427 (1962); M. A. Grillo and S. L. Palay, *Proc. Int. Cong. Electron Microscopy 5th* **2**, u-1 (1962).
12. A. Pellegrino de Iraldi, H. Farini Duggan, E. De Robertis, *Anat. Rec.* **145**, 521 (1963).
13. E. De Robertis, *Histophysiology of Synapses and Neurosecretion* (Pergamon Press, New York, 1964).
14. ——— and C. M. Franchi, *J. Exp. Med.* **98**, 269 (1953).
15. C. O. Hebb and V. P. Whittaker, *J. Physiol.* **142**, 187 (1958); V. P. Whittaker, *Biochem. J.* **72**, 694 (1959).
16. E. G. Gray and V. P. Whittaker, *J. Physiol.* **153**, 2 (1960).
17. E. De Robertis *et al.*, *Sesiones Científicas de Biología, Mendoza, Argentina, 1960*, p. 24; *J. Biophys. Biochem. Cytol.* **9**, 229 (1961).
18. A. Inouye, K. Kataoka, J. Shigawa, *Nature* **194**, 286 (1962); H. Weinsten, E. Roberts, T. Kakefuda, *Biochem. Pharmacol.* **12**, 503 (1963); R. W. Ryall, *J. Neurochem.* **11**, 131 (1964); M. Kurakawa, T. Sakamoto, M. Kato, *Biochem. Biophys. Acta* **94**, 307 (1965).
19. E. De Robertis, A. Pellegrino de Iraldi, G. Rodríguez de Lores Arnaiz, L. Salganicoff, *J. Neurochem.* **9**, 23 (1962); E. De Robertis, G. Rodríguez de Lores Arnaiz, L. Salganicoff, A. Pellegrino de Iraldi, L. M. Zieher, *ibid.* **10** (1963).
20. L. M. Zieher and E. De Robertis, *Biochem. Pharmacol.* **12**, 596 (1963).
21. ———, *Congr. Asoc. Latinoamer. Ciencias Fisiológicas 6th Viña del Mar, Chile* (Editorial Universitaria, S.A., Santiago de Chile. 1964), p. 150.
22. A. Kataoka and E. De Robertis, *J. Pharmacol. Exp. Therap.*, in press.
23. G. Rodríguez de Lores Arnaiz and E. De Robertis, *J. Neurochem.* **11**, 213 (1964).
24. M. Alberici, G. Rodríguez de Lores Arnaiz, E. De Robertis, *Life Sci.* **4**, 1951 (1964).
25. E. Roberts, Ed., *Inhibition in the Nervous System and Gamma-Aminobutyric Acid* (Pergamon Press, New York, 1960); E. Florey, Ed., *Nervous Inhibition* (Pergamon Press, New York, 1961); in *Symposium on Structure and Function of Neuronal Inhibitory Mechanisms, Inst. Meet. Neurobiol. 4th Stockholm* (1966).
26. L. Salganicoff and E. De Robertis, *Life Sci.* **2**, 85 (1963); *J. Neurochem.* **12**, 287 (1965).
27. B. Sisken, E. Roberts, C. F. Baxter, in *Inhibition in the Nervous System and Gamma-Aminobutyric Acid*, E. Roberts, Ed. (Pergamon Press, New York, 1960), p. 219.
28. E. De Robertis, G. Rodríguez de Lores Arnaiz, O. Z. Sellinger, *Nature* **212**, 537 (1966); E. De Robertis, O. Z. Sellinger, G. Rodríguez de Lores Arnaiz, M. Alberici, L. M. Zieher, *J. Neurochem.* **14**, 81 (1967).
29. E. De Robertis, *Int. Meet. Neurobiol. 4th Stockholm*, in press.
30. K. Uchizono, *Nature* **207**, 642 (1965).
31. E. De Robertis, G. Rodríguez de Lores Arnaiz, A. Pellegrino de Iraldi, *Nature* **194**, 794 (1962); E. De Robertis, G. Rodríguez de Lores Arnaiz, L. Salganicoff, A. Pellegrino de Iraldi, L. M. Zieher, *J. Neurochem.* **10**, 225 (1963).
32. E. W. Maynert, R. Levi, A. J. De Lorenzo, *J. Pharmacol. Exp. Therap.* **144**, 385 (1964).
33. R. E. McCaman, G. Rodríguez de Lores Arnaiz, E. De Robertis, *J. Neurochem.* **12**, 927 (1965).
34. E. De Robertis, A. Pellegrino de Iraldi, G. Rodríguez de Lores Arnaiz, L. M. Zieher, *Life Sci.* **4**, 193 (1965); E. De Robertis, *Pharmacol. Rev.* **18**, 413 (1966).
35. V. P. Whittaker, I. A. Michaelson, R. J. Kirkland, *Biochem. J.* **90**, 293 (1964); V. P. Whittaker and M. N. Sheridan, *J. Neurochem.* **12**, 363 (1965).
36. E. De Robertis, M. Alberici, G. Rodríguez de Lores Arnaiz, J. M. Azcurra, *Life Sci.* **5**, 577 (1966).
37. J. M. Azcurra and E. De Robertis, *Int. J. Neuropharmacol.* **6**, 15 (1967).
38. E. G. Lapetina, E. F. Soto, E. De Robertis, *Biochim. Biophys. Acta* **135**, 33 (1967).
39. J. C. Skou, *ibid.* **42**, 6 (1960); R. W. Albers, S. Fahn, G. S. Kowal, *Proc. Nat. Acad. Sci. U.S.* **50**, 474 (1963).
40. R. W. Albers, G. Rodríguez de Lores Arnaiz, E. De Robertis, *Proc. Nat. Acad. Sci. U.S.* **53**, 557 (1965).
41. R. J. A. Hosie, *Biochem. J.* **96**, 404 (1965).
42. O. Z. Sellinger and I. De Balbian Verster, *J. Biol. Chem.* **237**, 2836 (1963).
43. E. W. Sutherland and T. W. Rall, *Pharmacol. Rev.* **12**, 265 (1960); E. W. Sutherland, I. Øye, R. W. Butcher, *Recent Progr. Hormone Res.* **21**, 632 (1965).
44. E. De Robertis, G. Rodríguez de Lores Arnaiz, M. Alberici, E. W. Sutherland, R. W. Butcher, in preparation.
45. E. De Robertis, J. M. Azcurra, S. Fiszer, *Brain Res.*, in press.
46. W. E. Van Heyningen, *J. Gen. Microbiol.* **20**, 291, 301, 310 (1959).
47. D. W. Wooley and B. W. Gommi, *Nature* **202**, 1074 (1964).
48. R. M. Burton, R. E. Howard, S. Baer, I. M. Balfour, *Biochim. Biophys. Acta* **84**, 441 (1964).
49. S. Fiszer and E. De Robertis, *Brain Res.*, in press.
50. G. Rodríguez de Lores Arnaiz and E. De Robertis, *J. Neurochem.* **9**, 503 (1962).
51. E. De Robertis, E. Lapetina, J. Pecci Saavedra, E. F. Soto, *Life Sci.* **5**, 1979 (1966).
52. B. W. Moore and D. McGregor, *J. Biol. Chem.* **240**, 1647 (1965).
53. L. Levine and B. W. Moore, *Neurosciences Rev. Bull.* **3**, 18 (1965).
54. H. Hyden and B. McEwen, *Proc. Nat. Acad. Sci. U.S.* **55**, 354 (1966).
55. L. M. Seminario, N. Hren, C. J. Gómez, *J. Neurochem.* **11**, 197 (1964); J. Eichberg, Jr., V. P. Whittaker, R. M. C. Dawson, *Biochem. J.* **92**, 91 (1964); A. A. Abdel-Latif and L. G. Abood, *J. Neurochem.* **12**, 157 (1965); J. Durell and M. A. Sodd, *ibid.* **13**, 487 (1966).
56. E. G. Lapetina, E. F. Soto, E. De Robertis, in preparation.
57. S. H. Barondes, *Science* **146**, 779 (1964); *J. Neurochem.* **13**, 721 (1966).
58. P. Weiss and H. B. Hiscoe, *J. Exp. Zool.* **107**, 315 (1948).
59. R. Tanaka and L. G. Abood, *J. Neurochem.* **10**, 571 (1963).
60. E. De Robertis, in *Nerve as a Tissue*, K. Rodahl and B. Issekutz, Eds. (McGraw-Hill, New York, 1966), p. 88.
61. The recent original research contained in this paper has been supported by grants from the Consejo Nacional de Investigaciones Científicas y Técnicas and NIH (NB 06953-01).

