You And Your Students

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Preface

IN THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY there are many excellent teachers. For the most part, these men have gained their ability as teachers by hard individual work, by a deep interest in their students' progress and welfare, and usually by pursuing a long road of individual experimentation and development. Good teachers are made, not born. Yet how few of us regularly spend even one per cent of our annual professional time deliberately studying the mechanism of teaching — with a view to self-criticism and self-development. In the long run, such time is well spent, and it repays itself many-fold in improved teaching efficiency and in actual time saved.

This manual is not intended as a formula to tell experienced and successful teachers how to teach. Rather it is an effort to distill from their success those principles which have a recognized soundness, and to set these down in an orderly fashion as a starting point for further development and improvement.

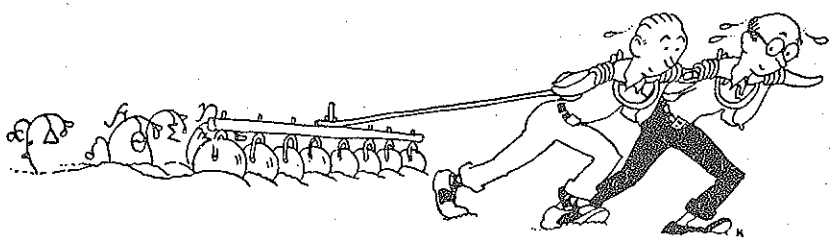
1
Educational Teamwork

EDUCATIONAL INSTITUTIONS exist for many purposes, including the preservation, organization, and transmission to new generations of *old knowledge*, the discovery of *new knowledge*, and the development of *wisdom* in the use of knowledge.

In a four-year undergraduate course at M. I. T., the average student devotes about 6000 hours to curricular work, including preparation time and class time. Each teacher whom he meets in class has probably devoted at least as much time as the student to preparation for the class. Thus each student also has the benefit of about 6000 hours of faculty effort. Such an expenditure of faculty time is economically feasible only when the instructor's time is shared by a number of students. The principle of group instruction has been applied to education to reduce unit costs to a tolerable level.

The educational process is one of *teamwork* between students and faculty. Every instructor continues to be a student, and every student must learn how to become his own instructor in later life. One of the student's goals must be to find out how to learn what he doesn't know. He must develop the skill of acquiring new knowledge and of applying it wisely.

The student's qualifications must include the ability to learn and the desire to learn. The *instructor's* qualifications must include qualities of inspirational *leadership*, the *desire* to teach, *knowledge* of the subject and its relationship to other fields which lie at its borders, and the *ability* to transmit knowledge to the student so that it is alive and meaningful.



II
The Learning Process

LEARNING AND TEACHING are parts of one general unit process. Superior teaching rests in part on a clear appreciation of the learning process. An awareness of the mechanism of this process helps both students and teachers in their joint undertaking.

An illuminating approach subdivides the learning process into three steps. These are (1) comprehension, (2) recall, and (3) creative thinking.

1. COMPREHENSION

COMPREHENSON IS THE absorption of ideas. Successful comprehension of a new idea generally requires a *motivation* and a desire to learn. The student will usually wish to learn if he can see that the material being presented may be useful and if he can feel that he is making visible progress. Comprehension of a new idea requires an adequate background of related

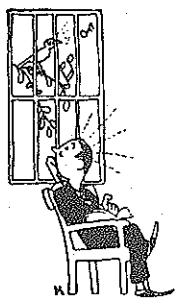
knowledge or, more briefly, *prerequisites*. The new idea must be expressed in a *vocabulary* which is familiar to the student. If the new idea requires a technical jargon or the use of specialized, precise meanings of familiar words, then these vocabulary problems must be met first and must not be permitted to obscure the idea or to impair or prevent comprehension. So fine a basic generalization as "the ontogeny traces the phylogeny" can be incomprehensible gibberish if the words are unfamiliar.

True comprehension generally requires *undivided attention*. The chronic mental wanderer may fail to learn merely by missing the first step — comprehension.

