PHYSICS IN THE OPEN-DOOR COLLEGE

A wide range of student goals and motivations, and a lack of defined objectives for the courses provided, add up to a colossal challenge.

Bill G. Aldridge

THE EMERGING two-year community college faces special problems in teaching physics to nonphysics majors. All the teaching difficulties present at universities are compounded at the junior college, and in addition the character of the college itself introduces new problems. Our pre-engineering courses, curricula for liberal-arts majors and the very difficult ones for two-year technology courses each present their own problems.

Particularly embarrassing is that we, in common with all physics educators, do not know what the result of our teaching should be. We have no definition of what a student should be able to do at the end of his course. Before planning any physics curriculum we should make it our business to define what our objectives are.

PURPOSES

Because the community college is an open-door institution, it must offer curricula and courses that the community needs, and in which members of the community can be successful. Meeting these needs dictates a number of purposes for the college. One purpose is to provide parallel college transfer for the first two years. This was almost the sole purpose of the junior college as it has been known in the past. Yet there is evidence that in just a few years less than 25% of all people entering community colleges will transfer to universities or four-year colleges.

Because many young people who want to study in the transfer program did not acquire sufficient ability in high-school reading or mathematics to enter transfer courses, and because others, older and already established in occupations, have forgotten much of what they learned years ago, developmental programs are needed to fill these ability gaps.

Many young people want to attend a college to gain occupational or technical skills. A community college must therefore also provide a cluster of technical and occupational curricula.

A growing number of students want two years of college, not aimed at a job and not aimed at transfer. For these, the community college must offer a general curriculum of a totally different kind.

Another major problem is to provide for the continuing education of adults in a community. A community college must therefore offer an extensive collection of short courses, seminars and meetings, to educate and inform people in the community.

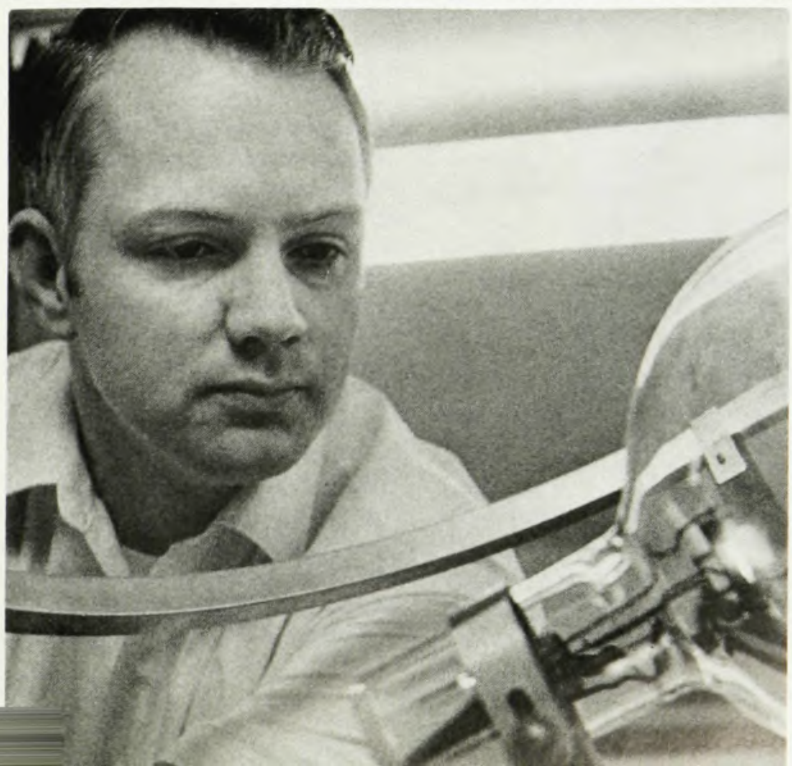
These purposes of a community college—to provide courses and curricula in parallel college transfer, two-year technical and occupational, developmental, general, and community service—make the institution a great deal more than the traditional junior college. They also make it considerably different from a high school, a four-year college, or a university.