"The Man-Made World," A New Course for High Schools

Concepts behind man's modern artifacts underlie a laboratory course for college-bound students.

E. E. David, Jr., and J. G. Truxal

The Engineering Concepts Curriculum Project is the outgrowth of a 1963 meeting, sponsored by the National Science Foundation, held to consider the teaching of physics. The project is developing a high-school cultural course with technical and scientific content. It is designed to contribute to technical literacy for high school graduates who will not necessarily follow a career in engineering or science. They should have a knowledge of science and technology sufficient to enable them to think rationally about technologically based issues affecting society.

This view is widely held by educators, and yet one still hears the obverse argument that, to *use* and to *benefit* from the fruits of technology, a person does not require technical knowledge but needs only a modicum of skill or familiarity with technique. According to this argument, the driver of an automobile need not understand the mechanism of the internal combustion engine and the television viewer does not need to understand the superheterodyne principle and Maxwell's equations. The answer is linked to the increasing influence of science and technology on the shape and quality of life in our society. Today, citizens must be knowledgeable in these areas if they are to be effective in guiding technology in directions that suit man's purposes without allowing it to impair his liberty, ruin his environment, or destroy his privacy.

There is a more immediate and, some think, a more compelling reason for educating citizens in technical matters. Modes of thought and action inspired by science and engineering are being increasingly used in business, goverment, economics, education, and medicine. The precision of thought and language gained through mathematics, through manipulation of symbols, and

Dr. David is executive director, Research, Communications Systems Division, Bell Telephone Laboratories, Murray Hill, New Jersey; Dr. Truxal is provost of the Polytechnic Institute of Brooklyn, Brooklyn, New York.

through modeling is becoming the key to mastery of complexity in practically every field.

Yet, every year there is a decrease in the percentage of high school students who take physics, and teachers tell of a decline in student interest in all the physical sciences. This trend, according to figures from the American Institute of Physics (*1*), has been evident for at least 50 years, and present-day courses and resources have not reversed it.

The reasons for this decline have not been firmly established. One cause may be the press of college-entrance competition; another may be the lack of qualified teachers. Still another may be a disinclination on the part of the general student to seek scientific knowledge for its own sake.

Science is often presented in the classroom as a way of comprehending the universe, the implication being that scientific knowledge is its own justification. There is a different view of science, one that began with Francis Bacon. It is that man, by inquiring into nature, can better his lot. Scientists of the highest order have sought out knowledge and simultaneously pondered its implications for society. The Engineering Concepts Curriculum Project (ECCP) takes this approach. Its experimental course, entitled "The Man-Made World," concerns the artifacts man has created to cope with nature and helps students understand the basic principles on which devices, systems, and processes depend. It is intended for the average college-bound student at the 11th- or 12th-grade level, who is not necessarily destined for a career in science or engineering. It is designed to attract students from the group (two-thirds of all college-preparatory students) who do not now take a science elective beyond the 10th grade.