2. RECALL

RECALL IS THE process of remembering. Several levels, or degrees, of recall are recognized. The lowest level is "*recognition recall*," at which we remember an item only after someone else has jogged our memory. In fact, we do not "recall" it at all but only "recognize" it as familiar after it has been recalled for us. Recognition recall is exhibited by those whose memories for anecdotes are only good enough to spoil the other fellow's jokes but who cannot contribute much themselves.

Volitional recall, or spontaneous recall, denotes the process of successfully remembering something which has been learned previously. Obvious examples of volitional recall would include the successful repetition of the multiplication tables or of the fundamental formulas of differential and integral calculus, or of the names of students in a class.



In a restricted but useful educational sense, we mean by the word "knowledge" only the power of volitional recall of comprehended material. Then *knowledge is a two-step process:* first comes *comprehension*, or understanding of the item; later comes *recall*, or remembering of the item. In this sense the concept of knowledge does not necessarily extend to the next intellectual step, which involves creative thinking or, more simply, the new use of knowledge.

3. CREATIVE THINKING

THE AIM of a scholar and of a university must greatly transcend the mere acquisition and transmission of knowledge. These processes alone simply preserve knowledge without contributing any intellectual progress. The society in which we live would not exist if the body of knowledge possessed by the early Egyptians had merely been passed along, generation after generation, without being enlarged.

It is clearly insufficient merely to teach facts, or merely to learn facts. Knowledge alone, as represented by comprehension plus volitional recall, is not sufficient. The *creative use of knowledge* must be the goal of both student and instructor.

Every instructor asserts that he is trying to teach his students "to think." But what, exactly, does this mean? Most simply, thinking is the transfer of learning to new situations.

The anatomy of thinking — that is, of the creative use of knowledge — needs consideration. It is useful

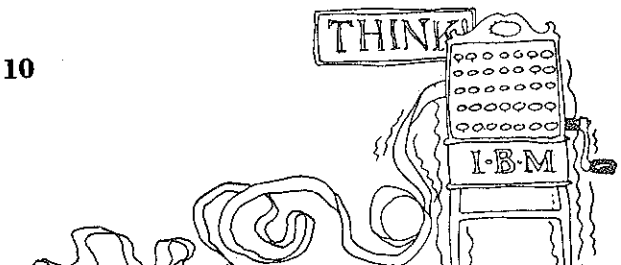
to recognize several approximate and non-exclusive categories of "thinking." These include:

ORGANIZATION AND CORRELATION OF IDEAS. This category of thinking involves the recognition of common factors among a variety of ideas. Consider, as an example, the correlation of electrostatic phenomena with gravitational phenomena, and the recognition of the basic common principles of the inverse-square law, of action-at-a-distance, and of field concepts. Recognition of the similarities and the differences between apparently unrelated facts or principles is one kind of organizational thinking. Likewise, the important process of generalizing from limited data to a broad hypothesis could be included here.

ELABORATIVE THINKING describes the process of bringing many sources and types of information to bear on a new problem or situation. It includes some cases of reasoning by analogy and of carrying knowledge in one field over into a second field; it connotes mobility of attack.

CRITICAL THINKING involves reflections on the consequences to be expected if a proposed action is taken. It includes the evaluation of experiments, mathematical derivations, or political theories, often by comparison with a standard.

The highest type of teaching involves helping the student to acquire the *ability to apply his knowledge to new situations* — that is, to think. Frequently an ingenious teacher can stimulate and expand his student's ability to think, even during the comprehension-teaching of new facts. This is particularly true



in discussions of scientific discovery. By a semi-historical approach, the student can be taken through the state of knowledge before the discovery; and if care is taken in presentation, he can vicariously follow the discoverer's steps and experience the discovery himself.

The educational process is seen to involve three steps: *comprehension*, *recall*, and *creative thinking*. The student and the teacher are a team, dedicated to the maximum realization of these steps by their own best efforts, expended both singly and jointly.

The instructor is responsible for developing the best possible methods of presenting his subject to accomplish all three steps. His is the problem of facilitating and aiding "comprehension" and of stimulating creative thinking on the part of the student. The instructor's methods will normally include a variety of so-called *teaching aids*, including models, slides, charts, blackboards, and other aids-to-comprehension discussed in a later section.

