A KALEIDOSCOPE OF THOUGHTS ON THE FUTURE— 2025

Technology increasingly will affect teaching and research across the disciplines, while interesting questions at the margins of the disciplines will strain the traditional organization of departments. How will science be taught in colleges and universities as technology takes hold and the public becomes increasingly concerned about the costs of research and education?

It is folly to presume to predict the nature of the extraordinary developments in technology that will shape life in the 21st century. But surely rich and easily accessible databases, interactive computational experiments, virtual reality and nth generation computation will affect all that we now do in the classroom and the laboratory. Assuming that the college as we now know it— a place away from home where students and faculty come together to learn and understand— does not disappear, our current reliance on the lecture as a technique of instruction will not speak either to our needs or our constraints: databases of easily accessible lectures by leaders in every field, computer interactivity across the world, and the need to individualize instruction in an economically constrained environment will all militate against gathering students to hear a professor lecture, no matter how brilliant.

Independence and discovery will become more central to the educational process, creating an environment more like that of 19th century Oxford, than the Sorbonne of today. Laboratories will have to be constructed to withstand the hard use of young people exploring on their own, with minimal supervision, and the faculty will be engaged in tutorial-like instruction, emphasizing the individual needs of students. Some experiments will exploit virtual reality— no noxious chemicals there— while others will be computer interactive with enough artificial intelligence to take account of student idiosyncrasies.

With so many interesting questions arising at the interstices of disciplines, and knowledge increasingly interrelated, departments as we know them will cease to exist: ad hoc groups will come together and disperse as common interests develop and wane. Students will study science in settings resembling the New Pathways program at Harvard Medical School rather than in, say, a physics program of today; that is, scientific problems will themselves generate the explorations of what are now the disciplinary ideas “owned” by departments.

With substantially more flexibility in the way knowledge is organized and presented, nonscience students will be able to pursue their studies in exactly the way future scientists do, but not necessarily at the same level of sophistication. Indeed, with growing concerns about public policy issues in medicine, technology and law, among other areas of concern, the well-educated citizen will not wish to leave science to the professionals. Everyone needs to understand how scientific knowledge is organized, and questions or disagreements resolved.

Excerpted from PKAL *Volume III:* *Structures for Science: A Handbook on Planning Facilities for Undergraduate Natural Science Communities.* 1995.

Although much is sure to happen that we cannot anticipate, we foresee two major trends as having powerful impacts on what society will demand from universities and colleges. One is ever more rapid technical change. The stunning developments over the last decades in areas from microcomputers to biological engineering are only beginning to reveal their consequences. Many of these developments not only have generated and will continue to generate significant technical changes—they also provide a powerful engine for the further acquisition of new knowledge. Second is the increasing internationalization, even globalization, of the U.S. economy and society. Abetted by rapid advance in communication technology, it is clear that future citizens will need to be comfortable with a much broader range of languages and cultures than they have traditionally required to live their daily lives. Higher education will play a central role in preparing citizens for this world.

—Michael S. McPherson and Morton Owen Shapiro. Spelman/FIPSE Conference on The Future of Higher Education. 1995.

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As we look ahead, there is a danger that science within the academy may be so starved for resources that separate institutions are formed, on the model of NIH, with only a passing connection to the academy. Perhaps the college/university will not be able to accommodate more than tabletop science. While this shift might seem economically attractive in the short run, especially as the public becomes ever more restive about the cost of higher education, it would lead to a weakening of the high level of training for undergraduate students. The academy must continue to engage the world of politics, even if only as "public intellectuals," in the interest of education and knowledge.

Finally, how might we best prepare for the future? Create a community of scholars, develop a lean, lab-rich curriculum, and enrich opportunities for independent exploration of our physical reality. We can no longer organize the teaching of science around answers to questions that students have not asked.

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I cannot predict future needs any better than can anyone else. But one can look back 35-40 years to see how people thought then, to see how many were able to foresee with any accuracy what today's circumstances and objectives would be like. The impact of computers— especially of international computer networks— was virtually invisible. Just 10 years ago it was still an uphill battle to get college faculties to think of computers as more like telephones than as adding machines or typewriters.

Who would have predicted the arrival of national standards for school education, and the discussion of national standards for higher education? How many would have predicted that the average age of college students would rise to nearly 30— as it is now— or that 80 percent of students in undergraduate mathematics would be studying subjects commonly taught in high school?

