Good Practice in Using the Internet and Information Technology in Teaching and Learning Science

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Information Technology has become an accepted tool for teaching and learning science. The modern science classroom includes Internet based computing providing visualizations and simulations, modeling, on-line probing and even connections to actual research institutions, scientists and web-based data. Changes are occurring rapidly at the research and development level as countries invest large sums of money into research and development projects. However, change at the implementation level is progressing slower than perhaps many of us are willing to accept. In this paper, I will look at issues of implementation as they present themselves to educational systems, schools, teachers and their students.

The Web-based Inquiry Science Environment (WISE: http://wise.berkeley.edu) project will be use to demonstrate what may be defined as good pedagogical practice in introducing IT into teacher education and science classrooms in the United States and Norway. The Norwegian version of WISE is called Viten: http://viten.no

What constitutes good science teaching?
Within the science education community there is consensus that science should be a part of what we define as general education. Scientific literacy is a term that has come into use to identify the reasons citizens should have a basic knowledge about what science is and how science works. The dimensions necessary for public understanding of science would include understanding some aspects of science content, understanding the scientific approach to inquiry and understanding science as a social process (5). In almost all countries science is included
as a main component of the curriculum together with mathematics and language, all of which form the basis of general education.

The arguments for including science in a basic education and thus creating a scientifically “literate” society include (1,8)

- The economic argument – preparation for work in areas of science and technology
- The utilitarian argument – being able to cope with science in daily life situations
- The democratic argument – preparation for participation in a democratic society, including decision making about controversial issues with a science dimension
- The cultural argument – that science is a part of our cultural heritage and therefore an important part of general knowledge

In most Western countries, there are demands and needs for all of the above mentioned points. Certainly in Europe where enrolments in the sciences are declining, we are concerned with recruiting enough youth into the sciences as an expertise. Educators seem to agree that countries can not start early enough in presenting motivating and engaging science programs in schools for all children such that an ample number of students will keep their options open for advanced studies in these areas. And certainly one cannot argue with the need for an educated society for participation in the democratic decision making process. Citizens will not only need to know some science, they will also need to know how science operates and where to access reliable information they can trust. The European Community has taken up the issues of scientific literacy in their statement on educational objectives from 2001:

As we are moving into a knowledge society, we will need to increase the general levels of scientific culture within society. Expertise in science and technology is increasingly called upon to contribute to public debate, decision making and legislation. The citizen needs to have a basic understanding of mathematics and science if they are to understand the issues and make informed – if not even technical – choices. (3)

**School science**

What are some of the reasons as to why school science seems to be in a state of decline with respect to recruitment and interest? Why are fewer students generally and girls especially, choosing to move away from science? Is the science curriculum the problem or could it be the delivery
by teachers and textbooks? Does our present youth culture find studies in science to be uninteresting and non-relevant?

The actual science curriculum delivered to students in most countries is dominated by what we would call the products of science (science content) where science is portrayed as being value-free, objective and indisputable. Students are delivered fragmented bits of facts, often not at all relevant to their personal experiences and interests. The “big ideas of science” are often lacking as students memorize the intricate facts of photosynthesis (sometimes in several different years), yet are often unable to make connections to the importance of primary production or even requirements for life on earth.

Teaching science is further troubled by being characterized as more difficult than other subjects in the curriculum; its contents not particularly appealing to young people today. As stated by Jonathan Osborne (7)

…to knowingly present science, not as it is but as it was is to mislead and misrepresent. Science teaching needs to shift away from its strong concentration on “what we know” into an understanding of “how we know”.

The Third International Mathematics and Science Study (TIMSS) report entitled, A Splintered Vision: An Investigation of US Science and Mathematics Education, reported that the science and math curriculum in the US was “a mile wide and an inch deep”(11). In the book, Characterizing Pedagogical Flow (10) the Norwegian science curriculum was characterized as being similar to that found in the US, with many topics covered in the course of a year and little time for depth. We believe this is the case in many Western countries, leading to a call for more in-depth coverage of fewer topics in the curriculum. “Less is More” could very well be an important slogan for science educators as they plan curriculum.