The student is responsible for developing efficient and effective methods of study. His so-called *learning aids* may include notes taken in class, notes made during private study of the textbook and of library reference materials, solutions of problems, and a textbook in which he has made his own marginal notes, underscorings, and annotations. Only a few students have given as much as one per cent of their study time to the considered development of efficient study habits and study techniques. Such a self-investigation is very worth-while and can usually increase learning efficiency by five to fifty per cent. Remember-

ing that the undergraduate student's investment of time alone amounts to about 6000 hours, even a small percentage of increase in learning efficiency is significant. The student's study aids and methods must not aim solely at comprehension; improvement in his powers of recall is especially important. Educational experiments have shown that great improvements can indeed be made by individuals in their ability to recall previously learned material. *Study methods should involve both aids-to-comprehension and aids-to-recall.* The student whose systematic efforts to develop his powers of recall consist only of cram sessions before quizzes is missing a large share of his educational opportunity. Throughout the learning process, the powers of recall should be constantly stimulated and exercised. Creative thinking and recall can often be cultivated simultaneously.

III
Objectives

THE INSTRUCTOR'S general objective in each meeting of his class is to implant in the minds of his students at least one new piece of information, a new technical skill, or a new experience in creative thinking.

The objectives of each subject of instruction, set forth in the General Catalogue of the Institute, have been established in order to fulfill the over-all purposes of each particular Course of instruction. The specific objectives at each meeting of the class must be carefully planned in advance by the instructor so that they are properly related, in terms of time and emphasis, to the objectives of the entire subject. The instructor, in his day-to-day planning of the class activities, should adopt a viewpoint which will maintain in proper perspective the objectives of the subject, of the Course, and of education itself.

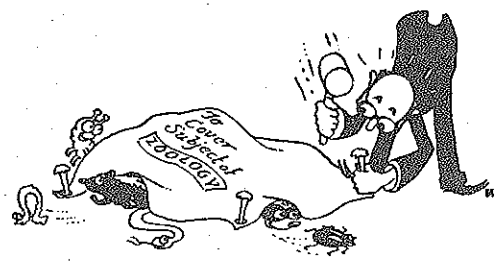
Most of us will agree with Dr. Karl Compton's observation that "the ultimate value of an undergraduate education depends far more on the quality of intellectual and moral discipline and inspiration than it does on the particular course of study which is the vehicle through which this discipline and inspiration are imparted."

The M. I. T. student body is rigorously selected and contains a rather large proportion of conscientious individuals with definite educational objectives. To some, their education is a tool for making a living and an aid to attaining and recognizing individual and family security. For others, the dominant motives are the desire to obtain a better understanding of modern society and their place in it, and to increase their ability to make significant professional contributions to progress. It has been found repeatedly that the *habits of quantitative thought* which characterize our undergraduate training in engineering and science are a superb preparation for other professional fields.

There will be instances in which specific abilities learned by students in our classes will later be of direct professional use to the student. These cases may be less common than we think. Our teaching objectives must be to prepare men and women for a useful life. We need to teach enthusiasm for learning, good habits of learning, good characteristics of critical thought, and an eagerness to accept the challenges of new situations and of new problems in daily life. Each class session needs to be planned by the instructor with these larger objectives also in view.

Technical competence in a selected group of topics is not enough; the student must learn how to acquire new knowledge on his own, how to appraise it, and how to use it creatively.

The material to be covered in any particular subject of instruction needs to be carefully selected. It is generally not possible to cover the entire subject. The most successful instructors are often those who teach less material but do it profoundly. We should "aim not to cover the subject but to uncover part of it."



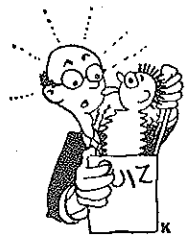
IV
Technique of Teaching

BEFORE THE TERM BEGINS

THE INSTRUCTOR should lay out the plan for the entire term, in the light of the objectives of the subject and its relation to the curriculum. He must decide which topics to omit, in order that those which remain will receive adequate time. He must guard against chronic underestimates of the time required for the students to grasp a given topic. It is better to include less material and to treat what remains well. The conscientious instructor who hates to omit one of his favorite topics must realize that he can and should teach his students in such a way that they will be stimulated to go beyond the actual class material by private study, if their time permits.

