

# Integrating Computer Technology into Science Curricula Using Internet Tools

## NSF PFSMETE Abstract, Dale Reed

While computer expertise is being touted as the “new literacy,” teachers are overwhelmed with the task of integrating computers into the curriculum. This problem will be exacerbated by President Clinton’s technology initiative to bring the Internet into every classroom over the next 5 years. Significant resources are being spent on computer-related electronic instructional materials, with U.S. K-12 educators projected to spend \$1.02 billion on electronic instructional materials in 1999. With 54% of elementary school teachers indicating that their schools fail to provide the training and support they need to “easily integrate” computers into their curricula, only 3% of U.S. schools are effectively integrating technology into their educational programs. One of the 6 PCAST recommendations is the application of technology to education. This is of particular concern in the *teaching* of science, as computer tools have become ubiquitous in the *practice* of science.

Computer technology can be a useful tool for instruction, helping overcome the cognitive bottleneck where too few students negotiate the transition from lower-level skills to higher-level skills, from basic rote memorization and re-telling skills to more abstract knowledge synthesizing and transforming skills. Appropriately integrating computer technology into science curriculum can be difficult because teachers have difficulty finding the right software and curriculum in the face of ever-expanding choices.

Web-based virtual learning communities have the potential advantage of unlimited participation and size, which brings up the problem of a teacher being able to find what she/he is looking for. We would like to move from simply what a user *states* in a search query, to what a user *means* by way of incorporating a user’s contextual information into their queries to provide more meaningful searches.

The key to making this successful is *meaningful indexing*. The vast majority of current on-line searches use keyword searching which largely ignore the larger context of the query. This makes the search space sometimes intractably large. Because of the rate of growth of information on the Web, the correlation of keywords to context must be largely automatic, using some sort of automatic filtering. Two possibilities for solving this problem would be a Nearest Neighbor (NN) system with a dynamic search space, and another approach that has been used successfully for similar problems is Latent Semantic Indexing (LSI).

The NN and LSI techniques would be used to implement a Web-based system to help teachers locate educational software tools and curriculum that are most germane to their situation. Based on a teacher’s separately described profile and query inputs (e.g. subject, grade level, type of software, instructional approach) the system would find results matching the query, while taking into account the context of the user as represented in the profile. The result would be matches showing software and curriculum that is most likely to be relevant to the teacher. These would be scaled according to how closely the query is matched. The goal is to make it *easy* to find relevant information. The system would be initially seeded by master teachers, where the on-going system would be contributor-based and *generative*. Users would find desired software and curricular resources using this system, and voluntarily contribute reviews (in the spirit of the on-line bookstore <http://www.amazon.com>).

The strength of this research lies in its combination of computer science “intelligent” indexing with a collaborative Web-based tool teachers can use to help integrate computer technology into their science curriculum. The proposed tool will help educators find appropriate software and curriculum.

As a separate, though not unrelated activity, I propose setting up an on-line introductory computer course (EECS 171) at UIC. Here I will be using the Web as a virtual classroom, using the Web as an asynchronous educational tool using existing Internet tools such as *Serfor Mallard*. This course would then be made available (on-line) to Chicago Public School students either as a high-school course, or as a head-start on college.

During the two years of the fellowship I will remain employed at UIC, teaching the on-line version of EECS 171 there once a year. My mentor would be Louis Gomez, who is an Associate Professor in Northwestern’s Learning Sciences Program. I would be affiliated with the recently NSF-funded Center for Learning Technologies in Urban Schools, of which Louis is a director.

Both my dissertation research and my directing educational intervention programs have directly prepared me for this work. My dissertation dealt with using the computer as an intelligent tool doing pattern-matching, applied to the interdisciplinary task of sound equalization. This fellowship would also involve interdisciplinary work using the computer as a tool with pattern matching. Additionally, as P.I. for NSF’s Summer Science Camp (SSC) Program and co-P.I. for a DOE Pre-freshman Enrichment Program (PREP) over six years, I have used technology to pique Chicago Public School 6th - 9th grade students’ interest in science, math, engineering and technology careers.

# Integrating Computer Technology into Science Curricula Using Internet Tools

NSF PFSMETE Proposal, Dale Reed

While computer expertise is being touted as the “new literacy,” teachers are overwhelmed with the task of integrating computers into the curriculum. This problem will be exacerbated by President Clinton’s technology initiative to bring the Internet into every classroom over the next 5 years. Significant resources are being spent on computer-related electronic instructional materials, with U.S. K-12 educators projected to spend \$1.02 billion on electronic instructional materials in 1999.<sup>1</sup> With 54% of elementary school teachers indicating that their schools fail to provide the training and support they need to “easily integrate” computers into their curricula,<sup>2</sup> only 3% of U.S. schools are effectively integrating technology into their educational programs.<sup>3</sup> One of the 6 PCAST<sup>4</sup> recommendations is the application of technology to education. This is of particular concern in the *teaching* of science, as computer tools have become ubiquitous in the *practice* of science.

