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AUTHOR Podany, Zita
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ABSTRACT

This report discusses how computers are being used in high school science classrooms. For this report, four high school science teachers were interviewed. The approach to science instruction described in these four interviews deals with the areas of scientific and technological literacy, making science learning fun and attractive, and stimulating the use of higher-order thinking skills. All are involved in the use of computers to enhance science instruction through activities based on microcomputer-based laboratories (MBL). The four subjects are participants in one of two projects dedicated to such computer application, LabNet and StarNet. Both LabNet and StarNet, projects of the Technical Education Research Centers (TERC), and MBLs are described. The characteristics common to all four of the interviewed teachers are discussed. The advantages and disadvantages of taking this approach are presented. (KR)

THE Northwest Regional Educational Laboratory
TECHNOLOGY PROGRAM

IDEAS FOR INTEGRATING THE MICROCOMPUTER WITH HIGH SCHOOL SCIENCE

Zita Podany

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Northwest Regional Educational Laboratory
101 S.W. Main, Suite 500
Portland, Oregon 97204

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INTRODUCTION

Tell me, I forget.
Show me, I remember.
Involve me, I understand.

- Chinese proverb

How are computers being used in schools, more specifically, in high school science classes? Although it is no longer uncommon to see computers being used for word processing, spreadsheet, database, and graphics applications, computers in the science room have taken a backseat to other curriculum uses, although they were initially associated with science and computer programming only. Even though the term telecommunications has been discussed a lot lately, it also is not being used to the full extent that it was once predicted. Reasons for this seeming underutilization range from lack of interest on the teacher's part to not having dedicated phone lines in rooms of interested teachers.

The above quote best captures the theme of this report. Traditional teaching methods generally involve the "tell me" and "show me" modes, with little emphasis being placed on the hands-on approach as a valid learning device. In most instances, the curricular structure doesn't allow for more; equipment may be too costly or some experiments may involve too much time in preparing students with the necessary skills needed for data gathering and analysis. Some of the more research-type experiments are bypassed because access to various tools is not possible, tools that would assist the students with the more cumbersome and time-consuming aspects of an experiment. Computers in the science classroom are a natural ingredient; they address the "involve me" mode of learning. What better way to become involved in the scientific process than to collect and analyze data with a machine capable of such tasks, leaving the user free to investigate further curious scientific phenomena. Although we might consider science and computers an ideal combination, the reality is that they are being underutilized in the school science curriculum, and their full potential has not yet been realized.

For this report, four high school science teachers were interviewed. All are involved in the use of computers to enhance science instruction through activities based on microcomputer-based labs (MBL). The four are participants in one of two new projects dedicated to such computer application, LabNet and StarNet. While there are other software examples and other users, these are examples of the approach.

LabNet is a project of the Technical Education Research Centers (TERC) in Cambridge, Massachusetts, sponsored by the National Science Foundation. The computer is used to supplement the physics curriculum through the use of word processing, database, and spreadsheet applications and various hardware sensors all within a project approach to instruction. Electronic mail is used to connect participating teachers with TERC, with each other, and with practicing scientists from universities or corporations.

The StarNet project, also at TERC, is supported by Federal Star Schools funds, and strives to incorporate technology in improving math and science curriculums. The computer, used to support hands-on investigations and telecommunications, is meant to provide support to the teacher during the course of the activities. Teachers are linked to other teachers doing similar projects via an electronic network. The Star Schools curriculum encompasses nine units: **Polls and Surveys**, an introduction to basic statistical tools and data analysis; **Connectany**, an exploration into iteration and mapping in a computer microworld, providing an intuitive foundation for fractals and chaos; **Triangle Chaos**, investigates iterating geometric transformations and analysis of resulting patterns; **Iterating Functions**, explores simple iterating functions, linear, logistic, quadratic, and sine; **Koetke's Challenge**, based on a dice game, encompasses probability, data analysis, logical thinking, game strategy, and general problem solving; **Design Project: Descent**; and **Design Project: Solar House** are two projects challenging students to develop different design problem-solving strategies; **Radon**, students are given tools and materials in order to conduct surveys of radon levels in the community; **Weather** is a unit investigating the governing forces behind weather phenomena; and **Trees**, students gather and share data about the trees in their community.