The *instructor's advance outline* should be a complete outline of the material to be covered (really, uncovered!), the order of presentation of new material, and the order of presentation within each topic. This order should be from the familiar to the unfamiliar, from the simple to the complex, from that which is easy to that which is most difficult.

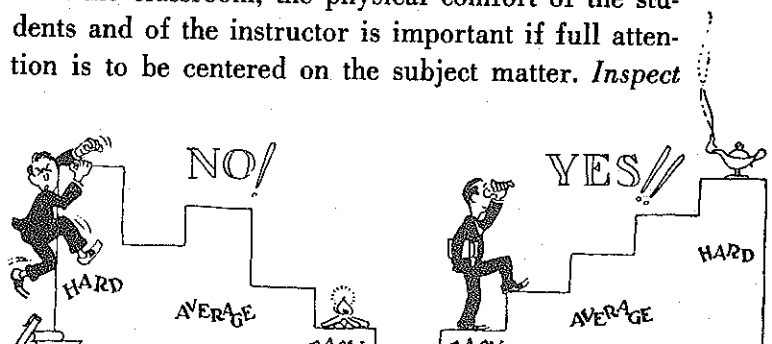
Plan in advance for *quizzes* to be given at the time of continuity breaks between topics. About five per cent of the allotted class time is usually adequate for testing purposes.



Decide in advance what material you are assuming the student already knows. Be definite in your consideration of these prerequisites. During the first week of the term, give an unmarked *quiz covering these prerequisites* and especially exploring the student's knowledge of the vocabulary of the subject. Such a quiz can supply vital information for the instructor; the results often will contain surprises. The deficiencies discovered at this early stage are the easiest ones to correct. Those deficiencies shown by only a few students can usually be corrected by outside reading. Deficiencies exhibited by a majority of the students will require appropriate compensatory changes in the plan for the term's work. Put a little leeway into the term outline to allow for such surprises.

Also, before the term begins, plan and begin to procure those *teaching aids* which require time for preparation, such as models, charts, and slides, so that these will surely be ready when needed.

In the classroom, the physical comfort of the students and of the instructor is important if full attention is to be centered on the subject matter. *Inspect*



your classroom before the term begins. Be sure you are familiar with its heating, ventilation, lighting, acoustical characteristics, and such controls as are available. Determine whether part of the blackboard is useless because of glare. Write something on the blackboard, then examine it from the back of the room so that you will know how large and how heavy your blackboard writing must be.

BEFORE EACH LECTURE OR RECITATION

MAKE A CAREFUL PLAN of what you expect to accomplish. Keep in mind the relationship of the day's learning to the objectives of the subject and of the Course. Be sure of your order of presentation, emphasis, and adequacy of time allotment.

Prepare adequate notes and master them so that an occasional glance is the most help you will need from them. Think through — or actually rehearse — the subject matter, order, and manner of presentation. Do not be ashamed to rehearse. It is worth your time. Indeed, some of the best instructors, whose semi-extemporaneous lectures now are models of clear and interesting presentation, will confess that at first they wrote out every lecture before meeting with the class. This type of training, this high degree of preparation, produces efficient and stimulating teaching. It inevitably saves the student's time, and in the long run it saves the instructor some time also. Obviously, a written-out lecture is not to be read to the class. The text should probably not even be brought to the room. Thoroughness of preparation is what is wanted.

Before class, collect all teaching aids which you intend to use. Make sure that demonstration experiments will work, that models to be used are in good condition, and that enough copies of any graphs or other material to be distributed are available.

If you have previously taught the same material, *criticize yourself*. Look for improved approaches to the subject which will make it more stimulating to both the students and yourself. Improve the presentation over the last time you taught this material. The most practical way of doing this is to write comments to yourself on your lecture directly after giving it. When you come to it next year, these comments will remind you of the changes which you should make. Make such notes on recitations and laboratories, too.