Computer technology can be a useful tool for instruction in the following ways:

- as a communication medium in collaborative learning,
- as a patient tutor in self-paced discovery learning, and
- as a tool allowing individualized exploration of content.

These approaches help overcome the cognitive bottleneck where too few students negotiate the transition from lower-level skills to higher-level skills, from basic rote memorization and re-telling skills to more abstract knowledge synthesizing and transforming skills. These uses of computers in education are additionally compelling in light of the trend toward distance learning, where virtual learning communities are established using the World-Wide-Web (the *Web*) and other technologies.

Appropriately integrating computer technology into science curriculum can be difficult because teachers have difficulty finding the right software and curriculum in the face of ever-expanding choices. Finding the right software and curriculum is made easier when teachers form virtual communities on the Web. An example of such a community is the Educational Object Economy,<sup>6</sup> which is targeted to function as an educational software cooperative. Educators can use the Web to find out what others use, retrieve it, use it, add to it, and then add it back into the educational archives, building on what was already there.

Web-based virtual learning communities have the potential advantage of unlimited participation and size, which again brings up the problem of a teacher being able to find what she/he is looking for. There is too much software and too many documents continually being generated for a person to directly keep track of them. Some kind of “intelligent,” intuitive tool incorporating indexing or hierarchical ordering of the search space must be used to make this burgeoning body of knowledge useful. We would like to move from simply what a user *states* in a query, to what a user *means* by way of incorporating a user’s contextual information into their queries. This contextual information could either be computed statistically or be represented by a user’s *profile*, which would be used in conjunction with keywords or phrases to provide more meaningful searches.

The key to making this successful is meaningful indexing. The vast majority of current on-line searches use keyword searching which largely ignore the larger context of the query. This context includes information such as research interests, subjects taught, and pedagogical approaches. Intelligently incorporating this information into the search can greatly decrease the size of the search space. Keyword matching often fails because a single word can have more than one meaning (e.g. plane), and conversely many different words can be used to describe a single concept (e.g. human factors, ergonomics).<sup>9</sup> Because of the rate of growth of information on the Web, the correlation of keywords to context must be largely automatic, using some sort of automatic filtering. Two possibilities for solving this problem would be a Nearest Neighbor<sup>10</sup> system with a dynamic search space, and another approach that has been used successfully for similar problems is Latent Semantic Indexing,<sup>11</sup> both of which are described below.

Nearest Neighbor (NN) is a method used to cluster together related information. It has been compared to Classifier Systems and Decision Trees,<sup>12</sup> with the added benefit of greater accuracy and system transparency. An n-dimensional search space is created using exemplar features. A new example is then mapped into this space, with predicted outcomes taken from the outcomes of its neighbors. This could be done dynamically by changing the popula-

tion of the search space over time, allowing the system to “forget” and to modify its search characteristics. Searching on keywords *indexing* and *computer* could find a neighbor with the *database* keyword.

Latent Semantic Indexing, (LSI) is a statistical method used to match words of queries with words of documents. A large matrix of term-document association data is used to construct a “semantic” space where related terms and documents are placed near each other. This space is then organized to reflect the most significant associations in the space. This can end up with terms not actually in the document being associated with the document.<sup>11</sup> For instance, searching using the keywords *indexing* and *computer* using LSI could trigger the keyword *database*, even though it was not in the original query but perhaps should have been. The desire is to identify only the information that is useful, such as applied to filtering email<sup>7</sup> and technical memos.<sup>9</sup>

I intend to develop the intelligent indexing techniques described above to implement a Web-based system to help teachers locate educational software tools and curriculum that are most germane to their situation. Based on a teacher’s profile (in a separate file) and query inputs (e.g. subject, grade level, type of software, instructional approach) the system would find results matching the query, while taking into account the context of the user as represented in the profile. The result would be matches showing software and curriculum that is most likely to be relevant to the teacher. These would be scaled according to how closely the query is matched. The goal is to make it *easy* to find relevant information.

For instance, a teacher could request educational software, where the teacher’s profile includes the facts that she/he is a biology teacher and uses project-based learning. After rating appropriateness of some of the matches found, further searching would then yield matches most similar to those highest rated. The system would be initially seeded by master teachers, where the on-going system would be contributor-based and *generative*. Users would find desired software and curricular resources using this system, and voluntarily contribute reviews (in the spirit of the on-line bookstore <http://www.amazon.com>).

The strength of this research lies in its combination of computer science “intelligent” indexing with a collaborative Web-based tool teachers can use to help integrate computer technology into their science curriculum. This tool will help educators find appropriate software and curriculum.

