or change settings of the online course elements and tools. The noticeable enhancement is the addition of external links and the tool linking with external classroom resources. However, to large extent, current e-Education software infrastructure is a technological imitation of traditional classrooms. It has not taken advantages of the rich information in cyberspace and instructional and pedagogical potentials of the information and the information technologies.

There are many noteworthy efforts creating online science education courses and modules. Water on the Web (WOW, http://wow.nrri.umn.edu/wow/index.html) is an excellent effort of online science education, offering unique opportunities for high school and first year college students to learn basic science by working with state-of-the-art technologies accessible through a free web site. The true power of WOW is to access real world water quality data, obtained through the Remote Underwater Sampling Stations (RUSS) located in four Minnesota lakes, in real-time or in archived formats. Data visualization tools embedded in the web site allow students to see and explore relationships that might be lost to them when the data appears as just arrays of numbers. GIS maps and an interactive GIS tool of the site helps students understand the region being investigated. Teachers and students can develop lesson plans through investigating the data by using the Visualization and GIS tools and through referencing to the WOW’s extensive online resources.

Another good example is the Kansas Collaborative Research Network (KanCRN). KanCRN is a project funded by US Department of Education Technology Innovation Challenge Grant during 1998-2002. KanCRN is a virtual community that promotes the notions of using "hands-on, minds-on" activities, investigating a
few questions in depth, connecting school science with the everyday world of the student, and allowing students to share and test ideas with their peers (http://kancrn.org). The KanCRN project is committed to inquiry as basic to education and as a controlling principle in the organization and selection of students' activities. The KanCRN project staff demonstrates that the best way to learn about something is to actually do it. The KanCRN project provides an online tool, called “Online Project Builder” After users read through its guide, they can quickly use the Builder to create their own KanCRN research project with live and interactive databases for their students' use.

These science e-Education sites are places to go and resources to tap for science educators (Stevenson, 2001). Science educators like the availability of raw data for classroom research and salute the provision of visualization and analysis tools for exploring the data and conducting inquiry-based learning. However, most of these sites are the outcomes of research grants. The tools and functions are not robust though their designs are technical innovative and pedagogically pioneering.

3. Key factors for a successful science e-Education

Internet-based delivery of instruction (e-Education) is a new invention due to the rapid development of information technologies and telecommunications. There is a strong technological and economic push for higher education providers to adopt online learning strategies. Most students and educators participating in e-Education concur that the practical benefits of Internet-based learning and instruction are self-paced study, life-long learning, instructor-led discussion, and peer-to-peer collaboration (Walker, 1998; Kirkby, et al, 2002). In addition to these salient features, a successful e-Education, from the science education point of view, should support obtaining knowledge from progressively growing volume of online scientific information, and conducting inquiry-based authentic learning (Hargis, 2001).

Internet technologies have created a special phenomenon—the so-called cyberspace, which provides free access to information. Cyberspace provides unprecedented possibilities for us to accumulate, process, and transfer information in the education arena (Popov, 2001). Increasingly accessible large volume scientific databases contain untapped knowledge about sciences. This information, if properly retrieved, organized and analyzed, can provide extremely useful materials to support inquiry-based learning. The outcomes can provide science educators and students with a competitive edge in teaching and learning sciences. However, the single biggest problem is that so much of this information is distributed across networks, and often continents (D.Min, et al, 2001). Readily access to online data has overwhelmed educators and learners with information. Therefore there is an urgent need to develop new tools and processes that can help transform data into knowledge.
An ultimate criterion to justify the success of e-Education for science, from the pedagogical point of view, is whether it generates new knowledge and creates a new educational environment that allows individuals to get high-quality education at any time, in any place, during the person’s entire lifetimes (Popov, 2001). Aleynikov (1989) has proposed four important actions of productive knowledge. Knowledge-acquaintance allows individuals to perceive and distinguish various phenomena and particular information. Knowledge-copies are used to reproduce acquired information. Knowledge-skills allow individuals to apply acquired information in practice. Knowledge-transformation brings the earlier acquired knowledge into the solution of new tasks and new problems. Aleynikov’s four activities of obtaining knowledge are important means and objectives of conducting inquiry-based learning.