In a recent paper presented to the EU, Svein Sjøberg (9) presented a list of reasons for what might be described as disenchantment with science and technology, including:

- Outdated curriculum presenting science as irrelevant and historical
- Science as a difficult subject in the curriculum
- Lack of qualified teachers in science
- Anti-science trends often rejecting scientific rational
- Post-modern attacks on science
- Stereotypical images of scientists and engineers
• Disagreement among scientific specialists – a communication gap between scientists and the public
• Science as controlling, often lacking ethics and values
• Problems with the image of science vs. youth culture

In a response to many of the negative problems facing the teaching of science, we also find trends that try to improve the situation. As a community we agree that science is an important component of basic education and that every student should be exposed to its content and processes regardless of future career choices. Public understanding of Science (PUS) and scientific literacy (SL) issues help us understand the different needs of our students as they take their place in society. We have introduced curriculum measures that integrate science into social contexts (Science Technology and Society; Science in Society) where wider perspectives are presented rather than factual bits and pieces of knowledge. Such science is often characterized by uncertainty and disagreement, thus introducing students into the actual processes of how science works as an academic and research discipline. We are concerned that social and ethical issues need to be a part of the science curriculum and have introduced ideas of teaching through controversy where students participate in authentic science, thus introducing them to the role of science in a democratic society. We want students to understand how science operates and have introduced curriculum connected to the Nature of Science (NOS). Finally, as is the topic of this paper, we are concerned about how Information, Communication Technologies (ICT) will become an integral part of the way science is presented.

**ICT in science teaching**

When we integrate the use of ICT into the science classroom, we are introducing possibilities that never before existed in how to teach and learn science. Through the use of the Internet, we are able to provide authentic data for students allowing them the possibility to make connections between basic knowledge and applications of that information. We are able to create simulations and animations, able to present scientific concepts in new dimensions making what often are difficult ideas in science more accessible to students. ICT allows us to help students access, evaluate and make use of information that connects science to society and decision making processes. Without question, the use of ICT in science teaching means that students are allowed to explore and ask questions about science rather than be passive recipients of information.
The following is an attempt to categorize the advantages we gain through the use of ICT in science teaching.

1. **Scientific literacy is connected to computer literacy**
   The knowledge base for life long learning is quickly becoming the Internet. If we are interested in providing citizens with the science they need to participate in a democratic society, we are obliged to also help students navigate this huge data base of information. Knowing where to look for information and who to believe is perhaps more important now then ever before since there is no control over information flow. Science teachers and curriculum need to address the issues of the nature of science so that students understand how science works, whom they will choose to believe, and where they will look for reliable information on issues. By connecting scientific literacy to computer literacy, we empower students with the tools necessary to engage in life long learning for responsible decision making.

2. **ICT provides new teaching possibilities**
   As a curriculum developer using ICT, this topic is perhaps the most exciting to reflect upon. ICT is certainly not the only way to teach science since we will continue to observe real phenomena in nature, read books and conduct experiments. ICT does, however, enhance the way we teach science by providing new possibilities for teaching difficult concepts and ideas. Complex systems may now be simulated, experiments involving expensive equipment may be animated, controversial topics may be discussed with experts and people outside the immediate classroom and information may be found linking school science to authentic science research. As new technologies become available, science educators need to be aware of the possibilities they afford for enhancing science teaching and learning.

3. **Science is connected to the real world**
   By including ICT in the science curriculum we are able to connect the history of science (things we “know”) together with actual Internet connections where scientific research is being conducted. These connections may include large research institutions such as NASA, CERN, CDC, etc; they may include sites where science and politics are integrated on a global scale such as The World Health Organization or the United Nations; they may include local and national research institutions. There is no longer a need to talk about outdated textbooks when ICT is available to keep science teaching and learning up-to-date. Our challenges are to help students access reliable resources, help them with
making sense of information and to understand the difference between science and anti-science.

4. Students today are comfortable with ICT
I always enjoy presenting this point since I believe it is so relevant to our work in schools today. As more and more homes and schools are equipped with computers and Internet connections, students are growing up in a world where information is always there and accessible. Educators and curriculum developers cannot neglect the youth culture since this will mean further separation between school science and the real world. I truly believe that we are able to keep abreast of new technological developments and at the same time present science in a pedagogically sound fashion.