As a separate, though not entirely unrelated activity, I propose setting up an on-line introductory computer course (EECS 171) at UIC. Here I will be using the Web as a virtual classroom, using the Web as an asynchronous educational tool using existing Internet tools such as *Serf* or *Mallard*.<sup>13</sup> This will give me first-hand experience with using the Web as a primary educational medium, and tangentially give me the opportunity to test the usefulness of the developed intelligent indexing tool. This course would then be made available (on-line) to Chicago Public School students either as a high-school course, or as a head-start on college.

### *Time Table*

Intelligent Indexing tool research and development: Fall '98: Reviewing indexing approaches using NN and LSI, focussing domain for Web-based application, exploring current iteratively-refined Web-based indexing. Spring '99: Collecting educational curriculum sites, starting on intelligent inference engine. Summer '99 - Fall '99 Complete both intelligent inference engine and interface to Web-based search tool. Spring 2000: Field test of tool with science teachers. Summer 2000: Incorporate user feedback. Spend ~ 50% of my time working on this.

Study: Reading cognitive science literature and participating in on-going work with the NSF-funded Center for Learning Technologies (CLT) under the direction of Louis Gomez. Include reviewing different modes of learning and educational software. Spend ~ 35% of my time working on this.

Developing a Web-based Introductory Programming Course - Fall '98: prepare on-line course, teach it in Spring '99 at University of Illinois, revise and expand it, teach it again in Spring 2000. Spend ~15% of my time working on this.

## *Career Goals*

Using technology in education has been at the heart of my grants and publications, and I intend to continue making this a primary focus. While still working on my dissertation, I was a P.I. for NSF's Summer Science Camp (SSC) Program and co-P.I. for a DOE Pre-freshman Enrichment Program (PREP). In working on those projects over a six-year period I used technology to pique Chicago Public School 6th - 9th grade students' interest in science, math, engineering and technology careers.

There is a trend in computer science learning right now for institutions to offer instruction on-line. The proposed work will directly give me experience in implementing such a course. By working on the proposed intelligent indexing tool for educators I will gain both understanding of implementing a software tool on the Web, as well as exposure to the many software programs and curricula in use. This acquired expertise in Web-based tools and applications will be useful as I continue to explore using the computer as an intelligent tool.

## *Rationale for selecting Institutions and Mentors*

During the two years of the fellowship I would remain employed at UIC, teaching the on-line version of EECS 171 there once a year. UIC is committed to using the Web as an instructional medium and has recently established a Web-based Masters degree in Science. My mentor would be Louis Gomez, who is an Associate Professor in Northwestern's Learning Sciences Program. I would be affiliated with the recently NSF-funded Center for Learning Technologies in Urban Schools, of which Louis is a director. My interests have been and continue to be interdisciplinary, which fit in well with the work in cognitive science being done under Louis' direction.

Though my degree is from Northwestern, my connection with Louis has come about indirectly through my work with NSF grants, not through my advisors or research while a Ph.D. student.

## *References*

1. New York Times 20 Dec 97, quoting a newsletter from Cowles/Simba Information, a division of the Cowles Business Media market research company.
2. Survey results at [<http://www.tenthplanet.com/Company/news/97survey/>].
3. CEO Forum on Education and Technology, a group of 21 education and business leaders, quoted in USA Today 12/17/97.
4. PCAST: President's Committee Of Advisors On Science And Technology. [<http://www2.whitehouse.gov/WH/EOP/OSTP/NSTC/PCAST/k-12ed.html>]
5. Discussed in: Bruer, John T. Schools for Thought. MIT Press, 1993.
6. Educational Object Economy, or EOE is found at [<http://trp.research.apple.com/index.html>]
7. Malone, Thomas W., rant, Kenneth R., Turbak, Franklyn A, Brobst, Stephen A., and Cohen, Michael D. Intelligent Information-Sharing Systems. *Communications of the ACM* 30(5): 390-402 (1987).
8. Teachers Helping Teachers is at [<http://www.pacificnet.net/~mandel/>]
9. Peter W. Foltz, Susan T. Dumais: Personalized Information Delivery: An Analysis of Information Filtering Methods. *Communications of the ACM* 35(12): 51-60 (1992).
10. C. Stanfill, D. Waltz: Toward Memory-based Reasoning. *Communications of the ACM* 29: 1213-1228 (1986).
11. Deerwester, S., Dumais, S. T., Furnas, G. W., Landauer, T. K., & Harshman, R. Indexing by Latent Semantic Analysis. *Journal of the American Society for Information Science*, 41, 6, (1990), 391-407.
12. Frey, Peter W., and Slate, David J. 1991 Letter Recognition Using Holland-Style Adaptive Classifiers. Machine Learning. The Netherlands: Kluwer Publishers, 6:2 (March).
13. Serf is found at [<http://www.udel.edu/serf/>], Mallard at [<http://www.cen.uiuc.edu/Mallard/>]