Microcomputer-based laboratories consist of sensory probes which are connected to a computer to facilitate measurement of various scientific phenomena such as temperature, pH, motion or sound. With some MBL packages, the software allows students to view data collection as real-time continuous graphs, or as large digital displays for whole-class viewing. Data can be looked at in a variety of ways from line graphs to pie charts and statistical analyses can be performed on collected data. However, the availability of the latter options will depend upon which software is used. The philosophy behind MBLs is to assist students in acquiring critical science skills in an environment closely resembling real life: designing an experiment, observing phenomena, collecting and analyzing data, predicting outcomes, and forming conclusions. In a short period of time students can collect and analyze vast amounts of data and, if necessary, carry out further investigations related to the observed phenomena.

Interview with Rick Sorensen

Rick Sorensen is a physics and chemistry teacher at Sherwood High School, Sherwood Oregon. His chemistry classes consist of sophomores, juniors, and seniors and physics classes are for juniors and seniors. Students must take chemistry prior to enrolling in physics.

Mr. Sorensen finds using the computer to aid science conceptualization is a vital aspect of the learning and teaching process. Students are given a chance to conceptualize ideas in the initial stages of learning scientific principles and then to formulate them into abstract mathematical models.

He feels there is room in the curriculum for using computers as a tool in the same manner that scientists might utilize a computer. Also, in using computers in the classroom, students are better prepared for a society that relies heavily upon this technology. Although the argument that computers are needed to better prepare our youth to compete in tomorrow's market may not be convincing to a lot of people, we should consider the added benefits students reap from learning in a dynamic environment that allows them time to explore and form conceptual links, empowering them not as students of today but as learners of tomorrow.

Of course, the money issue cannot be avoided. Computers are expensive tools and personal science lab equipment is no exception. If money was in plentiful supply, he would equip the lab so that more computers would be available for student use.

Mr. Sorensen uses the *Personal Science Lab* by IBM, and a PC clone with a 20MB hard drive. He feels these tools are flexible and useful to him and his students. Class demonstrations are presented with an overhead projection panel. In demonstrating the use of temperature probes in gathering data, he will measure the temperature of the room or body--for example, he might bring the probe up to his nose and the class can watch the temperature readings rise. After enough data is collected, temperature changes can be graphed. These types of demonstrations allow asking of questions and pursue abstract thoughts which normally would have taken a lot of time without the computer. He feels students are better able to grasp the key concepts when using computer-based science tools.

Besides using IBM experiments, he is planning to create his own experiments. He has designed activities using Microsoft Works spreadsheets. With spreadsheet activities, students collect raw data, get a chance to examine and manipulate it, and data files can be exported. Students can graph their data to get a visual feel for what's going on. For example, in using an ultrasonic ranger in experiments requiring distance measurements, graphs of distance vs. time aids students with concepts of speed, velocity, and acceleration, especially acceleration. Where students might be able to move at a constant velocity, moving at a constant acceleration is difficult not only to implement, but also to conceptualize.

Pursuing the idea of using spreadsheets, he has designed several activities. In one activity, students use a pull-back car with paper tape attached to it. As the students pull back the two-speed racer and let go, the tape which is attached to the back of the car, passes through a timer, making a mark on the paper. Students analyze the markings on the tape and input the information into a prepared spreadsheet. In one column they input the change in distance, another column is for change in time and another column calculates the average speed. Based on this information, students can plot the results as distance vs. time, and speed (cms) vs. time graphs. Because spreadsheets are versatile and multifunctional, he feels they are a valuable learning tool. He would also like to exchange ideas/activities with other science teachers who are using spreadsheets in their lessons. He has noticed that students tend to grasp the concepts of speed, velocity, and acceleration as a function of time more quickly than when they had to do it mathematically. Once students have a fair idea of what those concepts mean, the mathematical formulations make more sense. In asking students questions related to graphs and what they mean, they are required to apply what they know, rather than regurgitate a memorized formula. Before using computers, students would have had to learn these concepts mathematically by solving story problems. This latter approach places the focus not on the scientific processes, but rather on numerical manipulations. Needless to say, some students would get bogged down with mathematical formulas and miss the point of the experiment--they might never spot relationships that would help them understand how the formulas were derived.