Why an Alternative Approach?

The ECCP course has been developed as an alternative to other science courses, not as a replacement. The students which ECCP hopes to attract are those who would otherwise leave school with only 1 year of senior high school science, or none at all. Further, introduction of the ECCP course as an elective in schools should in no way imply elimination of any other course.

What does the ECCP course offer students that present courses do not? Essentially, it provides the "science-shy" college preparatory student with an alternative to the professionally oriented course. It has been said that many current high school science courses are taught from the viewpoint of the professional and provide a first course for the future physicist, chemist, or mathematician. Yet, as Weinberg points out (*2*), "education at the elementary level of a field is too important to be left entirely to the professionals in that field, especially if the professionals are themselves too narrowly specialized in outlook. Instead, curriculum reform should be strongly influenced by disciplines bordering the discipline being reformed. The mathematics curriculum should receive strong cues from the empirical sciences and from engineering; the physics curriculum, from engineering as well as from the neighboring sciences; and so on."

The ECCP course is based on technical concepts that have broad relevance and significance for society. Engineering is a natural base for such an approach since it has no permanent or traditional commitment to any formal discipline. Engineering has no Newtonian laws, no principle of conservation of energy, no Huygens' principle, although those pillars are as vital to engineering as to physics. At the same time engineering must adapt to new situations and adopt new subject matter, for engineering strives basically to match needs with possibilities, very often old needs with new possibilities. Despite its lack of commitment to a formal discipline, modern engineering is science-based and is beginning to establish certain principles, as engineering, science, and mathematics are merged by practitioners who are not constrained by the traditional distinctions. These principles involve the ideas of modeling, experimenting and measuring, selecting a metric for making judgments or choices, and organizing units into meaningful structures, either conceptual or actual. These ideas pervade much of human thought and action and are not unique to engineering. Yet they stem from the methods of science and of technical enterprise. It follows that they are worthy of consideration by any student who aims to view the world rationally.

How can such abstract principles be communicated? Science *appreciation* courses have a long record of failure, and educators no longer believe that cultural courses should be oriented toward mastery of skills. The ECCP attempts to involve students by presenting subject matter related to clearly recognizable real-world situations. Laboratory and computer facilities make this approach concrete, providing vitality and relevance. The context is that of modern society, and the ECCP course is neither historical nor abstract. It does not teach generalities. Students, however, can arrive at generalities of their own through involvement in the course.

It is important to stress the fact that the ECCP course is not a course in engineering or "pre-engineering." Neither is it intended to draw students into engineering, the sciences, or mathematics. Nor is it a survey of modern technology. Rather, it is a substantive approach, for the general student, to the technical bases of our society.

The Background

The need which ECCP hopes to fill has been noted by many educators. It was perceived by a group of engineering-oriented participants at a meeting sponsored by the National Science Foundation and held, in the fall of 1963, to examine the question, Are there approaches to the study of physics in high schools other than those presently available? Many of the participants, ourselves among them, thought the answer was "yes." Furthermore, it appeared to several of us that the engineering viewpoint offered an effective approach. A group of seven (*3*) met several times that fall, under the sponsorship of the Commission on Engineering Education (*4*), to examine the idea further. There appeared to be enough promise to warrant the formation of ECCP, with the aid of a National Science Foundation grant.

Ten of us made a 1-month study during the summer of 1964, in Cambridge, Massachusetts, to fix our objective and try to outline a course. We decided that the course should have the following characteristics.

1) It should appeal to the average college-bound student.

2) It should be at the 11th- to 12th-grade level.

3) It should be independent of the high school courses in physics, chemistry, biology, and mathematics—not a replacement for any of them. Physics, chemistry, and biology are traditionally

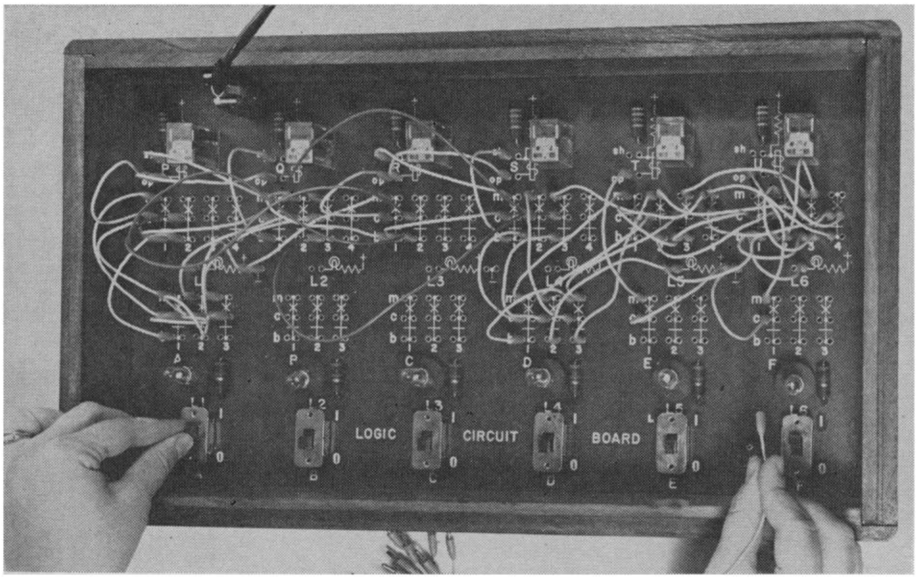

Fig. 1. The Logic Circuit Board, consisting of relays, manual switches, and lamps and energized by a 47-volt power supply, enables students to set up "and," "or," and "not" circuits as well as combinations that add, subtract, count, and transfer data from one circuit to another. Six experiments in part A of the ECCP course are based on use of this board.

concerned with natural laws—with the world as it is. The ECCP course is concerned with the concepts behind the man-made world—that is, with the world as it has been transformed by man. During the summer we identified a number of concepts that underlie the man-made world, among them feedback, amplification, stability, goal seeking, and machine logic.