No subject and no individual lecture can cover everything pertinent to the topic. Make a *considered selection* of the most important or the most stimulating material, allowing time for questions and discussion by the students as well as for necessary repetition and a summary. Do not try to cover too much material at the expense of clarity and complete comprehension. Experienced teachers — the older hands — often teach less material but do it thoroughly, aiming at illustrating "higher mental processes" rather than at mere "comprehension" of excess material on which "recall" may be poor anyhow.

When the student has an adequate textbook, guard against reproducing it too much. Rather, devote time to making the subject more meaningful and stimulating by connecting the material with the student's previous knowledge in this field and in borderline

fields. Orient the subject in the framework of his past and future experiences. Underscore the most important material. Clear up ambiguities. Remember that some students will need your help and guidance in improving their ability to use textbooks and reference materials effectively. Experience has shown that our students make very little use of reference material, primarily because they do not know how to use it. A little time spent in guiding them to reference material and teaching them how to use it yields rich dividends in understanding and interest.

Plan *provocative questions* and illustrative problems and situations in order to stimulate the student's interest, his oral discussion, and his critical evaluation of the material. Look for paradoxes, but be sure they are the kind which will enlighten the student and not bewilder him. Show the student also the limitations of present knowledge and methods, especially in advanced courses. Stimulate him with the intellectual challenge of the unsolved problems of the present day.

Do not be too quick to help a student who is struggling with a problem. He may have to muddle around in a subject for quite a while before it becomes clear to him. This muddling process is at the core of all creative thinking. By giving a student a clear explanation before he has struggled with a problem, you may save him a little discomfort; but you may also deprive him of the important experience of thinking things through for himself. Avoid giving a student the result of thought in such a way that you deny him the process of thinking.

Review frequently the standings, needs, difficulties, and special abilities of your individual students. Plan how you can be of greatest service to each during the class session. Be flexible; *use a variety of techniques* of presentation — lecture, recitation, discussion, demonstration, or other methods — as the circumstances indicate.

To be an educator in the sense of one who "leads out" the best that is in the student, you must do more than organize and impart information. You must *interest yourself in the student* as much as in the material, and you must learn to be sensitive to slight and subtle changes in the student's attitudes and personal reactions. While conducting a class you should be aware of facial expressions, shuffling feet, and other signs of interest, boredom, or tension. You should understand that some apparently simple situations are actually very complex, so that you do not act on the obvious and neglect the more subtle or atypical reactions. You should also know enough about your own personality so that you can understand your reactions to students and their reactions to you.

Level your attention and your planning at *individual students*, not to the class as an impersonal body of people. It is the individual student who counts. Prepare to meet him, stimulate him, and guide him at his level. Be aware of his individual needs. The class is composed of individuals. You meet them simultaneously as a class because it is economically impossible to meet them singly and also because there exists an intellectual competition among the

individual students which is stimulating and worthwhile in itself. But center your attention on the individual; *develop a warm, friendly relationship in the student-instructor team.* Practice the habit of calling students by name, whether in classroom or corridor.

You will often have contact during and after class with students who almost make nuisances of themselves by asking many questions not obviously related to the subject, usually at a more advanced level than the subject matter. It is unwise to consider these students as either nuisances or "show-offs." They may be bored. The instructor has a definite responsibility for maintaining their interest by giving them more challenging problems to think about.

Stage fright is not confined to the theatre. Even many experienced instructors feel emotional reactions which are akin to stage fright, especially before meeting new classes for the first time at the beginning of the term. If you feel stage fright, remember that this is a virtue. It proves you want to do a good job. It will dissipate under the impact of thorough preparation, a teammate attitude toward your individual students, and the realization that you can help them. Some of them may also have misgivings regarding their own abilities. Get together; you are both there to do the same job by a combined, joint effort.

AT EACH MEETING OF THE CLASS

BE PROMPT. Have ready any exhibits, slides, and papers to be distributed or used. If you arrive a little early, you may find excellent opportunities for personal discussions with individual students. These prologues to the class can mean much to all members of the learning-teaching team. Be pleasant, cooperative, sincere.