Students work in teams of four. Most of the students already have had computer classes. He usually starts with spreadsheet activities before introducing PSL-based experiments, and has been using this order for the past year.

In using the overhead projector for demonstrations, he can ask thought-provoking questions giving students a chance to predict the answers and later to verify the results.

Mr. Sorensen was involved with LabNet, a teacher-to-teacher telecommunications project using hands-on activities to provide students with a sense of doing science as scientists do. This year he hasn't had much time for the projects through TERC in Boston. He feels the form they use is too time-consuming and telecommunication charges add up very quickly. Instead he is exploring other telecommunication networks for lesson ideas and activities sharing. For example: Learning Initiative International, a PC-Users group for educators, and People-Sharing Info Network which will have a host computer at Catlin Gabel School, Portland, Oregon. Lowell Herr (interviewed later) has been trying to get this latter bulletin board going for the purpose of sharing ideas and lessons between science teachers.

Interview with Chuck Heil

Chuck Heil is a physics teacher at Tigard High School in Tigard, Oregon. Students in his classes vary from the sophomore to senior levels. He has been using TERC units for three years. Currently he is using the Weather Unit with his students. Last year he did Radon, an activity that moved into unexpected avenues due to equipment reading errors.

His classroom contains four Apple IIe computers, two Apple GS machines with a half megabyte of memory and no hard drive, and three ImageWriters. Typically, students work in groups with about four students per group. Depending on the activity, students will use various software applications to help them reinforce concepts under investigation. Students can use AppleWorks to type up their lab reports and graphing utilities to help them analyze their data. Computer skills tend to vary, but most students have had some computer experience prior to the science experience.

Throughout the year students engage in various activities to hone their data acquisition and analysis skills. The activities are designed to help students make connections regarding how variables relate to one another. By using graphical analysis programs, they can analyze trends and derive linear equations based on their data.

Mr. Heil tries to teach concepts, not the book. As a result, his teaching approach leans toward guided discovery. He realizes this is not always an easy process for students so he tries to model the reasoning process as much as possible. To emphasize the importance of focusing on the problem, he provides students with a worksheet divided into six quadrants. In one of the quadrants students are asked to state the problem. Each successive quadrant requires the student to focus on a particular aspect of the discovery process leading to the final quadrant where the student finally writes the solution to the problem. He devised this worksheet to challenge students to ask questions--a necessary skill for meaningful learning experiences.

Even though there have been times when he has been disappointed with the LabNet and Star Schools Projects, he feels the TERC approach is still a good idea, especially once they become attuned to the demands and dynamics of the classroom--a sentiment echoed by the other teachers who participated in the projects. At times it is hard to determine whether the problems that arise are software or hardware related. Although significant changes and improvements have been made over the three years he has been with the project, glitches still occur. There are software and hardware limitations that need to be taken into account--for example, the thermoprobe ranges are limited. Also, there isn't always enough lead time provided by TERC prior to implementing lessons. Some of the teachers have found it necessary to adapt and modify the experiments to fit their needs, a case of knowing what they wanted, and what they reasonably could do.

In introducing the units to students, Mr. Heil separates the content into very small activities, allowing time for students to become acquainted with all the equipment to be used in the experiment, doing introductory activities included with the unit, stressing the importance of careful observation, measuring quantities, and gathering and recording data. A class profile summarizing the results will be written by the students. When they are ready to go on-line, groups of two to three students write a part of the profile for which they are responsible. The profile, composed with a word processing application, can be printed out for grading purposes.

He sees benefits in using computers as a tool to enable the learning process. To some extent, students are forced to articulate the problems to themselves in order to derive meaningful solutions and to communicate their results to others. In some essence, the experiment is no longer an academic exercise but rather a steppingstone to the real world of research. It allows teachers a chance to present research-type activities to which students don't already know the answers. This approach provides students with a different perspective toward science, one that readily admits scientists don't always know the answers ahead of time, but must seek them.