5. The changing role of the teacher
Strange to include this topic on the list of advantages for using ICT in science teaching? Perhaps in the short run, since teachers seem to be lagging behind their students in ICT skills and applications. In the long run, however, I believe teachers will begin to appreciate their new role in teaching science when they include ICT. The teacher will become the hub of many divergent activities going on within a science classroom where students are asking questions not necessarily directed towards the teacher. Teachers will be present to help students understand scientific concepts through discussion and presentation. They will also be there to help students engage in questions that do not necessarily have “correct” answers.

Using ICT in the science classroom – WISE/Viten as an example
The WISE/Viten learning environment, curriculum and assessments are all designed according to the *Scaffolded Knowledge Integration* (SKI) framework (6). This framework has been continuously refined through years of classroom trials, comparing different versions of technology tools, different approaches to guidance, and different designs for curriculum. The WISE/Viten learning environment is developed to scaffold students as they work with inquiry based science projects. By encouraging learners to connect new ideas and perspectives to their existing ideas about the scientific phenomenon under investigation, the framework promotes cohesive understanding. Students compare, contrast, critique, sort out, and reconceptualize their scientific ideas, incorporating new information, evaluating alternative accounts, and connecting everyday and scientific ideas. Our goal is to help students become
lifelong learners of science, critiques of information, and collaborators in argument.

The SKI-framework includes four major principles that guide the design of successful inquiry activities and technologies. **First, make science accessible:** Inquiry curriculum requires an appropriate level of analysis for the scientific content so that students can restructure, rethink, compare, critique, and develop more cohesive ideas. **Second, make thinking visible:** Inquiry curriculum should challenge students to articulate what they know and mean about scientific topics so that they are able to restructure their thinking when new ideas are presented. **Third, help students learn from each other:** Inquiry curriculum should include opportunities for collaboration, discussion and debate, enabling students to articulate their own ideas for their peers, as well as to receive and exchange feedback. **Fourth, help students develop autonomous learning skills.** To help students become autonomous science learners, inquiry curriculum can enable the development of lifelong learning skills such as critiquing evidence, debating arguments, or designing solutions to relevant problems.

All WISE/Viten activities, both developed and those currently under development, support the ideas for knowledge integration in the science curriculum. Students are asked to connect diverse sources of evidence to their own ideas through personally relevant activities. The WISE/Viten software, curriculum and teacher support tools compliment the teaching of science while also making extensive use of the Internet. The goals for the WISE/Viten project include:

- **Bridging disciplines and connecting to local resources.** The activities are designed to allow students to explore relevant issues in science (global ecology, space exploration, disease/cures, etc.) while connecting these themes to local issues and personal relevance.
- **Assessing student progress.** WISE/Viten activities are designed simultaneously with assessment activities. The WISE/Viten technology administers pre- and post tests to monitor student progress and to help teachers identify student ideas.
- **Developing lifelong learning skills.** Science instruction should prepare students to continue to refine their ideas about relevant topics in science that are of global as well as local concern to citizens. Students learn skills such as critiquing information, supporting arguments, informing
designs and collaborating. The WISE/Viten software is designed with prompts that encourage student reflection and integration of ideas.

- **Incorporating constantly improving technology resources.** Science curriculum should always be improving the uses of innovative technologies, including use of the Web as a resource. Students are placed in contact with scientists, research groups and on-line communities for information.

Typical projects engage pairs of students in designing solutions to problems (e.g., building a desert house that is warm at night and cool during the day), debating contemporary science controversies (e.g., should we have wolves in Norway?), or critiquing scientific claims found in web sites (e.g., vaccine or pesticide research best for Malaria control?) WISE/Viten curriculum projects do not replace existing practices in science teaching; rather, they enhance them by providing a new means of presenting science. WISE/Viten projects are often used at the end of topics, where teachers are looking for a “capstone” project able to connect science to contemporary issues in society.