Today's curriculum, even if revised just last year, is not a proper base for designing a permanent facility. The design goal of the facility needs to be flexibility, to permit easy and inexpensive conversions to uses not yet conceived. The questions should not be so much about ideal circumstances for the best of today's pedagogy, but about facilities that could serve a variety of styles, subjects, and approached to education.

The impact of international computer communications will radically change the very concept of a college or university. Resources for learning--traditionally professors, libraries, laboratories and texts—will soon become a "virtual university" available to any student anywhere. This will happen sooner in sciences and mathematics than in other fields, but it is coming everywhere. Science revolutions now come too rapidly to be held back by mere bricks and mortar.

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The amount of information becoming available in the sciences is increasing at an astounding rate. In the field of genetics, for example, it has been estimated that the amount of new information doubles every 4.5 years! That means that in barely more than the normal period of time for a student to achieve a college education, twice as much knowledge in this one field of study will be available for learning. Does this mean that faculty should lecture faster? Does it mean that historical information is of little value relative to what is new? Does it mean that genetics should become a sequence of courses rather than the traditional one or two courses?

In my estimation, the above example suggests that science education in the future, by necessity, will focus on helping students to understand better the nuances of the scientific process, to gain perspective on making judgments on scientific issues relative to what issues are pertinent to any given situation, and to learn how to use data and information acquisition systems effectively to gain access to pertinent details about a particular subject.

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Students who specialize in science will continue to do so and they will most certainly seek in-depth answers to issues of personal interest, but no longer are students identifying themselves as a major in biology, chemistry, etc. Science is, always has been, and will forever be an interdisciplinary course of study. The interdisciplinary nature of science will be recognized in a formal manner, and by 2025 first-year students at universities and colleges will take some one (or set of) common denominator courses that will introduce them into the art of scientific investigation.

Many issues heretofore not traditionally associated with the sciences will become integral to all courses taught in science programs. Communication of scientific issues, principles, and thoughts will be a must, and thus students will be helped to develop skills in writing and public speaking. They will also be encouraged to question critically what they read (in both technical and popular literature) and to ask informed questions about relevant issues.

Ethics in science will become of paramount importance (it already is important but not necessarily stressed) and students will be challenged with important tasks involving "risk assessment." For example, questions pertaining to issues about whether a scientific fact should be sought (e.g., splitting the atom) will be weighed against how this could be used (e.g., bombs or power).

Mathematics will increasingly become the language of the sciences. Mathematicians will finally come to grips with the understanding that "applied" mathematics is not bad, and we will find many mathematically-oriented scientists dispersed throughout what will be a large, interdisciplinary scientific division within an institution.

Finally, science will once again assume its overall importance in the general education of all students. Majors and nonmajor course distinctions will no longer exist, and issues of science will be dealt with in all fields of study throughout an institution.

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Thirty years from now what will it be like? The barriers that currently exist between science, social sciences, humanities, and the arts will have been removed. Faculties in the humanities will teach the history of science, logic in science, and scientific writing as they do American history, Greek logic, or creative writing. Science faculties will incorporate in their classes the social implications of scientific discovery, art forms in science, and other topics that currently appear at the fringes of classroom instruction.

This unification of faculties, made possible by increased international competition in technology which led to a rapid increase in the science literacy in the early years of the 21st century, has resulted in an increased humanization of science. With greater public understanding of science, decisions in science and technology were made by a broader spectrum of citizens.

The typical curriculum at colleges and universities devotes two years to introductory courses that include language, writing, social history, science, art, and mathematics. Each student is expected to take unified courses in these areas which are taught by college/university master teachers. All of the courses have a laboratory component which exposes students to the practice of the discipline. Science courses provide broad exposure to the traditional areas of biology, chemistry, earth sciences. physics, and technological science. The remaining two years of the four-year curriculum are devoted to specialization in a field of student selection, based on performance and available positions. Because colleges and universities now include a cap on admission to specializations, consistent with national employment needs, not all students are admitted to their first choice of specialization. However, graduates are now guaranteed placement in schools for advanced study, industry, or government as a result of the active role that society has taken with education.

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Specialization is related to the European system of education developed in the 20th century. Research is an expectation of all students, although original research is normally performed by those students who are expected to enter schools for advanced study. However, faculty are expected to be continually engaged in research to guarantee their ability to prepare the next generation of scholars and to advance their discipline. Universities employ teaching specialists and faculty. The teaching specialists prepare the framework for instruction (technical displays, laboratories, demonstrations); the faculty implement instruction and engage students in original investigations. Thirsty years from now there are twice the number of teaching specialists as there are faculty, but the number of faculty is only about one-third their number at the end of the 20th century.

