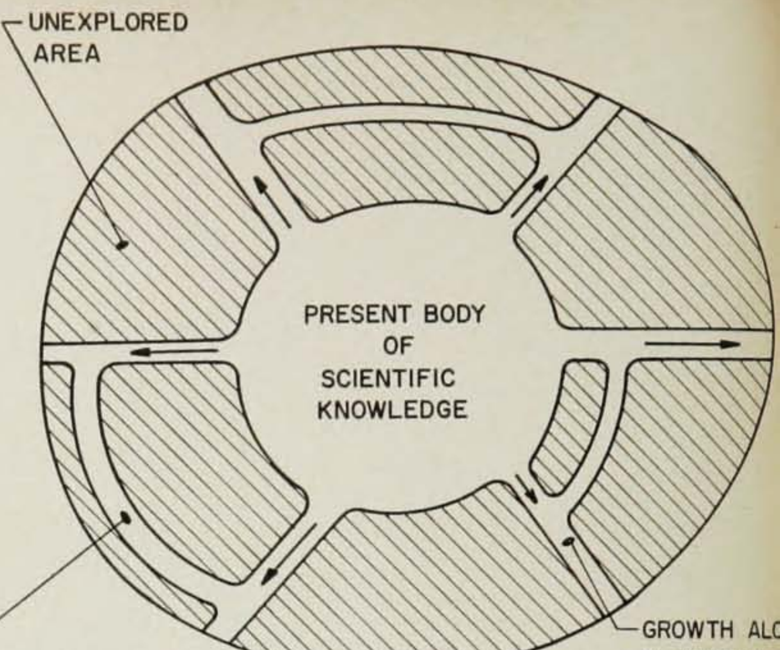

THE FOURTH DIMENSION IN SCIENCE EDUCATION

By Ladis D. Kovach

IN the March 1960 issue of *Physics Today* there was a letter to the editor written by David Redfield of Fairview Park, Ohio. The first part of this letter reads as follows: "The symposium papers in the January issue of *Physics Today* deal with the role of the physicist in a number of industries. When considered together with other similar articles, they represent a widespread desire for more physicists to direct their efforts toward a multitude of related fields. In view, however, of a small number of physicists in this country (the first article in the same issue indicates that there are less than 20 000), these papers raise a question of paramount importance to physics and, ultimately, to these other fields as well, 'What about physics?' That is to say, if physicists shift into the many neighboring fields in response to the demands from these fields, who will be left to do physics?"

Mr. Redfield's concern is quite understandable. The breed of scientist known as "general physicist" is rapidly disappearing in much the same way that the general practitioner in medicine has become almost extinct. The rapid advances in science and technology have produced a new breed, called "specialist". This is an individual who has become so intrigued with a new subject that he has decided to devote his entire effort to one narrow field. He has put on blinders in some cases so that he can concentrate more easily on his subject. The objective of this paper is to find out *why* a scientist puts on these blinders, what effect this action has on science in general, and on the science teacher in particular.

It is easy to see what has happened to the general physicist. He has been swallowed up by the vast number of new fields that have sprung up in the last decade or two. Some of these, such as solid-state physics, plasma physics, nuclear physics, atomic physics, infrared physics, chemical physics, ionospheric physics, radio physics, astrophysics, and molecular biophysics, have retained the word "physics". Others (for example, molecular electronics, thermoelectricity, cryogenics, statistical mechanics, thermonucleonics, magnetohydrodynamics, quantum electrodynamics, statistical thermo-

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dynamics, and quantum electronics) have lost the word "physics" but have retained some of the subject matter of physics. Each of these fields has a number of subdivisions so that the physics student is confronted with a terrifying number of new and difficult topics.

Specialize or Generalize?

IT is small wonder then, that a student will often choose some one subject in which to specialize. In his opinion it is impossible to master such a formidable list of subjects, and who wants to have just a nodding acquaintance with each of them? Doesn't one gain a measure of *security* by mastering *one* subject? Wouldn't it be more *gratifying* to be universally recognized as an *expert* in some field? Isn't it far *easier* to extend the frontiers of knowledge along one *narrow channel?* There seem to be definite, undeniable advantages to specialization. Let us examine the matter carefully, so that we will not be misled by appearances.

The security, the renown, and the ease accruing from specialization may be considered as selfish motives and, hence, will be disregarded in our discussion. If we consider the extension of knowledge along narrow, individual channels, then an obvious danger exists. The acquisition of new knowledge along separate channels is radial in nature and the farther out we go the farther we get from adjacent channels and the more difficult the problem of communication between channels becomes as shown in the accompanying sketch. Hence the true value of radial growth depends on the rate of growth of the interlinking communication channels.

It was believed by some that the way to make the greatest advance was by means of team effort. Although teams have operated successfully in certain areas (e.g., in operations research), this does not seem to be the answer either. In the final analysis all thought, action, and innovation reduce down to the individual. There is no such thing as *team* initiative, for example.

Thus it seems that there is only one way out—we must face the awesome array of new and difficult subjects. We must face the fact that there is no "easy" way out and that our only hope of vanquishing this Goliath is in finding the proper ammunition for our slings. The first step toward this goal is to develop the proper attitude. To do this, it will be helpful to consider a specific example, although it should be understood that the example given here may not be the best one and the reader undoubtedly can think of others.