4) The only prerequisite for the course would be 2 years of mathematics.

There followed a brief but successful trial, outside of school hours, at the Polytechnic Institute of Brooklyn, in the spring of 1965. Included were 15 students and five teachers from the New York and New Jersey areas. E. James Angelo of the Institute lectured and added his own considerable insights to what had been produced the preceding summer. During the summer of 1965 a group of some 30 people met at Tarrytown, New York; this group produced a 28-chapter textbook and assembled the equipment needed for some 30 experiments. Of the 30 people, ten were associated with high schools, and five of these taught the ECCP course as part of the regular curriculum during the school year 1965–66.

There were about 90 students in the five classes; of these, approximately 60 had not had physics. The progress made by the two groups—the 30 who had had physics and the 60 who had not—was not spectacularly different. Reaction from the five trial classes, monitored systematically in regular meetings with the teachers, indicated that a firm bedrock of material had been established. However, the year's experience also convinced us that the level of the material was uneven, and that much of it was too difficult. Also, we agreed that there was too much detailed mathematics, and that the subject matter was too narrow. These faults were attacked during the summer of 1966.

Revision of the textbook was carried out at Boulder, Colorado, with the cooperation of the University of Colorado. The 1966–67 trial textbook consists of 15 chapters (consolidated from the earlier 28) divided into three parts: A, Logic and Computers; B, Models and Measurement; C, Energy and Control. While the writing session was in progress, ECCP conducted a preparation program for 23 additional teachers. They, and the original five teachers, are presenting the course in their 27 schools (*5*) during the academic year 1966–67. There are some 800 students, many of whom fit the description "average, college-bound, and not science- or engineering-oriented." The broad spectrum of student backgrounds and school systems will provide the basis for a more extensive evaluation than was possible in 1965–66. The materials will be again revised in the light of this evaluation. An even more extensive trial is contemplated for 1967–68, to aid in a third revision. Subsequently, the materials will be made generally available to schools, probably through commercial publishers and manufacturers of equipment.

Perhaps the most fortunate aspect of the project thus far has been the broad participation by diverse elements (*6*). University people from at least seven institutions have provided the hard core. Industrial scientists and engineers have participated actively. In addition, the development of equipment has been pursued imaginatively by American Machine and Foundry Company, Bell Telephone Laboratories, Electronics Associates, Inc., and Measurement Control Devices, Inc. Perhaps even more helpful have been the insistent and, at times, fiercely independent criticisms and suggestions from high school teachers and administrators, who were quick to point out that much of the early effort was at odds with high school needs. By insisting on clarity and teachability, to the extent of refusing to use certain of the course materials beyond the initial trial stages without drastic revision, they have performed a valuable service.

The staff of the ECCP is small. There are three full-time members: E. J. Piel, former principal of West Essex High School, North Caldwell, New Jersey; B. A. Sachs, former physics teacher at Brooklyn Technical High School; and Manfred Brotherton, former staff member at Bell Telephone Laboratories. The ECCP office is located at the Polytechnic Institute of Brooklyn.

The Content

In examining the course content the reader should remember that the motivation for the course is cultural. The ECCP course is intended to correct misconceptions and oversimplifications. Notions such as "science is omnipotent" and oversimplifications such as "engineering is applied science" miss the true nature of the scientific and technological enterprise, overlooking its creative and esthetic aspects. The course helps the student understand that the true scientific attitude combines great flexibility with healthy skepticism, and that engineering, in particular, involves value judgments.

Many crucial judgments for both society and the technical enterprise today involve not what *can* be done but what *should* be done. Today the possibilities opened by science and technology have become so vast that choice between alternatives has become a central issue for all of society. Should we go to Mars? Should we have a national "data bank" containing personal information on all citizens? We have reason to believe that these enterprises are possible, but are they desirable? Issues such as these can be properly resolved only through technical expertise and wise value judgments based on knowledge. What are the advantages and disadvantages of a course of action, and to what extent do the advantages offset the disadvantages? These are questions too large to be answered by high-school students, but they should be raised, and the content of the ECCP course should insure that they *are* raised.

"The Man-Made World," the textbook for the course, has three parts. Part A is concerned with logic and digital computation.

Part A: Logic and Computers. It has been said that man's greatest achievement is his language—his ability to symbolize and communicate his thoughts and perceptions in spoken and written words. In recent years man has made a significant addition—the ability to symbolize and communicate by means of electronic circuits. This ability is based upon machine logic. The basic element here is the simple switch, which can implement the logical concepts "and," "or," and "not," taken in almost their everyday sense. In this context, the student is shown the congruence between real situations stated logically and the corresponding circuitry. The relevance of machine logic to such diverse situations as majority voting and seat ejection from aircraft is demonstrated.

The natural extension of logic circuitry is the digital computer, itself a composite of such circuits. Students are shown how such a machine is organized to perform various tasks, each requiring detailed and errorless specification of the steps to be taken. Students are taught some programming, but, for the student, the importance of this part of the course lies in his involvement with a huge and intricate, yet understandable, assemblage of parts—a digital computer. Yet, the course does *not* require that students have access to a computer. The course is not intended to make the student a computer expert or even a computer programmer, but it does show him that ideas, situations, and solutions can be represented in concrete form and rigorously tested. The power to be derived from putting information and ideas into a formal structure (in this case, a computer program) is amply demonstrated. At the same time, the process of formulation involves choice among alternative schemes or strategies. For example, there is no unique program for simulating the path of a billiard ball on a table with elastic cushions. In creating programs, students become involved in designing for a purpose, which man must do if he is to change his world for the better.