THE STUDENTS

The students attending a community college are different from those at a university. They have not been nearly as successful in their school studies, and of course their academic abilities, as measured by examinations, are similarly lower than their university counterparts. There are exceptions; these exceptional students have been successful in the past, and they also score high on tests.

Community-college students have an enormous range in aspiration, experience, age, ability and motivation. The

AT FLORISSANT VALLEY COMMUNITY COLLEGE, students have access to laboratories and apparatus for as long as they like whenever they like.



majority have not been successful with the kind of education provided in their elementary and secondary schools. They are practical, yet they recognize that they need education beyond the high school. Most of them aspire to the college-transfer program, because of the status given to it by our society. But the most conspicuous feature of community-college students is their lack of motivation. They, especially those at the lower end of the ability distribution, have had an educational life filled with failure.

THE COURSES

One may well wonder what kind of physics can be offered in an institution such as I describe here. Because I teach at a relatively new college, Florissant Valley Community College, (one of three colleges of the Junior College District of St Louis City and County) most comments that follow will reflect my experience there. However, I have served for two years on the Panel on Physics for the two-year colleges of the Commission on College Physics, and therefore have a view of two-year teaching problems on a national scale.

Florissant Valley Community College has six full-time staff members in its physics faculty, plus a laboratory technician and student assistants. In the last seven years, no more than three students have continued as physics majors at universities or four-year colleges. Either we are doing a very bad job of interesting students in physics, or they are already committed to other areas by the time we get them. Evidence supports the latter conclusion. Our students are practical. They become engineers, technicians, and pharmacists.

As we do not prepare physicists, what kinds of physics do we teach? And to whom? From our current college enrollment of 4300 students, 72 are enrolled in Engineering Physics, 112 in College Physics and 29 in Technical Physics. In Physical Science we have 161 students. We offer a developmental course, Basic Science, in which there are 47 students. Related to physics are two other courses staffed by members of our department, a humanities course, Impact of Science on Man, in which 58 are enrolled, and General Astronomy with 23 students.

Engineering Physics is a three-semester sequence to prepare the engineering or science major for transfer to four-year colleges or universities. It is a calculus-level course with a strong emphasis on vector calculus in mechanics, electricity and magnetism, with the third semester covering modern physics. The material *offered* the student is at as high a level for an introductory course as is found at most universities.

We have a strange mix of students in college physics. The courses are supposed to serve students *both* in the "upper level" two-year technology curricula as well as liberal-arts students. The concern is that any other kind of physics course, not transferable, limits the technology student should he want to continue his education after graduation from the community college. Our "lower level" two-year technology curriculum requires a nontransfer course, Technical Physics. These two courses are supposed to give the background of physics needed by a technician for other courses and for his later work. The college physics is a typical, noncalculus general course. Technical Physics is *supposed* to be different from college physics, being more directly concerned with practical applications.

For nonscience majors, we offer a course, Physical Science, using the PSNS ("Physical Science for Nonscience Students") materials developed at Rensselaer Polytechnic Institute by a staff of scientists and educators. This course is designed to acquaint the student with physical phenomena, to get him to ask questions about science, to encourage him to try to answer some questions through experiments, and to help him build models for phenomena he has summarized.

The course entitled "Impact of Science on Man," is, in the words of its teacher, "designed to bring each student an understanding of the massive way in which scientific thinking and acting has altered his world, and the course is designed to impress upon students the need for controlling science so that it works in the best interests of all men."

PROBLEMS

It might appear that we would have few teaching problems, because we offer physics at so many different levels and in so many different ways. Yet serious problems do exist.

A common, and major, problem in all courses is to get students to read assignments and to work problems. In lower-level courses this problem is especially serious. Students have the idea that coming to a classroom three days per week, sitting passively listening to someone talk and looking at the pages of their books superficially is sufficient work on their part.