Figure 1 displays the WISE interface where students navigate through activity steps in the left-hand frame of their Web browser, called the "Inquiry Map." Each step in the project can result in the display of Web pages (e.g., to be used in support of student designs or debates), in the appearance of the WISE notes window, an online discussion, or any one of numerous inquiry tools (e.g., Java applets for data visualization, Flash simulations, and causal maps). As pairs of students work through the sequence of activities that comprise the project, the teacher circulates within the classroom, interacting with one small group of students at a time, helping them interpret Web materials, reflect on the topic and interact with their peers. All of these materials may be seen, and activities explored at the project Web site: [http://wise.berkeley.edu](http://wise.berkeley.edu) or at the Norwegian site: [http://viten.no](http://viten.no)
Figure 1: Example of a WISE screen page and the WISE note taking tool
Figure 2: Example of a Viten page – Interactive page on life cycle of malaria mosquito where objects are moved (flyttbare objekter) with the cursor into the life cycle ring. Clicking on “fasit” provides a correct answer.

The WISE/Viten servers deliver interactive Web pages and curriculum materials to schools, as well as manage and store students’ project and assessment work. WISE/Viten include a number of student software tools, including a note-taking tool, on-line assessment, a Web-based discussion tool, concept mapping and argument building tools, search pages, student/teacher generated quizzes and web-based newspapers. Additionally, external tools and pages from the Internet are easily made to function within the software. Whereas the WISE server is located in Berkeley, California, the Viten server is located in Norway where the software development has taken a slightly different orientation. Both WISE and Viten projects have free access and are available to all teachers and schools with Internet connections.

Curriculum development design issues – promoting ICT and science
In the creation of Web-based curriculum we are working across academic boundaries as Science, Pedagogy and Technology together create an intricate “web” of interaction. It is not enough to have sound pedagogical ideas about how and what to teach in science or to make intelligent electronic delivery systems for the collection and distribution of
information. Web based curriculum development involves teams of people with expertise in areas integrating technology with subject content; pedagogy with electronic delivery systems; classroom research with ICT in schools.

Our research and design activities are based on a continuous improvement model combining development of materials with classroom evaluation. All curriculum projects are developed in teams consisting of teachers, science educators, IT technicians and experts from the academic discipline. Once themes have been constructed using the WISE/Viten software toolbox, they are sent to trials in the classroom where we participate as classroom researchers. In order to understand the challenges faced by teachers and their students while implementing WISE/Viten projects, we must take into account the realities of everyday life in science classrooms and school systems. We include pre- and post testing as we are looking for conceptual growth. We videotape groups of students working so that we can better understand the role of social discourse in learning concepts. We collect data from responses collected in the software program and analyze them for content demonstrating conceptual growth. We interview students before and after their introduction to our projects, trying to understand their views on the use of ICT and their knowledge about actual science topics in contextual settings.

By working in actual classroom settings with teachers and their students, we are able to see first hand how curriculum materials are or are not successfully implemented into the existing science curriculum. In 1998, the WISE project moved into Norway to begin translation and implementation studies. We have developed a “sister” software platform called Viten where we now provide 3 science units to teachers in grades 8-14 (Wolves in Norway, Cycles of Malaria and Radioactivity) and have 3 more on the way (Geology, Plants, Sinus and Nature of Science). Classroom science teachers and their students have provided valuable input into the further development of Viten projects.

What are teachers telling us?
It is without question our greatest challenge to convince teachers to use web-based materials in their teaching. Norway has one of the largest concentrations of ICT/Internet home users in the western world. Norway is also well equipped with on-line computers at the junior and senior secondary levels. The disparity occurs in relation to the use of computers and the Internet between students and their teachers. Modern youth are
growing up in a world where chatting and homework are done on the computer, whereas teachers are slowly entering this world and forever feeling left behind.

We know the situation in Norway is not unlike what is happening in other countries. We take these considerations seriously when developing Viten projects because the reality of schooling is that teachers decide what will actually go on in their classrooms. Classroom teachers have informed us that if the titles to our projects do not correspond with the wording in our national curriculum, they may not consider them as important. If we are unable to develop user-friendly materials for teachers, we will never succeed in reaching their students no matter how exciting our materials prove to be. Furthermore, if our materials are not “better” or “different” than the teaching materials currently used by teachers, they will never use the extra time and energy to implement ICT into their teaching regardless of what national curriculum statements recommend.