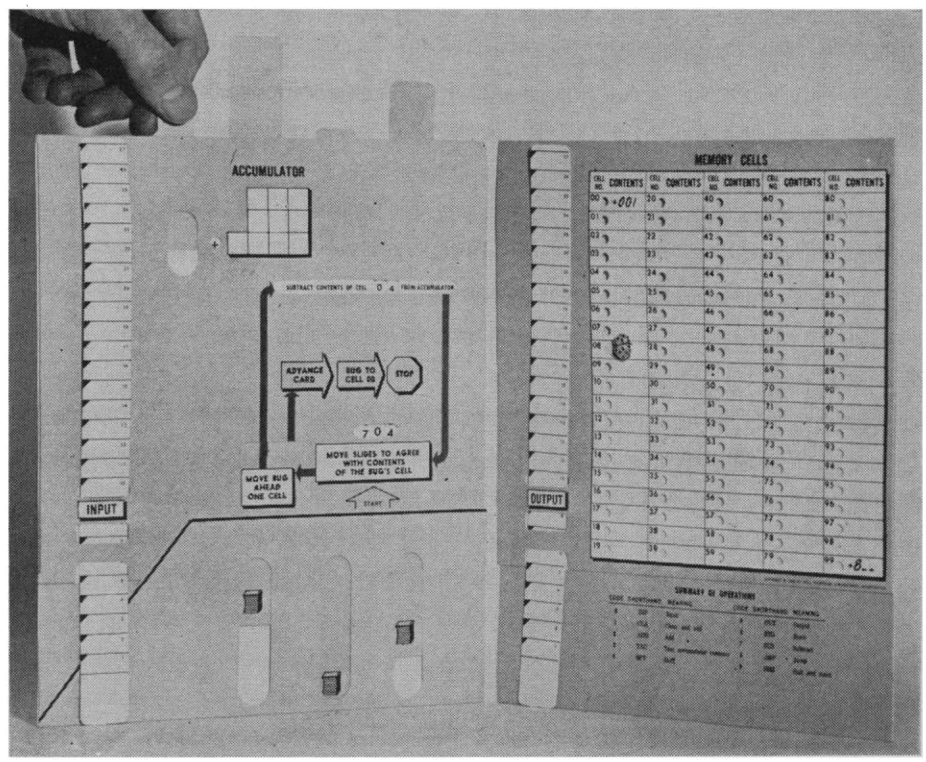

Fig. 2. CARDIAC demonstrates the basic units of a digital computer and the way in which they cooperate to carry out a stored program. Applying a specified cycle of operations to the program of instructions written in the "memory" (right), the student solves simple arithmetical and logical problems.

For the laboratory work of part A, two special pieces of apparatus, the Logic Circuit Board and "CARDIAC," were designed by D. W. Hagelbarger of Bell Telephone Laboratories. The Logic Circuit Board (Fig. 1) enables students to connect and operate various logic circuits for several experiments; CARDIAC, a cardboard model computer (Fig. 2) also developed by Bell Telephone Laboratories, enables students to follow the steps in the mechanical execution of stored programs. Additional apparatus would be required for actual processing of a program by the student, should that be desired by schools. Consoles communicating with remote computers are a possibility, and two trial schools are experimenting with consoles this year. Let me say again, however, that the course does not require access to a computer.

Part B: Models and Measurement. In part B the student is introduced to models as tools for aiding human thought and understanding, for predicting the trend of future events, and for fashioning devices, systems, and processes. Models are shown to be simplifications of reality; they may be physical, mathematical, or literal. Population models based on various growth laws are considered, together with their implications for urban areas and the nation as a whole. Models for representing mechanisms ranging from the lungs of animals to automobile suspensions are studied. The resonant spring-mass system is presented as an aid in understanding and creating artifacts ranging from bridges to radio receivers. An analog computer specially developed by American Machine and Foundry Company aids the students in working out these ideas in the laboratory (Fig. 3).

Modeling leads directly to consideration of sensing and measurement as the means for tying models to reality. Sensing is treated as the process of bringing a quantity to a form observable by the human senses or accessible to a machine. Thus, a compass "senses" the direction of the earth's magnetic field, a spring scale "senses" the gravitational field, and an accelerometer "senses" the derivative of velocity. The vital role of sensing in communication and self-regulating control is explored. Measurement is treated as the process of bringing precision to observations of sensed quantities through comparison with a numerical scale. Here the problems of accuracy and uncertainty are introduced. The laboratory work for this section of part B consists mainly of work with electrodynamic sensors and measurement of position by triangulation. A special instrument package (Fig. 4) was developed by Measurement Control Devices, Inc., for use in these and other experiments.

Models also provide the basis for determining the "best" solution to a problem or the "best" course of action. The idea of an optimum solution or course of action leads to discussion of objective criteria of effectiveness; these may be related to cost, time, or distance or to combinations of these with other factors. Once suitable criteria are selected, one can find an optimum solution—for example, the shortest path from one point to another in a network of city streets or the cheapest animal-feed mixture containing nutrients in given proportions. While the student is not required to become proficient in finding optimum solutions, he comes to appreciate the central role of an effectiveness criterion in making value judgments and decisions among various alternatives.

Part C: Energy and Control. Central to problems of control is the subject of feedback. In part C, feedback is introduced as a means of achieving a specific goal—for example, arrival at the specified end-point of a trip. Feedback insures arrival at the goal, despite errors along the way. Feedback neutralizes such errors by comparing present position with the desired end position, and taking action to decrease the difference. Feedback plays an indispensable role in human actions as well as in the operation of automated production facilities, automated weapons, and self-regulating controls.