Try to imagine how Michael Faraday must have felt when he discovered the basic laws of motor and generator behavior in 1821. The principles of electricity and magnetism were not clearly understood and Michael's head undoubtedly reeled from the many strange phenomena he observed in the laboratory. Imagine the vast unknown he faced when he first produced the continuous rotation of magnets and wires conducting electric current round each other. He may very well have felt that a whole lifetime would not be enough to learn what was happening here. Now, 140 years later, Faraday's experiments and discoveries are described in a few sentences in our textbooks. We have gained the advantage of being able to stand at a distance—not in length but in time—so that we see only the essentials of Faraday's work without all the intricate details.

Our present problem then is to determine, if we can, how we will look at a particular subject, say, a hundred years from now. Regarding solid-state physics, for example, will we say that some solids are conductors, some are insulators, and some are semiconductors? In other words, what are the *essential* facts about a topic? How can we paint the so-called "broad picture"?

Epitomize and Summarize

THIS is the problem that is confronting the science teacher today. In order to do an effective job of teaching, the teacher must understand the subject thoroughly. But more than this, he should have the ability to explain a difficult subject to a layman. When a child asks us a scientific question we do not deluge him with mathematical formulae and scientific detail. We leave off all the trimmings and serve him the meat. If he keeps asking questions, we give him a side dish or two, and if he is truly a brilliant child, we may even give him dessert. The important point is that we begin our explanation by projecting ourselves a considerable distance in the future and looking at the subject from that vantage point. We might say that we are, in effect, using the fourth dimension in education.

This technique is absolutely essential if we are to produce general physicists. Otherwise, as the list of subject matter grows, students of general physics will have to go to school longer in order to assimilate all this new knowledge. Eventually, they will be faced with the prospect of going to school all their lives. Thus the educator's course is clear. He must devise more effective methods of teaching, he must motivate his students so that they will learn more readily, he must be more efficient and not get involved in unimportant details, and he must not impose repetitious work on his students. In short, he must separate the wheat from the chaff and feed the wholesome wheat to his students. Some teachers are already doing this but there is a need for many, many more.

In order to develop the ability to extract the hard core of a subject so that it can be presented to a student, the teacher should consider the following suggestions. They have been found most helpful in preparing lectures on modern science to secondary-school science teachers.

One technique that science teachers can cultivate is that of writing abstracts of scientific articles. This is already being done by electronic computers which will, no doubt, be of immeasurable value to librarians everywhere. Nevertheless, it is very important for the *teacher* to learn how to write a brief abstract or summary of an article.

In fact, the teacher who keeps a card file of the books in his field has already taken an important step in learning to summarize. He has reduced the main features of the book—both good and bad—to the size of a 4 x 6 index card. This same idea can be applied to articles in various magazines and journals. All of the proofs, all of the footnotes, all of the redundancy have been left behind. What is left is expressed in the summarizer's own words and filed away for future reference.

An excellent way to learn to abstract and summarize is to study the work of newspaper science writers. Consider the following excerpt from an article in the *Los Angeles Times* of June 5, 1960, by Alton Blakeslee of the Associated Press.

> A tiny, amazing new genie is coming alive in electronics. It may bring you TV sets worn like a wristwatch, or even built into a pair of spectacles. It could fashion radios no bigger than a fingertip, or electronic "brains" the size of a shoebox. First it promises vital jobs in guiding missiles and satellites, in exploring space, and in military communications.
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> Based on a new principle, this genie is molecular electronics. One tiny sliver of material can do the work not only of vacuum tubes but other components such as rectifiers, resistors, and condensors. This vastly slashes size and weight. There are no moving parts, nothing to wear out. Simplicity means more reliability, far less chance that something can go wrong electronically, for example, in a million-dollar satellite wheeling around the earth.
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> The secret is creating zones or domains of special types of molecules within one thin sliver or round dot of semi-conductors. Each domain performs one job, and is separated from others by boundaries or interfaces within the material. Electronics can be made to follow orders. Voltage or power is fed in, and controlled energy comes out. Only two wires or leads are soldered onto the chip of material, which may weigh as little as one one-hundredth of an ounce.

In addition to dramatizing the subject (and thus creating interest) the newspaper reporter must reduce the whole to a few succinct paragraphs. The teacher can learn much by studying the reporter's techniques. We owe much to these "popularizers of science" who have stated that their aim is to continue, correct, and fill the gaps in school education which inevitably lags behind the march of progress.

Recognized experts in this field of using the fourth dimension in science education are the 372 members of the National Association of Science Writers who form the backbone of the science reporting team in the United States. This association, founded by 12 men in 1934, now includes science writers for 48 newspapers in 32 metropolitan areas, 18 nationally distributed magazines and two book-publishing firms. In addition to writing, these men give lectures and teach science journalism. Their methods can well be adopted by science teachers in order to create links between specialists in different disciplines, in order to arouse in the student the desire to take up research, and in order to make science a living, growing, interesting subject.