So we listen to teachers and we try to learn from them. In an earlier paper (4) we reported on a study that followed 3 teachers (two from the US and one from Norway) as they implemented WISE/Viten projects over a period of two years. In the following section we share information from the Cycles of Malaria project implemented in both the United States and Norway over a two year period.

The Cycles of Malaria project

In the Cycles of Malaria project, students debate three different approaches for controlling Malaria worldwide: (a) developing of an effective pesticide that targets the anopheles mosquito, (b) developing a vaccine against this disease, and (c) creating social programs that reduce exposure to mosquitoes (e.g., through distribution of bed nets or community clean-ups). Students explore evidence relating to each control method, and debate alternative approaches. The curriculum provides three main activity areas:

1. Malaria: A Global Problem – students are introduced to Malaria as a global problem with an emphasis on where this is a problem in the world.
2. The Cycle of the Disease – students begin working with the complicated life cycle of the malaria organism, including the life cycle of mosquitoes. Control measures are introduced, locally and globally.
3. Where do we break the cycle? – students work through activities which demonstrate three different approaches to control of Malaria: social measures to control the spread of mosquitoes, development of a vaccine against the malaria organism and development of pesticides.

The project includes animations and video of the mosquito and parasite lifecycles, as well as maps showing the worldwide incidence of Malaria. To make the debate accessible to students, we included the story of Kofi, an African child suffering from malaria. The project promotes lifelong learning by encouraging students to compare scientific viewpoints, evaluate conflicting recommendations, and reflect on personal travel decisions. To learn from others, students discuss their ideas with peers and engage in class debates. The Norwegian version of the curriculum sets the project into a case where students are biologists making recommendations to the World Health Organization (WHO) on how money should be spent to combat this disease. Students look at the economical and ethical arguments for why vaccine development, for example, should be a concern for all countries, even those where malaria is not a problem.

WISE/Viten projects require teachers to foster personal interactions with students as they work in pairs or small groups, supporting autonomous investigations while making complex decisions about allocation of instructional time. Teachers must set up a WISE/Viten project, help students register for WISE/Viten and manage their passwords and user accounts. This includes motivating the inquiry topic, as well as explaining the WISE/Viten interface and promoting success with the learning environment. While we have observed a wide range of approaches from teachers who use WISE/Viten the first time, most are preoccupied with implementing the technology and simply surviving the day. The opportunities offered by WISE/Viten for interacting with students concerning their ideas about science are often lost amidst the flurry of new challenges in simply getting WISE/Viten to run successfully with their class.

Perhaps the most important challenge concerns the adjustments teachers must make in order for the inquiry project to fit well within an existing course. The teachers who have had the best success with WISE/Viten have made substantial changes to their course content immediately preceding and immediately following the actual project run. Preliminary activities help students develop important ideas that they will draw upon
in the course of the WISE/Viten inquiry unit. Follow up discussions or activities help students make connections between the WISE/Viten project and corresponding science curriculum.

In this study we followed two teachers in the US (Sandra and Gilbert) and one teacher in Norway (Marit) as they taught the *Cycles of Malaria* project first in year one, then in year two. The differences in the educational systems between the US and Norway also provided us with valuable information on the possibilities of customizing projects effectively. We contrasted teaching strategies of the three teachers as they integrated the WISE/Viten project into the curriculum, looking for differences in teaching styles. We measured student performance in WISE/Viten by analyzing pre and post test gains as well as looking at embedded assessments in the form of note taking. Finally, teachers were interviewed after implementation each year.

**Results**

In the first year run of *Cycles of Malaria* we started to see the emergence of different teaching styles when using WISE/VITEN materials. Sandra had a pattern of engaging deeply with individual students for several minutes at a time, while Gilbert and Marit showed a different pattern of cycling through the classroom, stopping at each group to see if they were progressing. Whereas all of the three teachers seemed to be letting the technology run their classes, Marit and Gilbert relied more on the technology to lead the way. When interviewed, all of the teachers expressed concern about being unfamiliar with the new curriculum materials and methods and did not completely understand how the net-based program would work with their current science classroom practice.