The idea of stability is presented as that property of a system which enables the system to maintain its equilibrium despite disturbances. Economic and structural examples are used to illustrate the principle. Stability may be desirable or undesirable, depending upon the situation, but recognition of its importance is requisite in creating lasting systems.

Some tasks are fundamentally impossible—for example, the creation of a perpetual-motion machine. Others require special technological aids. For example, in order to fly for any considerable distance, man requires an engine and an airfoil-craft. These points are made in considering the concept of energy. The principle of conservation of energy provides a fundamental limitation, but practical limitations are often more immediate and significant. The difficulties of purely man-powered flight provide an illustration; man can just barely generate enough power to lift himself and his glider-like aircraft off the ground, even when the plane is especially tailored for the task. Man overcomes such limitations by using secondary, controlled sources of energy—for example, an engine in flying. Controlled energy sources, commonly called amplifiers, are at the heart of communications, chemical processing, transportation, and many other functions vital to our society.

Laboratory Work

The text of the ECCP course is supplemented by laboratory experiments performed by the student, and by several demonstrations. The laboratory equipment is mentioned above. The demonstration equipment includes a sonar to demonstrate sensing at a distance (Fig. 5), a power-winch amplifier, a mass-spring system to demonstrate resonance, and a bridge with stable and unstable supports. In general, the equipment used in the ECCP course is more elaborate than that customarily used in high schools. This is in line with our conviction that the course should relate to real situations. "Chewing gum and sealing wax" experiments can illustrate principle and may even charm the more sophisticated student by their elegant simplicity, but it is difficult for many students to relate them to the world of technology.

While the cost of the special equipment for the course is modest (the present estimate of total cost for the logic circuit board, CARDIAC, the analog computer, and the instrument package is about $700 for small production lots), financing may be a major problem for some schools. The ECCP hopes to decrease instrumentation costs as advanced electronic techniques become available, and hopes for increased government support of education.

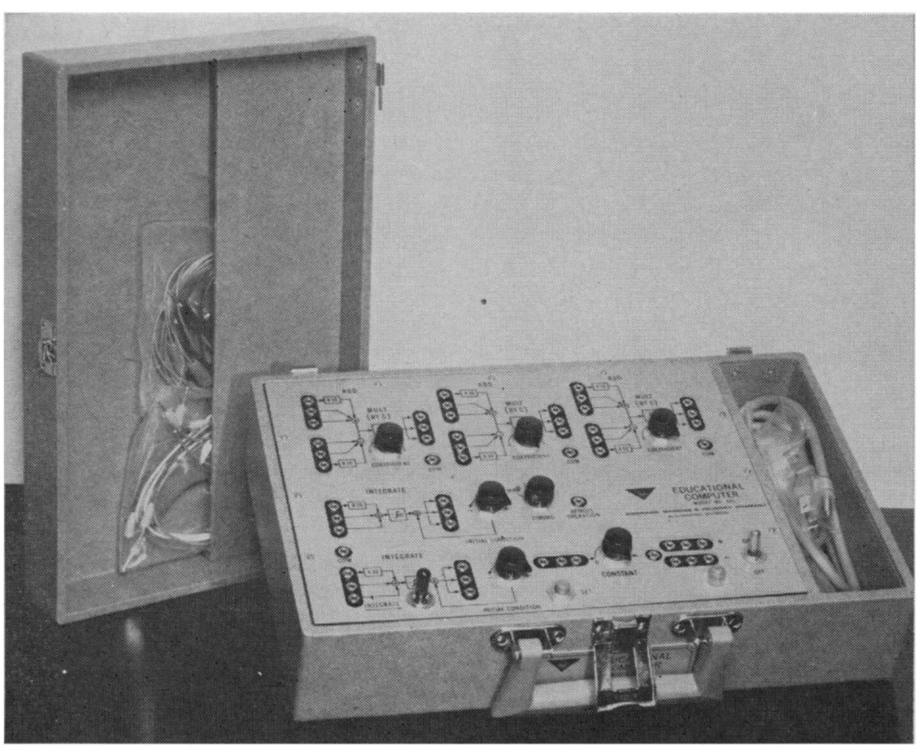

Fig. 3. The special electronic analog computer incorporates two integrator-adders, three scaler-adders, a variable direct-current signal generator, and a timing circuit permitting integration for 0.1-, 0.25-, and 1-second intervals. The single unit simulates simple dynamic systems. For more complicated systems, several units may be "slaved" together.

Prospects

When ECCP was initiated, the participants realized that they were trying to create an entirely new course, not revising an existing one. In essence, they were asking whether a course based on the concepts of ECCP could be taught to high school students, and whether such a course would be a useful addition to the high school curriculum. This investigatory phase of the project has met with reasonable success, and definitive results should be available by June of 1968. By the end of the summer of 1968, ECCP expects to have (i) completed preparation of the text "The Man-Made World," in readiness for publication as a book; (ii) completed trials of the course in 75 to 80 schools (the trials will have included the special instruction of teachers, during the summers of 1966 and 1967, in preparation for giving the course); (iii) completed a laboratory manual and a teacher's guide, and arranged for production of the special equipment required for the course. Thus, by that time, the first version of the ECCP course will be generally available to the schools.

There will be, of course, all the problems familiar to educators in adopting a new course—problems of teacher education, college-entrance credit, and curriculum crowding. Approaches are being sought, but in many instances the details will depend on situations in the individual schools.

Perhaps the most vexing problem is that of preparing teachers to present the course. The ECCP hopes to enlist the support of universities to aid in this effort. In the present trial, each of 23 universities has assigned a staff member to aid the nearby schools that are giving the course. This plan will be followed in the future and will make advice and counsel available to the teachers. In the future, too, universities will be assisted by ECCP in conducting summer institutes for teachers. It goes without saying that some formal preparation is necessary before a teacher attempts to present the course.