By their practical nature our students are more interested in specifics than abstractions. They are interested in applications of physics, but not in most of the models we present with the appearance that they are the final answer. At any given level the most useful theory is presented, without alternatives, or alternative theories are persented briefly as bad steps toward our presently accepted "ultimate" theories. It is only on the PSNS physical-science course that our students get a chance to create models of their own for observed phenomena; yet this activity should be most extensive in the higher-level courses.

In spite of our efforts to offer courses for many different interests and at different levels, we find a great range of abilities within each class. It is not uncommon to have students in Physical Science who can not do simple arithmetic at the fifth-grade level along with other students who have a working knowledge of algebra and trigonometry. This variance is decreased in Engineering Physics, where math prerequisites limit the distribution–at least in that respect. However, the open-door policy of a community college assures a great range of experience, age, background and ability within any class. Universities or four-year colleges with selective admission often deal only with the range within the upper decile or less. As we have some students who are as capable as some of the best in the university, plus the remainder of the distribution, the range with which we must deal is an order of magnitude wider.

Transfer courses

Our most serious problem for transfer courses is that our students start with fewer abilities, on the average, than those in universities; we spend the same time in class with them as teachers do in universities, yet our students must reach the same level of competency in physics as do their university counterparts. To solve this problem within the ordinary educational constraints of credit hours, classes and semesters surely must violate some

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AIR-TRACK DYNAMICS. This is one of the experiments in the open lab.

kind of conservation law. It is perhaps surprising that so many graduates of community colleges *are* successful when they transfer to universities and four-year schools.

Physics for technology

In the nontransfer technology courses, the problems for transfer courses are magnified. The students' mathematical abilities are severely limited. They enroll in two-year technology curricula so that they can learn to *do* something and then get a job. They are thrown immediately into physics and mathematics courses that appear to them to be totally unrelated to their educational and occupational goals. What is worse, these students are the ones who were moderately to extremely unsuccessful with academic subjects in high school, having acquired the burden of punishment for their little failures that manifests itself as passivity, disinterest and sullenness. They fail or withdraw from the kinds of physics we give them, never having an opportunity to taste the pleasure of success in their major area, the success that would likely spark them on to success in related areas. Withdrawal and failure rates in "technical physics" approach 60–70% in some institutions. Some community-college technology departments are so disturbed at this situation that physics is simply being dropped as a requirement for their programs.

Recognizing the problems in technical physics, the Commission on College Physics supported a national conference (directed by the author) on Physics for Two-year Technology Curricula at Florissant Valley Community College on 15, 16 and 17 May, 1969. Physicists, representatives of industry and government, as well as members of technology departments from across the nation, attended the meeting. A report of this conference is available from the Commission.

Physical science

The widest variations in reading ability, mathematical competence and motivation to study science appear in students of our physical-science courses for nonscience majors. Because the problem of teaching such students has been attacked nationally by PSNS and similar curriculum projects, and because the PSNS *seems* to offer an initially appropriate solution to many of our problems for nonscience majors, let us look at other areas where problems remain more severe.

An embarrassing omission

The single, major problem, basic to virtually all other instructional problems, is that we do not know what our students should be able to do as a result of our "teaching." We should feel embarrassed at this admission, except that all evidence available to us indicates that no one else appears to know either. Physics is committed to an operational approach to defining physical quantities; yet when talking about physics education, physicists do not hesitate to use words such as "knows," "understands," "covers," and so on, as though these words meant something.

ATTEMPTS AT SOLUTIONS

The problems that have been detailed here so far have been ones encountered at this community college. The urgency of teaching requires that many of them have immediate solutions of some kind.

The problem of deficiencies of students in transfer courses was handled by determining what specific abilities students lacked upon entering those courses. I wrote a textbook to teach those prerequisite abilities: *Quantitative Aspects of Science and Technology* (Merrill, 1967). We offer a course, Basic Science II, that uses this text. The results are not good. A few persons take the course who need it, but many more take it who do not. While studying the developmental material, students do not see the point of

AUDIO-SLIDE EQUIPMENT provides assistance for problem-solving.

it. They are not convinced they will need those abilities for physics. What we should have are developmental units of material that fit specific deficiencies of students at the points *within courses* where they are needed to fill gaps.