Begin with a short review, connecting the previous class work with the new material you intend to present. Remember that your own mind is deeply immersed in the subject and may have been occupied solely with it for the previous hour or two. The student, however, has probably just come from class experiences on a totally different topic. Begin class by getting your minds together on the present subject; recall what you last did together. If there were points of general difficulty, clarify these.

Arouse interest; stimulate the yearning to learn; open the students' minds a little wider; gain undivided attention for the new material and ideas to be presented and discussed. To do these things, the instructor himself must *feel and exhibit enthusiasm* for the subject. The student must see how the new topic is connected with what he already knows, why the new topic is important, how it will relate to things he will come to know in the future. To learn effectively and efficiently, the student must first have the desire to learn. He will have the desire if he understands why the new material is important and if he feels that he is making steady progress, that he is getting somewhere.

Introduce new material carefully. *Move from the known to the unknown,* from the simple to the complex. Make sure the student understands the pertinent technical vocabulary. Define all terms which may be

new or which are used in a specialized sense. "Illumination" and "brightness" are nearly synonymous to a layman but are entirely different concepts to a physicist. The word "nucleus" (and also "fission" and "triton") has a completely different meaning in physics than in biology. Do not obscure understanding and thought by a technical jargon. Use the proper word in the proper place, but be sure the student has or acquires full competence in the precise meaning of specialized technical terms.

A moderate amount of *varied repetition* is desirable. Be considerate of those whose minds wandered — or who were momentarily preoccupied taking notes — and who therefore missed an important item the first time you said it. Repeat it a little later, and in a different way. Spencer is said to have put a similar concept this way: "It is only by varied reiteration that unfamiliar truths are forced upon reluctant minds." It is almost impossible for anyone to pay close attention for fifty minutes. If you are lecturing, make the assumption that at any one time some student who wants to learn is taking a "cat-nap."

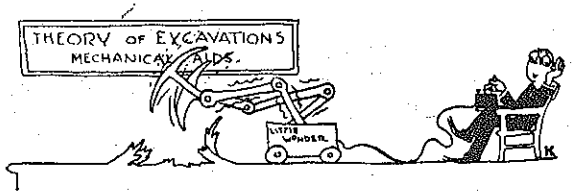
In teaching, try to *appeal to as many of the receptor senses as possible.* Among the five senses (sight, touch, hearing, taste, and smell), the most effective in the learning process usually is sight. Retention is generally poor from hearing, if unaccompanied by other stimuli. It is for this reason that lecture material is much more readily understood, absorbed, and retained if the lecturer makes effective use of the blackboard, of models, and of other visual stimuli while speaking.

This is an age of mechanical aids. We tend to ride, rather than walk; we dig ditches or level airfields with machines, not by hand. We make use of levers, pulleys, wheels, and innumerable other aids to the accomplishment of maximum effects. In teaching, also, there are a number of aids which the instructor should use in order to increase his effectiveness. The most common *teaching aids*, arranged in order of merit, include the following:

ACTUAL OBJECTS. Wherever possible, show the student the actual object being discussed. Let him use as many of his senses as possible in getting acquainted with it. Actual contact with a sample of gneiss, a salamander, a block-and-tackle, or a labor leader is better than thousands of descriptive words.

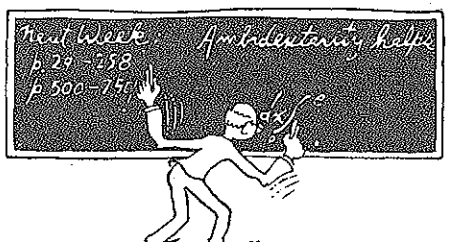
MODELS. Many objects cannot be brought to the classroom or laboratory. The Golden Gate Bridge, a tellurium atom, or an insulin molecule have to be dealt with in some other way. A three-dimensional model is the best approximation in such cases. Different parts of a model show up better if they are painted in contrasting colors. Make effective use of color in the model itself. Pleasingly painted apparatus puts everybody in a better mood than apparatus which demonstrates the same principles but which is rusty, dusty, or otherwise neglected.