The ECCP course has been reviewed by many independent observers. As a result of their reactions, several possible and promising extensions of the basic idea are being considered. (i) The course material might be packaged in independent units usable in current courses in physics, general science, and mathematics (ECCP will consider producing such units during the coming year). (ii) Certain elements of the course might be useful in vocational education. (iii) Many educators point out that the course would be of interest to college-level audiences—liberal arts majors, premedical and prelaw students, and even freshman engineering students. These possibilities remain to be explored.

An exciting prospect is the imminent availability of computing services via remote-access terminals in the high schools. These services could provide an entirely new dimension for the ECCP course. They could make the understanding and application of concepts independent of algebraic manipulation and could permit the student to consider "operating" models of significant real-life situations. In addition, the computer could provide the motivation as well as the means for reaching an unusual depth and clarity of understanding. For, in order to communicate with the computer, the student must phrase his procedures and models in clear, unequivocal, logical language (language which is, in many senses, equivalent to an equation). The computer could give him a direct objective evaluation of his effort.

The computer also has potential in the teacher-education area. If each teacher could have his own computer console by means of which he could master special resource material, this would go a long way toward solving problems of teacher education. The ECCP was encouraged to proceed along this line by last summer's experience, when all teachers at its Boulder conference found the available computer console a powerful tool in coming to grips with part A of the course. Two of the schools taking part in this year's trial have arranged to

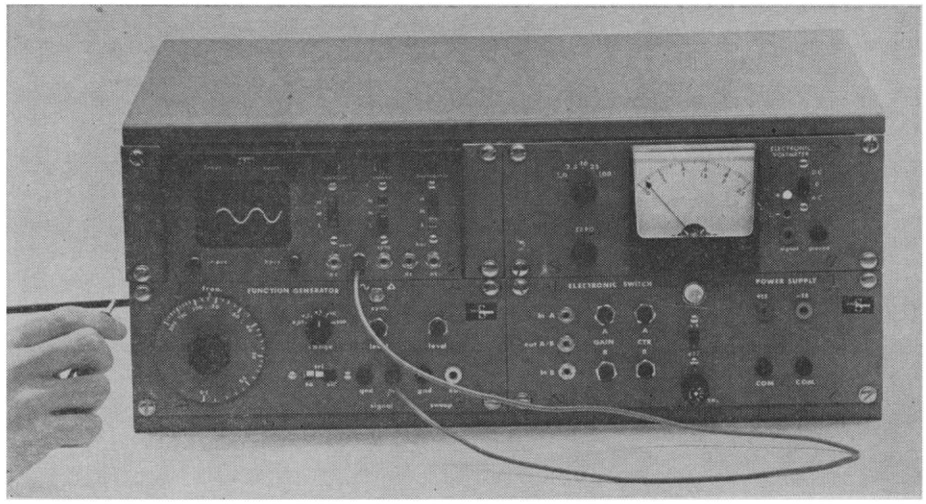

Fig. 4. The versatile instrument package compactly incorporates five apparatus units: a 15-volt direct-current power supply; oscilloscope with automatic synchronization control; function generator producing sine, triangular, and square waves at frequencies from 0.2 cycle to 20,000 cycles per second; electronic voltmeter (1 to 100 volts); and an electronic switch permitting simultaneous display, on a single-beam oscilloscope, of the input and output signals of the analog computer of Fig. 3. Almost all the experimental work in the course involves use of this instrument package.

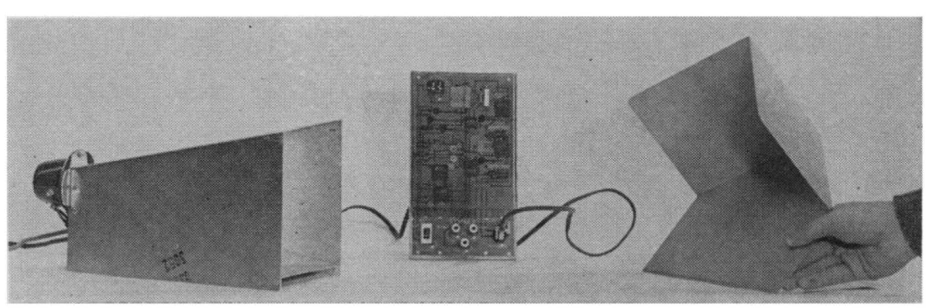

Fig. 5. The sonar set demonstrates "sensing and measurement at a distance." The oscillator (center) generates 20 to 60 sound pulses per second at 12,500 hertz. Transmitted by the horn-transducer (at left), the pulses bounce off the "corner" reflector (at right) and return to be picked up by the horn. The transmitted and received pulses, as displayed on the oscilloscope, indicate distances up to 7 meters.

provide similar consoles for their ECCP students. However, the course, as it now exists, in no way requires that students or teachers have access to a console.

Those who have contributed to ECCP realize that there is much yet to be done if the project is to realize its full potential. However, we believe that even the present version will give students a start toward understanding the man-made world and how it came to be as it is. They will be made aware of the influences from science and technology that will shape the future. This background will enable them to confront moral issues and make the wise value judgments demanded of today's citizens.

