ıce establishes irrefutable
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f the time, we answer
; though we were in a court
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ıdgment until the last tittle
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vard broad understandings
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ropositions.
at frustrates policy-mak-
of them, sadly, respond
runs around scientific re-
ısing selective data,
; conclusions, loading ques-
tions, or searching out dubious experts to say what they want to hear. The resulting shouting matches produce still more delay, as still another committee studies the problem.

lack
high

On many pressing issues, we don't need to change our committees. We need to change our metaphor. We need to stop looking at environmental issues as though they
rt cases. We need, instead,
of ourselves as homeowners
surance. You don't insure
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ect? We can't prove they're
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nce, and take basic steps to
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ve, as the Iowa corn withers
Sahara expands, make seri-
ges in our fossil-fuel use? Or
appoint another committee?

A Monday column

Fifth-grade students in Earleysville, Va., install rain collectors for an acid-rain experiment that used a computer linkup of 200 classrooms around the world.

Kids' science data network

By Simson L. Garfinkel
Special to The Christian Science Monitor

Cambridge, Mass.

MEASURING the acid in rain water is a classic elementary school science experiment. But this spring, when 4,000 fourth, fifth, and sixth graders in 200 schools around the world used an electronic mail network to exchange the results of their tests, students learned more than basic scientific facts.

"Kids all across the US, Canada, Mexico, Hong Kong, Argentina, and Israel collected rain," said John Miller, an acid-rain specialist at the National Oceanographic and Atmospheric Administration. They determined its acidity with special paper that changes color to indicate the pH level and sent their findings to a central data bank.

Dr. Miller analyzed the data and sent it to every school, with a brief report. Students then compared their findings with results from all over the world.

EDUCATION

"Not only did the kids here do the hands-on science," said Richard O'Grady, a fourth-grade teacher at the Riverview school in Wisconsin, "but the students could also see that science is a collective enterprise."

"The real plus of the program was being able to analyze other people's data and make comparisons with their own," Mr. O'Grady said. "The kids were real scientists. They discovered things."

Jamie, an 11-year-old student in Nebraska, agreed: "You can understand better when you have someone else's data along with your own," he said.

Students entered their observations into Apple computers that automatically telephoned the electronic mail network each night to send the observations and retrieve any summaries, said Robert F. Tinker, director of the Technology Center of the Technical Education Research Centers in Cambridge, Mass. The experiment began in February with the "hello module."

"The subject matter is very basic geography: It asks three questions – who are you, where are you, and what do you do?" Mr. Tinker said.

Answers to the questions were shared among all the classrooms to introduce the students to each other and teach them how to use the system. With the answers, the children built a data base and wrote reports based on actual data from all over the country.

In March, the students started the "acid module," which covered acidity, pH – a symbol for the degree of acidity or alkalinity, and acid rain. The module included three weeks of measuring the acidity of rain storms and distributing the findings to all the classrooms.

An important aspect of the Kids Network project was having Miller as a scientific adviser. Using the electronic network, Miller took a few minutes each day to comment on the students' findings and answer questions.

"Because it's all worked through the central data bank, the kids could send me letters. They had read in the Weekly Reader that the dinosaurs had died because of acid rain," Miller said. "I explained that it was one theory: that a meteor had struck the Earth, and acidity had gotten into the air and killed the plants, but that it was only a theory."

The network let students ask all kinds of questions: "One kid asked me if smoking cigarettes caused acid rain," Miller said.

The last three weeks of the course were spent on policy issues surrounding acid rain.

"The kids brought in a lot of articles they found in newspapers and magazines about Canadian and American differences, how our government wanted to do more research and the Canadian government wanted to act," O'Grady said.

Then there was a vote on whether the US government should continue to study the problem or take action.

"Overwhelmingly the kids wanted action taken to reduce acid rain," Miller said. "The only exception was in poorer areas where we think that the kids might be more sensitive to the job loss issues that might be involved."