Reflecting upon his role as a teacher, he sees himself as a director of research and development, guiding students through their discoveries, encouraging them to make educated guesses as part of the scientific process. It takes time for students to put seemingly unrelated concepts together. Since learners acquire and apply their knowledge at different rates, discovery needs to be personally achieved by each individual. It is in an environment like this, where structure is provided to assist students rather than thwart their thinking processes, that new ideas/methods of teaching can grow to fruition.

Have some of the problems he's faced on-line extinguished his desire to keep on trying telecommunications projects? Far from it. After all, one never gives up on good ideas, but to get around the obstacles. In one activity with TERC, Lego Logo, students used electronic mail to talk about Logo projects using legos to build things such as robots, however, the project lacked cohesiveness in that activities were only discussed without real implementation. In the future, he would like to try an on-line spacecraft project, where one side would transmit design code information to operate the device--akin to what NASA does--and the other side would actually implement the plan. In this context, the network would mimic the space probe. A project like this would entail some programming and more hardware but it would provide students an opportunity to experience science at a more realistic level--of using the computer in much the same way as scientists do.

His advice to anyone interested in the idea of using computers as a learning tool to enhance concept development is to stick with it through thick and thin, tailor activities to most immediate needs, allow students a chance to make discoveries on their own, realize the process of implementing new tools is dynamic and everchanging, results may not go according to plan, and when things do go awry, go with the flow and do what you can with what you have. He readily admits commitment and vision play a major role in making the whole process meaningful.

Interview with Dennis Holm

Dennis Holm, a science teacher at Grant High School, Portland, Oregon, teaches chemistry and physics to sophomores, juniors, and seniors. This year, he and two other teachers have combined their efforts in designing and team-teaching an interdisciplinary course called "Introduction to Research," which is geared toward selected incoming freshmen.

Mr. Holm has participated with the Star Schools Projects for three years, conducting the Weather, Radon, and Connectany units. This year he is preparing the students for the Trees Unit. The difficulties he and others have experienced with the projects was in making them fit into the existing curricular structure. Now that he is team-teaching a research-oriented class with a math and a history instructor, the curricular structure is wide open for flexible use of Star Schools or other projects.

The student reaction to telecommunications has thus far been very positive. Some are amazed that communication with the East coast is possible with a computer. They are curious about other schools and what the cities are like. Last year they communicated with an American school in Italy. There was an immediate interest in the other school, what the students were like, and what was happening at the other end.

Although there are no computers (other than the teacher's Macintosh) in the science classroom, they do have at their disposal sixteen Apple IIes in a computer lab. Generally, students work in groups of two. Computer literacy among the students vary from being very proficient in using a computer to those who are learning to type. Typically, some time is spent teaching students to use AppleWorks so they are all be competent in engaging in computer-related projects.

Mr. Holm's opinion which is echoed by the other teachers, is that computer-based projects provide students an opportunity to engage in "real-life" research projects where the answer isn't always known and allowing students to reason out the results. Students gain practice in gathering and analyzing data and in summarizing their results. These are all vital skills in scientific research and the one factor in all of this that facilitates this type of skill acquisition is the computer. Students get a feeling for what science is really like and an appreciation of the computer's role as a valuable tool in research. With the computer assisting in data analysis, students can concentrate on the experiment itself and what it means, what results can be predicted and then compare it to actual results. Patterns are easier to spot and students can try "what-if" conjectures with greater ease when doing computer-based projects.

The "Introduction to Research" class for selected freshmen students was inspired by the Institute of Science and Math. Students would be required to take certain courses and the focus would be on innovative teaching methods. With that idea in mind, a group of teachers started developing the "Introduction to Research" class. Students had to fill out an application in order to enroll in the class. The response was immense and some students had to be turned down due to class size limitations.

The class consists of three components: History, Math, and Science. In the history component, students focus on the dynamics involved in doing research and writing research papers. Cooperative learning, and group-related activities are a major part of the math component. For example, in math, each student group is designing a park. Careful planning is involved in strategically placing trees, swings, tennis courts, and other park-related facilities. An activity such as this one is not as easy as it sounds for it entails the student gathering information and then synthesizing what has been learned into a reasonable design that is aesthetically pleasing, functional, and safe.