The open laboratory

The problem of scheduling, plus the added problem of instruction associated with a variety of laboratory courses, has been solved rather satisfactorily at our institution. For five years we have had an "open" laboratory. It is open in the sense that students may come to the lab at any time of the day or evening. They can stay as long as they like, and return as often as they like. The lab is staffed continuously by senior faculty. The details of our open laboratory are discussed in the September, 1969 issue of *The Physics Teacher*. We are especially pleased that several departments within our own college, and several other community colleges, have opened their laboratories after having looked at ours.

The advantages of the open lab are many. Student schedules are no longer restricted by the two or three hours of time blocked out on certain days of the week. The sequencing of laboratory work can be as closely associated with classroom discussions as desired. Because two or three student stations will handle a class of 30 students, better laboratory apparatus, purchased in smaller quantities, enhances the capabilities of the laboratory. Students from various courses are mixed in the laboratory, and many different things are going on at once. This makes the lab a more interesting place. The freedom to investigate is encouraged, and students enjoy the laboratory.

Individualized instruction

There is frustration in trying to teach students with an enormous range of abilities, interests and experience in a course that meets three times per week for a semester, to have them complete the course at some minimal level of competency. In the fall of 1968, I conducted an experiment in which each of two classes of students in College Physics alternated from one unit to the next, through six units of study under two different kinds of learning. One method was individualized instruction, in which students followed a carefully structured syllabus, with individual appointments with the teacher. The other method was a conventional lecture–discussion. One can show that under this alternating design, all student and unit characteristics are accounted for to first order, and that comparisons between measures of success under the two treatments depend to first order only on the variables associated with the treatments. (The mathematical basis of the experimental design uses summations with a Taylor's series of a function of three variables.) The results of the study indicate that the form of individualized study used was at least as effective as the conventional classroom situation *here* for all students and was more effective for better students.

On the basis of this experiment, four courses in physics and physical science were offered during the summer of 1969 under individualized instruction. With the open laboratory, carefully structured syllabuses, and four faculty members, 135 students were able to take course work. Most of them could not otherwise have attended college during the summer. They could move at whatever pace they liked during the eight-week session, individually taking competency examinations at several points within each course.

The summer-session individualized-instruction program was not without difficulties. Many tests had to be written, duplicated, administered and graded. Laboratory apparatus for experiments had to be set up on demand, and our lab facilities were strained by that requirement. Staff members had to be in the open lab from 9 am to 9:30 pm every day. Because many of our students held full-time jobs, fitting their study and lab activities to times that fitted their work schedules, some found it impossible to keep up. Through withdrawals we lost about 30% of those students originally enrolled. This withdrawal rate was not excessive compared with the rates for other courses during the summer, or when compared with our withdrawal rates during the regular terms. Successes with students who would never have made it under conventional classroom instruction gives us optimism about the feature possibilties of this method of instruction. We are presently offering ten courses under individualized instruction, and these courses will be repeated under this mode in the spring and summer of 1970.

We have some doubts about using structured syllabuses for entire courses, because the student is told too explicitly what to do. We anticipate revising the syllabuses for the next semester to provide for a gradual phasing out of the built-in structure.

As the student gains ability to learn physics on his own, we would specify the instructions in more general terms, so giving him greater freedom to select what to read and what to do in the laboratory. Near the end of a course, the syllabus would then be quite open-ended.

We hope to attack the problem of testing next year by placing all test items in storage on a computer file. Quantitative problems can be varied by having the computer generate physically reasonable data after each use of that item. Tests over a given topic can be requested as needed and printed out with correct spacing. When it becomes economically feasible, such competency exams could be taken at individual terminals.

A more difficult problem with individualized instruction is to remove the restriction on the time required to complete a course.