It faces several important technical challenges to obtain knowledge from overwhelmingly distributed information, including, data mining and explorative analysis, knowledge database construction and meta-knowledge accumulation.

Data mining is the overall process of finding and interpreting meaningful knowledge from data. It is also referred to as the interactive and iterative knowledge discovery in database process, involving repeated application of the specific data mining methods or algorithms (Fayyad, et al, 1996). Data Mining is often done based on three paradigms, knowledge needed now, strategic planning knowledge, and continuous information assessment. Knowledge needed now, for instance, can be obtained by evaluation and assessment. This knowledge can be used to extract a list of chemicals of pollution concerns, look at statistics in environmental and ecological changes for environmental indicators, or create a profile of environmental concern for public briefing. Strategic planning knowledge may include statistics on where the pollutants come from, what impacts they have on water quality, and how much they interact with wind and water flow characteristics. Information such as this can help drive new policy advisory and decisions for reducing pollution. Continuous information assessment allows agencies to monitor those strategic plans in action; watch for outcomes based on key decisions.

Date explorative analysis is an important technique of data mining, which visualizes the data through scientific methods. One of the common tools for data explorative analysis is Geographic Information Systems (better known as GIS). GIS has proven to be a powerful set of tools for extracting information into meaningful knowledge (Hunter and Xie, 2001). GIS is comprised of hardware and software to store, manipulate and analyze spatial data (Batty and Xie, 1994). GIS uses real data at a variety of scales, so students can look at information from around the world or their local area (http://www.emich.edu/visit). Students learn to create maps, explore patterns, ask questions, and analyze issues. GIS, as interdisciplinary tools, can help students learn in all core subjects and extra-curricular activities (http://ceita.emich.edu/lsatraining/TManual/index.html).
Development of knowledge databases is an important process to accumulating knowledge and encourages collaboration of specialists from various disciplines. This brings about a cooperative effect to eliminate interdisciplinary barriers that are strongly manifested in the modern educational system and, especially negatively, in higher schools (Popov, 2001). These barriers do not allow students to see the correlation between the subjects and their significance and connection with the student’s prospective profession and life. This definitely decreases interest in learning. Development of knowledge databases should be done by the learners themselves while they are studying and accomplishing particular creative goals (Popov, 1995). This process continues bringing together new information resources from experts of multiple disciplines, their expert knowledge on the solutions to specific inquiries, and their experience of how to cooperate and share. What being created here is the meta-knowledge.

Moreover, there is a rising awareness of the pedagogical issues that underpin good teaching and learning practice among technology education researchers (Radcliffe, 2002). Technology is an enabler. The adoption of web-based technology in education is an important advancement. But the most effective use of new learning technologies is often held back by poor underlying pedagogical assumptions. In many occasions, we saw tensions between the pedagogical pull and technology push in conventional campus-based programs and opportunities and challenges offered by increasingly growing online scientific data sources. It takes additional efforts to integrate pedagogy in online education and takes innovative ideas to create a truly new learning environment.

4. Prototype designs to enhance science e-Education infrastructure

Several prototype designs of science e-Education software are illustrated in this section: vertical (in-depth) exploration of time-series data, horizontal (geographic) exploration of time-series data, user-collected data integration tool, and knowledge database construction tool.

1) Vertical (in-depth) and horizontal (geographic) exploration of time-series data

The online vertical data exploration tool, called Profile Plot, was originally developed by Water on the Web research group (WOW, http://wow.nrri.umn.edu/wow/index.html), and enhanced by the Virtual Immersion in Science Inquiry for Teachers research group (VISIT, http://www.webpolis.info/pplot/index.html). This package allows students to choose a lake, a water quality parameter, a visualization method (By Depth, By Time), and an observation time duration to analyze the changes of a parameter in vertical direction or in time-series (Fig. 3). Profile Plot can also be used to explore relationship between multiple parameters or compare spatial variations between different lakes.
The Online DataView is a web-based scientific investigation tool developed by the VISIT project (Fig. 4, [http://maps.acad.emich.edu/dataview/](http://maps.acad.emich.edu/dataview/)). It is designed based on the Rouge River water quality database and the design of the Rouge River National Wet Weather Demonstration Project software package, DataView ([http://www.wcdoe.org/rougeriver/](http://www.wcdoe.org/rougeriver/)). The water quality data sets and their
associated phenomena can be analyzed from the perspectives of different disciplines and school science curricula, and by location (city/township and observation station – Search Location), by parameter (Search Parameter), or jointly by location and parameter (Query Builder). The Online DataView can explore relationships between multiple parameters or compare spatial variations between different locations in the map (Fig. 5), graphic, and table (Fig. 6) forms.