In the Science component, Mr. Holm will be doing the Trees Unit. Grant High School is fortunate to be next to a park--Grant Park. This fortunate circumstance provides a ripe learning experience for the students. The park contains many tree varieties posing great classification challenges. Each group will collect information on the trees in their location and input the information into a database file. Afterwards, the database files will be merged to form one large class database. Students will need the gathered data in order to set up a spreadsheet to calculate the height of the trees. With the flexible structure of the class, he can easily invite guest speakers to discuss content-related material. For this unit, a Mt. Hood forest ranger was invited to speak to the students about tree classification. Students benefit both directly and incidentally from these experiences, they gain a more rounded outlook on applied scientific processes and their real-world applications, and they are presented with real role models.

The new class structure provides great challenges not only to the students but also to the teachers involved in the project. Each teacher is assigned a home group of 32 students. Each week the groups rotate so all will have an equal chance of doing the same activities, meaning that each teacher will basically do the same activity for three weeks with different classes. Grading and student accountability provide another challenge because the activities don't fit neatly into a traditional grading structure.

Interview with Lowell Herr

Lowell Herr teaches physics (11th-12th graders) at Catlin Gabel High School in Portland, Oregon. He has been involved with LabNet projects for four to five years. Currently, students are engaged in a project measuring the length of a light bulb in terms of time. The computer controls the turning on and off of the bulbs at various intervals. Bulbs from different manufacturers, of assorted wattages and voltages are also being tested. He estimates that the project will last until March or April. A group in Colorado is experimenting with a light bulb being turned on and off underwater. They are investigating the question of whether cooling makes the bulb last longer.

Catlin Gabel students are very computer-literate with most of the students having access to computers and modems at home. Many of the students use BitNet to communicate with past Catlin Gabel graduates who are now in college.

Lowell Herr is very committed to enhancing the science curriculum so his students can obtain an optimal learning environment--one that provides meaningful science experiences with technological tools. A great deal of time and effort is invested in blending technologically new tools into his curriculum. This is not always an easy task with a limited number of available computers, learning and integrating new software applications, conducting workshops, and keeping up with the latest in technological and educational trends --a tall order for short days.

On top of everything else, he can be found on local, national, and international bulletin boards. Using BitNet, he can communicate with colleges and universities all over the country and overseas. He has even shared ideas with teachers in Israel and Samoa. Another computer network being explored is the K12.Net specifically geared toward K-12 professional educators who wish to share ideas and engage in short-term projects in various curricular areas. At this writing, K12.Net echoes reach as far as Hawaii and Australia. Locally, K12.Net can be found in the SciNet area on the HighTech Tools bulletin board. Bulletin boards are an ideal way for teachers from across the country to share their labs and lesson ideas. Files can be easily uploaded and downloaded at the user's convenience, and if hardware and software configurations are the same on both ends, files can be received in the same way they were sent, i.e., formatting is intact. Lowell is starting a bulletin board at Catlin Gabel which would feed off of the HighTech Tools board. His goal is for teachers to share their knowledge, expertise, and tried-and-true activities/lessons with each other.

Various software is used to complement classroom activities and investigations: MBL Microcomputer-based labs, graphical analysis programs, light gate type of software to drive smart pulleys and simulations exploring principles in physics, from Newtonian laws to Milikan oil drop experiments. Integrating technology into the curriculum can enhance learning by helping students overcome acquired misconceptions. In lab experiments related to thermal, electrical, potential, and kinetic energy, students can sometimes miss key reactions, but with thermistor probes aiding the experimental process, students aren't liable to miss maximum peaks; they can watch the result rise in real-time.

Students utilize computer applications to write their lab reports, including graphs, diagrams, and other graphics to explain their findings. Several Apple computers are available in the lab and occasionally an IBM or two can be borrowed; one Macintosh is available for desktop publishing and a PC-386 server will be used for telecommunications. The school acquired a mini-supercomputer last spring which is licensed to handle 1000 users. Besides the minicomputer, a VAX mainframe is available to students. Freshmen are required to write their papers using the resources on the mainframe and all students get their assignments from the VAX.