THE MOST PRESSING NEEDS

There is in education today a dichotomy of those who believe that teaching is an art and learning a mystery, and those who believe learning is a science; although teaching may be an art, it may also be influenced by a science of learning. Physicists in universities are deeply involved in exciting research. They have little time to be concerned with the various learning theories. They regard their subject as so intrinsically exciting that anyone worth his salt would learn it under any circumstances—the others don't really matter. Educators in the schools of education have spent so many years concerning themselves with a psychology of personality and adjustment, and with curricula about methodology without a rational basis, that they scarcely noticed the experimental psychologist beginning to talk about human learning in operational terms. We now have the peculiar situation of a science of human learning in its infancy being opposed by inertia, on the one hand by the physicist for lack of concern, and on the other hand by professional educators for the blatant intrusion into their area of jurisdiction by the psychologist.

Instructional objectives

The greatest need in physics education is the specification of sets of objectives of instruction for all courses at all levels. There is already a remarkable similarity of topical material from one textbook to another. Yet we have not even begun to determine and specify what it is that the student should be able to do with respect to these topics.

We need to state objectives of instruction in observable or measurable terms. A given topic in physics is selected; then what we want the student to be able to do with the topic is specified. Words such as "knows," "understands," "appreciates," and "comprehends" are of little value in making these statements, because such words have as many different meanings as the number of persons using them. Instead we need to state operationally what the student would be doing, with respect to a topic, to demonstrate that he has a desired intellectual ability. The objective should also include conditions under which the student is expected to demonstrate his competency and an arbitrary level of minimal acceptable performance.

Many physicists reject such objectives. They claim to be teaching something else, which they say cannot be specified in observable terms. It is curious how the same physicists would regard anyone as a charlatan who made claims about physics in the same nonoperational way as they themselves do about their teaching of physics.

If we ever do learn to specify our objectives in operational terms, evaluation of our teaching will finally be possible. We will then see how little we accomplish with our present approaches to teaching, and how totally unrealistic much of our present expectations are for students. Whether we like it or not, our tests and problems convey to our students what are now our objectives. It is sad that such information about what is expected is too often given to the student *after* the learning is to have occurred, rather than before, when the information would be useful to him.

We do not know what the students should be able to do as a result of our teaching. The students do not know what is expected of them until after we demand the performance. The levels of acceptable performance are nebulous at best, and our teaching is often unrelated to what we demand of students.

If words such as "learning to think," "being creative," and "doing physics like Bethe" really mean anything to the physicist using them in stating his goals of teaching, then under careful and directed questioning by another person, this physicist could be helped to define those phrases in operational terms. Of course, if they are just meaningless words uttered for their effect, to impress us, then such questioning will reveal that fact as well.

I have tried to write objectives for an entire course in introductory physics. I regard my effort as a failure. There are other examples of objectives that people have written for physics, but what I have seen of these are at least as bad as my own. It is time that a national effort be made in the preparation of objectives for physics instruction.

Elimination of constraints

When we have objectives stated for physics, then we can *begin* to learn how to teach. We will have unambiguous statements of expected performance concerning physics topics, which can be used by teachers everywhere; teaching methods can then be evaluated in terms of their ability to produce these desired performances in our students. We can also find out how much time is needed to "learn" physics.

With such knowledge about how physics abilities can be taught, our present constraints can be broken. Courses will be replaced by small learning units stated as such, instead of as so many weeks of exposure. Lectures will be replaced by some program of interaction between the student and the teacher, whether he be a computer or a human. Time restrictions of three classes per week for 16 weeks will be replaced by the provision of whatever time it takes a given student to acquire abilities in physics he needs. Grades will be replaced by measures of how fast students acquire these abilities. No student would fail. He would simply decide at some point that he had all the physics abilities he desired and would stop his formal education in it at that point.

If we had, built into our physics, objectives that would teach students to like the subject and others that would give them the ability to learn it without our help, we would not have to teach everything. For the rest of their lives, these students would learn the subject at every opportunity. The nonphysics majors might, during their lifetime, even want to support the work of professional physicists because they regarded physics as being important. □