Fig. 5 Viewing data in the map form – Online DataView

![Map Image]

Site ID: M3003690, in ALLEN PARK, Kingswood?

(Right Click on the map to zoom the map)

23 parameter(s) found.

Fig. 6 Viewing data in the table form – Online DataView

<table>
<thead>
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<th>Parameter</th>
<th>Value</th>
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</tr>
</tbody>
</table>
2) User-collected data integration tool

There are many reasons for using the Internet to conduct science education. Some principal incentives are its ability to engage students as active participants, the motivational influence of Internet-based authentic learning activities, and the ability to include student inquiry and cooperative learning in Internet-based lessons. However, the ability of e-Education software that allows students (learners) to upload their own field observation data and to conduct comparative studies with achieved data is a critical technical prerequisite for all of these feats.

The Online DataView package contains a tool set called, *Databases*, which supports the integration of users’ data with the online achieved data and the comparative authentic inquiry (Fig. 4). When a student clicks Database, a screen of data uploading instruction is opened (Fig. 7).

Fig. 7 Instruction screen for uploading user’s databases in Online DataView

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**Databases**

Users can view data from two of DataView’s Databases: System Achieved Database and Special User Database. The System Achieved Database is the Water Quality Database created by the Rouge River National Wet Weather Demonstration Project and read-only. Users can upload self-collected data (in text file format) into the Special User Database.

- If you want to upload your own data, click [here](#).
- If you want to select a database to view, click [here](#).

If a user chooses to upload the self-collected data (your own data), the User File Upload Form will be opened (Fig. 8). This form contains a sample text file to show the user the required file format. This form can activate a file browser that allows the user to navigate to a right folder to locate the file. After the special user file is uploaded, the user can view this special file, and make comparative views of this file with a selected achieved data set that has an association with the user file, either in location, or in parameter, or in time series.

3) Knowledge database construction tool

Another interesting experiment of the Online DataView is the tool called, *Save to My Library*, which is actually a tool for constructing knowledge database. When a user is conducting data analysis through *Query Builder* in the Online DataView, the query results will be reported along with a button, *Save to My Library* (Fig. 9). This option button calls the Knowledge Database Construction Dialog (Fig. 10). The user will be prompted to fill the dialog with the necessary reference data,
Users can upload self-collected file to the Special User Database. The user file is formatted into a comma (tab) delineated text file. The file should look like the following:

<table>
<thead>
<tr>
<th>TName,</th>
<th>SITE_ID,</th>
<th>PARAMETER,</th>
<th>Date,</th>
<th>TIME,</th>
<th>VALUE,</th>
<th>UNITS</th>
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</tr>
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<tbody>
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<td>D1003002,</td>
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<td>4/1/94,</td>
<td>1:00:00 PM</td>
<td>2,</td>
<td>IN</td>
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<td>NORTHVILLE TWP.,</td>
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<td>RAIN,</td>
<td>4/1/94,</td>
<td>1:00:00 PM</td>
<td>4,</td>
<td>IN</td>
<td>Yichun</td>
</tr>
</tbody>
</table>

Please fill in the file-upload form below,

File to upload: ____________________________

Press to upload the file!

along with the system achieved query criteria, to populate a SQL server-based knowledge database. The user and other users visiting the Online DataView in a later time can retrieve and search the knowledge database through two gateways, My Library, and Search. Therefore the Online DataView package provides an innovative tool for constructing and managing knowledge database through the functions, Save to My Library, My Library, and Search for supporting science inquiry and authentic learning. This functionality is a ground-breaking in the context of science e-Education, though the tool is at the prototype stage.
5. Discussions

The design and development of science e-Education are complex undertakings. This is partly because the cyberspace is experiencing dynamic evolution. Increasingly more and more scientific data and materials are available to educators and students. Another part of the reason is that the development process involves many interrelated elements that must work in unity to form a coherent system for learning. Each of the elements is critical to the success of the science e-Education and the learning experience that the student receives. In short, the challenges we are facing can be clustered into two dimensions: data mining and exploration for data to be transformed into knowledge; and pedagogical alignment with educational standards and benchmarks for creating a new online learning environment.