All of the three teachers commented that the project did not fit well into their planned curriculum, thus having problems making connections to other planned topics. Marit also commented that had she known more about the intentions of the project, and had she had more time for preparation, she would have included important parts of the syllabus in her teaching before presenting the Malaria unit.

Despite these observations, the students in all three classes were successful with using and learning from WISE/Viten. Across classes students made clear gains on the WISE/Viten pre-post items designed to test a deep understanding of the science principles, rather than factual recall.
Year two of *Cycles of Malaria - Marit as a case example*

In the second run of the curriculum unit, we started to notice differences in how teachers were preparing their students. Marit planned the Malaria unit as a part of her year-long syllabus, including chapters on microorganisms and disease and sickness before using *Cycles of Malaria* as a capstone project to integrate information. She made assumptions that her students knew this information and could refer to these chapters as the unit was being taught and in discussions about malaria. Marit customized the unit by including homework assignments, having students write and draw in their workbooks, and provided time for continuous classroom discussions. She was more careful to ask students to support the answers they provided on their notes, and was more successful in talking to groups of students about their progression throughout the unit by looking with them at their completed on-line work. She completed the malaria unit by having groups of students compose a song, based on some aspect of the unit.

Marit was able to customize the malaria unit to fit into her pedagogical style of teaching as well as into her content goals for her science syllabus. She commented that she was much more comfortable teaching the unit the second time and expressed a sense of ownership in materials as compared to the first year when she was both anxious and skeptical to using this new form in her science teaching. When asked about using WISE/Viten, Marit’s students commented that they wanted more WISE/Viten projects, thus supporting Marit’s observation that this is a positive way to introduce variation in teaching science.

Pre- and post test scores on open ended questions were evaluated using a coding system of 0-3 for responses. All classes show gains as they complete the project. A closer look at the quality of the responses has given us clues to understanding how individual teachers have adapted the curriculum to their own teaching sequences, resulting in more meaningful ways of using the malaria curriculum. As teachers feel more ownership with the projects, they expect more of their students and are able to influence how students participate with the curriculum materials. Improved quality of note taking within the curriculum unit has led to improved quality of open-ended responses on test items.
Figure 3: Pre- and post test learning gains

Student comments
It was not unexpected that student logs would reflect positive attitudes about using ICT in science teaching. Our experience is that students like most things connected to computers and with variation in teaching methods. A common comment in the student logs was “give us more WISE/Viten”. The positive comments we found most often included using computers in science and learning more about malaria and disease. On the negative side, we have learned that students at this age do not like reading lots of text on the computer. Particularly, in Norway, students thought they were asked to read too many difficult English links (for example to CDC). We take these comments very seriously in our revisions as we explore better ways to deliver information within the WISE/Viten platform.

Our continuing research concentrates on refining ICT based science curriculum as we continually experiment with new technologies. We are also taking a critical look at the oral and written discourse between student pairs as they work through the projects in Viten. Similar development and research continues with the WISE project at the University of California, Berkeley. We are fortunate to share our findings and developments from an international perspective, with the WISE and Viten projects working so closely together.

Connecting Viten and museums
As part of our continuing efforts to develop applications for using WISE/Viten in schools, we have begun working with museums in the US and Norway. Museums have a need to develop curriculum materials for schools, thus providing links between school frameworks and the contents of the museum. The Internet seems to be the perfect medium for
these projects in that “Virtual Museums” provide access to materials that otherwise are only available for the visitor.

Our first Norwegian project is connected to the Geological museum at the University of Oslo (http://www.nhm.uio.no/palmus/). Web-based curriculum development will follow the model developed by Frøyland and Jorde (3) where museums work with schools to develop interactive units on themes to be used before and after the museum visit. Since the Geological museum is already a prize winning “virtual museum”, our task will be to provide a pedagogical framework for curriculum development using Viten. We are also interested in the added value such development will have for students throughout Norway, who will not be able to visit the Geological museum in person.

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