Last year, during the pilot test of

Please see **SCIENCE** next page

OR 6

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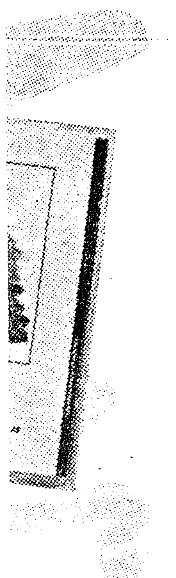

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familiar equations. As James Gleick describes it, "Chaos has become not just theory but also method, not just a canon of beliefs but also a way of doing science."

Gleick begins with the problem of weather prediction. For physicists who believe that all you need to do is provide a physicist with the initial conditions and an understood mechanism to completely define the future state of the system, weather predic-

...tage of not being subject to the uncertainties of a real physical system. Repeating an interesting section again, he noticed that the results of the second run differed markedly from the first run even though the initial conditions were almost the same. Soon he had constructed very simple systems that had the apparently conflicting properties of being deterministic (that is, exact equations described the behavior of the parts) and having results that were unpredictable. In a word the equations produced chaos.

Gleick describes the situation: "In science as in life, it is well known that a chain of events can have a point of crisis that could magnify small changes. But chaos meant that such points were everywhere. They were pervasive. In systems like weather, sensitive dependence on initial conditions was an inescapable consequence of the way small scales intertwined with large.

"His colleagues were astonished that Lorentz had mimicked both aperiodicity and sensitive dependence on initial conditions in his toy version of the weather; 12 equations calculated over and over again with ruthless mechanical efficiency. How could such richness, such unpredictability – such chaos – arise from a simple deterministic system?"

On still another level, Gleick explains a beautiful and universal theory, without resorting to the language and equations of the mathematician and specialist. Through simple examples in a variety of fields, the nature of this new science emerges. The philosophical and physical impact of this "new science" of chaos is likely to affect humans in deep and profound ways.

Although the details may escape us in fields other than our own, "Chaos" is an important book for today's thinkers. It may even set your own work on new directions, dusting off those problems that before were unapproachable. Readers of this book may find themselves joining ecologist William Schaffner, who to quote Gleick, "could not work in the old way any more."

Paul A. Robinson Jr. is a staff scientist at the Jet Propulsion Laboratory in Pasadena, Calif.

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the project with 31 schools across theUnited States and Canada, Miller discovered a systematic shift between rain acidity measured by the elementary schools and measurements made by the Federal Acid Rain Network. Using the Kids Network, Miller had different schools try measuring the rain in different ways until, working together, they determined the source of the error: the pH paper used by the children was out of date.

"At first we were disappointed that the experiment had bugs," Tinker said. "But soon we realized that the bugs were a feature that gave kids a realistic look at the way science proceeds; only school experiments work perfectly the first time."

A kit containing software, teaching aids, and associated laboratory equipment – pH paper, beakers, and other measuring equipment – will be produced in 1989 by the National Geographic Society, said Dorothy Perreca, who is supervising the Kids Network project for the Society.

Next year, 1,000 schools across the country will participate in the "hello module" to make sure that the network can handle the load, Tinker said. By 1991, he hopes to have the

"The kids were real scientists. They discovered things." *– Richard O'Grady, fourth-grade teacher*

acid-rain curriculum in one-quarter of the school districts in the United States.

Acid rain is only one module being developed, said Tinker.

"Future units will draw experiments from air and water pollution, weather, land use, epidemiology, and fitness," he said. Each will culminate in a national experiment involving 1,000 other classrooms.

"Students really learn by doing projects, by undertaking things that they care about, spending an extended period of time getting involved in something," Tinker said.

"It's not that we want them to emulate scientists just for the cultural aspect. The role of technology in this is to give kids the kind of tools that scientists have. It gives them unprecedented power to do their own investigation."

So far, the project has made a big difference for a lot of kids.

"Before, I knew a little bit about acid rain, but I didn't care. Now I do. I want to do something about it," said Erik, an 11-year-old living in California whose class participated.

Kids Network was funded by a $2.3 million grant from the National Science Foundation, with a matching grant from the National Geographic Society. Apple Computer donated 175 Apple IIGS computers for the schools to use.