There are plenty of rooms for further development to transform information into knowledge from the perspective of e-Education software development. The paper has illustrated several novel functionalities that are very important for online science education. The data exploration and mining tools, such as the distributed GIS-based online mapping and graphing tools, visualize and analyze data in
multimedia formats, which helps students to better understand the spatial and statistical characteristics of the data. The user data integration tool allows students to input and merge field observation data with the achieved or published data. The data integrations are truly authentic learning activities happening on the Internet platform, on which students become active participants in inquiry and cooperative learning. The concept embedded in the development of the knowledge database construction tool is significant to science e-Education. The abilities of storing, sorting, searching and retrieving knowledge, through a database built by specialists and learners themselves, are important means of sharing, acquiring, transforming and generating (new) knowledge.

The development of these new functionalities was inspired and supported by theoretical and empirical research in science e-Education. Although the prototype tools were developed for specific research and education projects, the design ideas are easily transportable to future development of generic and commercialized e-Education software packages.

Moreover, it will go beyond the capability of a specific e-Education software system to create a collaborative and creative online learning environment. Within the context of software infrastructure, fast and well-informed access to vast and interlinked network of scientific data, and adequate handling of meta-knowledge are the biggest challenges. The simple reason is that good Internet projects and resources for science teachers and students are plentiful, and there is an almost endless list of really great sites out there. Therefore it is hard to decide which sites to review for specific topics. It is extremely challenging for system developers to invent online tools, which could be used to find out which contents these sites contain, and transform information into knowledge that could be fused into a learning process. There is an urgent need for cooperation between national or even international communities that share the interest in e-Education.

U.S. National Science Foundation has launched a national effort, called National SMET (Science, Mathematics, Engineering and Technology,) Education Digital Library Program (http://www.ehr.nsf.gov/ehr/due/programs/nsdl/). The NSDL program plans to offer direct access to and delivery of instructional resources through the establishment of a federation of representative SMET digital libraries. The NSDL program is developing various tools, such as search tools, meta-data tools, learning object management tools, and community building tools. These tools would permit users to learn, connect and manage their personal educational portfolio. The NSDL digital libraries seek to connect communities of educators and learners to a rich set of pedagogical resources for SMET education (http://www.smete.org/). The NSDL program is pointing to a right direction for e-Education and it will lead e-Education to a new era if it succeeds as it promises.
References


http://kancrn.org, The Kansas Collaborative Research Network, 1122 West Campus Road #702A, University of Kansas, Lawrence, KS 66045-3101.

http://maps.acad.emich.edu/dataview/, The Online DataView, Institute for Geo-spatial Research and Education (IGRE), 125 King Hall, Eastern Michigan University, Ypsilanti, MI 48197.

http://wow.nrri.umn.edu/wow/index.html, Water on the Web, the Natural Resources Research Institute, University of Minnesota Duluth, 5013 Miller Trunk Highway, Duluth, MN 55811.


http://www.emich.edu/visit, Virtual Immersion in Science Inquiry for Teachers, Institute for Geo-spatial Research and Education (IGRE), 125 King Hall, Eastern Michigan University, Ypsilanti, MI 48197.

http://www.smete.org/, SMETE Open Federation Headquarters, 3115 Etcheverry Hall, Berkeley, CA 94720-1750.

http://www.wcedoe.org/rougeriver/, the Rouge River National Wet Weather Demonstration Project.


http://www.webpolis.info/pplot/index.html, The Profile Plot, Institute for Geo-spatial Research and Education (IGRE), 125 King Hall, Eastern Michigan University, Ypsilanti, MI 48197.