References and Notes

1. *A Statistical Handbook* (American Institute of Physics, New York, 1964), p. 3.
2. A. M. Weinberg, *Science* **149**, 601 (1965).
3. The members of the group were as follows: E. E. David, Jr., Bell Telephone Laboratories; R. L. Garwin, International Business Machines Corporation; D. A. Huffman, Massachusetts Institute of Technology; J. R. Pierce, Bell Telephone Laboratories; G. I. Robertson, Bell Telephone Laboratories; A. B. Rosenstein, University of California; J. G. Truxal, Polytechnic Institute of Brooklyn.
4. The Commission on Engineering Education is a nonprofit organization dedicated to the development of new educational resources. The commission acts as the administrative framework for ECCP, among other activities, and members of the commission—in particular, N. A. Hall, its executive director—have contributed to ECCP both technically and in other ways.
5. The 27 schools are as follows: Andrew Warde High School, Fairfield, Conn.; Annunciation High School, Detroit, Mich.; Bear Creek High School, Morrison, Colo.; Brooklyn Technical High School, Brooklyn, N.Y.; Episcopal Academy, Philadelphia, Pa.; Glen Rock High School, Glen Rock, N.J.; Highline High School, Seattle, Wash.; Hill School, Pottstown, Pa.; Iolani School, Honolulu, Hawaii; James Caldwell High School, West Caldwell, N.J.; John Dickinson High School, Wilmington, Del.; Jordon Vocational High School, Columbus, Ga.; MacArthur High School, Houston, Texas; Monroe High School, Monroe, Wis.; Nazareth High School, Brooklyn, N.Y.; Needham-Broughton High School, Raleigh, N.C.; Niskayuna High School, Schenectady, N.Y.; Pasadena High School, Pasadena, Texas; Phyllis Wheatley High School, Houston, Texas; Poway High School, Poway, Calif.; Reagan High School, Houston, Texas; Russell High School, East Point, Ga.; Severn School, Severna Park, Md.; Staples High School, Westport, Conn.; Washington Park High School, Racine, Wis.; Weequahic High School, Newark, N.J.; and West Essex High School, North Caldwell, N.J.
6. The participating consultants are as follows: E. J. Angelo, Polytechnic Institute of Brooklyn; N. W. Badger, Garden City High School, Garden City, N.Y.; Euval S. Barrekette, International Business Machines Corporation; John S. Barss, Andover, Mass.; D. L. Bitzer, University of Illinois; Joseph Bordogna, University of Pennsylvania; Ludwig Braun, Polytechnic Institute of Brooklyn; A. E. Bryson, Massachusetts Institute of Technology; D. R. Coffman, James Caldwell High School, West Caldwell, N.J.; R. L. Garwin, International Business Machines Corporation; J. Richard Goldgraben, Polytechnic Institute of Brooklyn; A. Jay Goldstein, D. W. Hagelbarger, and L. D. Harmon, Bell Telephone Laboratories; W. H. Hayt, Purdue University; Charles Hellman, Bronx High School of Science, Bronx, N.Y.; Lester Hollinger, Glen Rock High School, Glen Rock, N.J.; D. A. Huffman, Massachusetts Institute of Technology; W. H. Huggins, Johns Hopkins; C. E. Ingalls, Cornell; L. G. Johnson, Sidwell Friends School, Washington, D.C.; R. W. King, Staples High School, Westport, Conn.; A. E. Korn, James Caldwell High School, West Caldwell, N.J.; George Maler, University of Colorado; J. R. Pierce and G. I. Robertson, Bell Telephone Laboratories; A. B. Rosenstein, University of California; Samuel Schenberg, Board of Education, New York; W. M. Siebert, Massachusetts Institute of Technology; M. Simpson and R. A. Went, West Essex High School, North Caldwell, N.J.; G. Brymer Williams, University of Michigan; J. D. Ullman, Bell Telephone Laboratories; Andries van Dam, Brown University; and E. E. Zajac, Bell Telephone Laboratories.

NEWS AND COMMENT

Money for Research: LBJ's Advisers Urge Scientists To Seek Public Support

After World War II, science's emissaries to Washington devised incantations that served well to bring their profession to its present state of corpulence.

What they discovered was that, in seeking support for basic research, they could start up the Treasury's check-writing machines with words such as *Russia* and *cancer*. Since, in prewar days, they and their predecessors had failed with less emotional and more rational appeals, they cannot be blamed for sticking with a method that worked. Nevertheless, after 22 years of a boom in basic research, Russia and cancer endure as serious problems. The public and its politicians, by and large, remain friendly to the scientific community, but science's ever-growing appetite for money, its unique ways of handling federal funds, and public uncertainty about the payoff it is receiving on its investment in research—all have evoked a good deal of uneasiness. Congress endlessly pokes and probes into the affairs of the community. Last week, for example, Senator Fred Harris (D–Okla.) held another of the Congress's innumerable hearings on the geographic distribution of research funds. Not unrelated to congressional skepticism about the scale and administration of support for science is a decline in rates of growth of federal research budgets, and scientists wonder whether their government is slipping into a dark age. Against this background, it is interesting to note that two scientists who occupy extremely advantageous positions for observing the science-government relationship—White House science adviser Donald F. Hornig and his deputy, Ivan Bennett, Jr.—have lately taken to admonishing the scientific community for what they consider to be its naive perceptions of political reality. What they have been saying, in effect, is that science can no longer expect to be subsidized on the basis of vague assertions about its value to society, and that, if scientists want their profession to flourish, they had better put their house in order, formulate an empirically based case for government support, and clearly state it to the public.

To get some idea of the ideological shift implicit in what Hornig and Bennett have been saying, it is useful first to take note of some of the traditional political rhetoric of science. In 1959, for example, a White House panel on high-energy physics proclaimed: "It is not possible to assign relative priorities to various fields of science. Each science, at any given time, faces a critical set of problems that require solutions for continued growth. Sometimes these solutions can be acquired at little cost; sometimes larger expenditures of funds are needed. Hence, the cost may not reflect the relative value but rather the need. Each area must be funded according to these needs."

And, in 1964, Lee DuBridge, president of Caltech and vice president of the National Science Board, appeared before a congressional committee and stated:

"What is it that determines when our national budget for basic research in universities is adequate? Just one thing, I submit. It is adequate when, and only when, every competent research scholar in our universities is finding adequate