Mr. Herr has observed that students do benefit from the hands-on approach integrated with computer-based tools. They tend to get a better grasp of motion, distance, velocity, acceleration, and energy conservation. They can see changes on the computer screen as they are occurring enabling them to relate concrete experiences into abstract formulations. Working in groups forces students to work cooperatively with each other, which is definitely an added bonus.

As for future directions, Lowell Herr would like to see more teachers involved in sharing ideas and lessons on computer bulletin boards. Priorities need to be redefined in forming realistic equipment budgets and assessing their usable lifetimes. From a classroom management standpoint, more computers are needed so all students can be involved, greater space needs to be allocated to accommodate equipment, students, and experiments in progress. A technologically integrated curriculum is one that's not without its pains, but it is worth the investment. He hopes that Catlin Gable can become a model and support site for other teachers, schools, and communities who are interested in seeing what computers can do for them, how they can get started and where funding can be obtained.

Concluding Remarks

The characteristics that are common in all four of the interviewed teachers are: persistence, the ability to stick to a good idea even though hurdles tend to appear with great abundance in their paths, and the willingness to try new ideas and approaches to entice students into the world of learning even though skeptics and the curricular structure are unyielding. They dedicate a good portion of their time learning new software applications, hardware configurations and designing ways of using their ideas not only with their students, but also with their colleagues.They persist even though support from all fronts may be lagging, and in some instances, lacking. In several cases, they are the only ones using computers as lab tools in their school and even in their own department--interest generated in their own buildings is on the same order of a passing notion, as though with tolerance, the fad will run its course and die off.

Interviews with each teacher took place after school. The teachers were to reflect upon their experiences with using the computer to complement their science lessons. There is general agreement that time is the biggest enemy in their endeavor to provide meaningful learning experiences for their students. If hands-on activities complemented with computer-based tools are to ever stand a chance of succeeding, more support needs to be garnered from more teachers, administrators and the community.

We live in a time of an increasing rate of technological change. Society has a need for people who are both scientifically and technologically literate. The type of approach to science instruction described in these four interviews deals with both areas of knowledge, makes learning science fun and attractive, and stimulates the use of higher-order thinking skills. However, teachers taking this approach are in the minority. Several barriers have been noted: high cost of equipment and communications, the need for an intense level of teacher training, the need for planning time, the need for curriculum revision, and collegial and community support. Overcoming these barriers will require time, commitment, and financial support, but there is no more important area of the curriculum to address, and the benefits to society will be worth the effort.

PRODUCTS AND ORGANIZATIONS MENTIONED IN THIS REPORT

Personal Science Laboratory
IBM Educational Systems, Inc.
1133 Westchester Ave.
White Plains, NY 10601
800/IBM-2468

Microsoft Works (IBM)
Microsoft Corporation
16011 N.E. 36th Way
Box 97017
Redmond, WA 98073-9717
1-800/426-9400

Technical Education Research Centers
2067 Massachusetts Ave.
Cambridge, MA 02140
617/547-0430

NORTHWEST REGIONAL EDUCATIONAL LABORATORY

The Northwest Regional Educational Laboratory (NWREL) is an independent, nonprofit research and development institution established in 1966 to help others improve outcomes for children, youth, and adults by providing R&D assistance to schools and communities in providing equitable, high quality educational programs. NWREL provides assistance to education, government, community agencies business, and labor by:

- Developing and disseminating effective educational products and procedures
- Conducting research on educational needs and problems
- Providing technical assistance in educational problem solving
- Evaluating effectiveness of educational programs and projects
- Providing training in educational planning, management, evaluation, and instruction
- Serving as an information resource on effective educational programs and processes, including networking among educational agencies, institutions, and individuals in the region

Board of Directors

Northwest Regional Educational Laboratory
101 S.W. Main Street, Suite 500
Portland, Oregon 97204
(503) 275-9500
GTE: NWREL.LAB FAX: (503) 275-9489