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In 2025, an undergraduate with a pocket computer notebook will be able to choose from among different types of educational experiences. There will still be liberal arts colleges that are residential in character and personal approach; however, they will function without science departments since the sciences and mathematics have become so interconnected that departments no longer make sense.

On the other hand, there will be no more research universities that provide on-campus instruction; they will have evolved into research institutes that provide only on-line lectures that registered students receive at home. There will be graduate students at the institutes who serve as TA's for the courses. They will meet with students in an on-line discussion, similar to chat rooms offered by home computer services. Some existing facilities of research universities will have been sold to a new type of institution, the "university learning center," which will be an entrepreneurial center connected to a national network.

Students (in science or in the arts) will go to the center for an extended residency at regular periods, for hands-on activities within a laboratory, so that the experiential aspect of learning can develop over time.

Since many science classes at universities will not offer laboratory work, the experience of the practice in these fields will be carried out by students downloading data and providing analysis and design of future experiments based on that data.

Liberal arts colleges and comprehensive universities are likely to take advantage of the on-line lectures from the research institutes in several ways. For example, students may be able to take courses, including elementary and intermediate languages, and complete a degree in two to four years.

The language facility of science students would be valuable for potential international internships. On-line instructors would be available 24 hours a day. It is also possible that secondary school science and mathematics courses could be taken by high school students, thereby giving them additional credit hours upon entering college.

In 2025, no distinction will be made in teaching at the undergraduate level for majors and for those who are majoring in the fields of science and mathematics; it will be obvious that all citizens need to be comfortable with science and technology. By 2025, we will have determined how best to incorporate an ethical dimension into learning science and technology, we will know how to assess the value of active learning, we will have determined the right balance between "content" and "process" in our teaching.

Facilities will have interdisciplinary labs not connected with a particular department; facilities that can be used for truly interdisciplinary teaching and research. Moreover, these facilities will promote interdisciplinary interactions, by having faculty offices and research labs arranged in close proximity according to interdisciplinary areas of research (for example, biotechnology, materials science, surface science, etc.) rather than having a separate area or floor for each department.

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Although I am at a loss to envision science education in 2025, I predict changes in undergraduate science education in the next thirty years will continue to increase at an accelerating rate. These changes will probably be considerably more dramatic and unpredictable than those in the past thirty years. If current trends continue, we'll need curricula and facilities that support collaborative learning, informal student-teacher interchange, the study of interdisciplinary topics, and the use of sophisticated computer tools and scientific instruments.

In the face of accelerating change it will be critical for teachers to realize that what students learn will be less important than how they learn. Recently a physicist, just retired after a long career at Los Alamos National Laboratory, listed about 20 topics: laser spectroscopy, telemetry, neutron activation analysis, nuclear magnetic resonance, electron spin resonance, tunneling phenomena, electron microscopy, etc.

Students were mystified when asked what these topics had in common: none of these topics were in the curriculum when he graduated college in 1949 and he had worked on all of them during his career. Alas, very few of these topics are in the undergraduate physics curriculum today!

In the face of uncertainty about future areas of scientific research and the nature of research tools it will be critical to make new facilities as flexible as possible. Between now and 2025 instructors and students will probably use facilities in ways which are currently inconceivable.

Suppose the disciplines are disbanded? Can laboratories and classrooms be reoutfitted to support interdisciplinary work? Is conduit installed so electrical and computer networks can be repositioned whenever the furniture is completely rearranged? Is the furniture modular and sturdy? Are there spaces for large, medium, and small groups to work collaboratively? Are there spaces where individuals can pull away to ponder and reflect? What about ceiling and floor hooks? What about access to computer media? Internet? Telephones? The outdoors?

The metaphor for the science laboratory-classroom of the future is that of a giant electrical Lego set capable of being constructed in an endless array of fractal patterns to enhance learning through both collaborations and individual discovery.

Over thirty years ago John Steinbeck observed:

"*We…can have no conception of human life and human thought in one hundred or fifty years. Perhaps my greatest wisdom is the knowledge that I do not know. The sad ones are those who waste their energy trying to hold it [change] back, for they can only feel bitterness in loss and no joy in gain.*" ■