TWO-DIMENSIONAL REPRODUCTIONS. When models are not feasible, a good photograph, drawing chart, lantern slide, or other flat representation may be chosen. Motion pictures with sound are excellent because they appeal simultaneously through sight and hearing.



BLACKBOARD. Our most commonly used teaching aid is undoubtedly the blackboard. Even though it may rank well down on the list of general teaching aids, it is our most common ally in the classroom. In subjects which are primarily mathematical, the blackboard is usually the preferred teaching aid. The effectiveness of an instructor at his blackboard can generally be greatly increased if he carefully follows these few almost self-evident principles.

1. Where possible, plan in advance what material is to be written on the blackboard, in what order, and how placed.
2. Use a chalk which is soft enough, and bear down on it hard enough, to produce lines which show plainly from any part of the room. If your chalk tends to squeak, hold it at a sharp angle with the blackboard.
3. Write a little larger than is necessary for clear and unambiguous reading from any part of the room. This will generally be larger than one near the board would guess. Letters whose height is about one-half per cent of the depth of the room are adequate, if they are drawn heavily enough. This means that letters two to three inches high will suffice in most Institute recitation rooms, while letters three to four inches high are needed in lecture halls.
4. Adjust the window shades or other lighting arrangements so that the blackboard is free from reflected glare. If this cannot be done, find out what portions of the blackboard are dead and avoid them.
5. Do not use colored chalk indiscriminately. If you expect the student to take complete notes from



the blackboard, remember that he is probably writing with one color only. Do not use colors the student cannot copy to achieve clarity in a drawing which could be made clearer with white chalk alone, plus a little more effort. If you want your blackboard diagrams to be aids to initial understanding but do not expect students to copy the diagrams in their notes, the use of colored chalk can be very helpful.
6. Write, print, or draw neatly and legibly. Do not scribble. Use standard abbreviations if their meaning is obvious, but do not resort to abbreviations as a cover-up for spelling deficiencies.
7. The blackboard is the visual counterpart to the oral presentation. Devote equal care to each. It is the combined impact on the senses of sight and hearing which is sought.
8. Talk to the students, not to the blackboard.
9. Stand in such a position that what you have written and are in the process of writing is visible, not obscured by your body. Left-handers have some advantages here, but right-handers can manage well with practice in the minor contortions which are needed.
10. In general, do not begin writing in the middle of the blackboard. Start in the upper left-hand corner. Proceed downward until a first column is filled, then move to the right for a second column, etc. If you reach the right-hand side of the board and need more space, erase the entire first column and begin again, from left to right. Systematic use of the blackboard makes note-taking easier for the student, has an orderly appearance, and permits your listeners to

review the past steps you have taken without searching for disordered bits here and there. During or at the conclusion of a lecture, an orderly and sequential set of notes should be obtained if one were to photograph the blackboards. In lecture halls which have vertically rising and overlying boards, begin writing on the outer or front board. When it is full, elevate it, and continue on the inner or back board. Thus the entire sequence of the presentation will be displayed in an orderly and most useful way.

GESTURES. The fifth teaching aid is a sense of good theatre or *showmanship*. If a speaker has to proceed without any of the teaching aids, and has to rely on voice only, then at least he should learn to use his hands and his facial expressions both in holding interest and attention and in the actual process of conveying ideas. No one who has seen it in action will ever forget "Doc" Lewis' forefinger!

TALKING HABITS. In our language the most important part of the sentence usually comes at the end. Avoid the natural tendency to lower your voice at the end of a sentence. Remember also that punctuation must come from the inflections in the speaker's voice. As much care must be taken to do this properly in speaking as is taken in writing. Emphasis does not always come from raising the voice. Separating an important conclusion from the normal discussion by an abnormally long silence is one of the most effective ways of reaching an audience.

ASSIGNMENTS. Homework assignments should be planned carefully in advance. They should be illustrative of the current work, with an occasional review problem thrown in to break up the crank-grinding state of mind which commonly results from a number of problems on the same topic. Their length should be carefully adjusted to the time allowed for the subject. The student rightfully resents the instructor who consistently demands more of his home time than he should.

Be sure that your assignments are clearly stated and thoroughly understood. It is good practice to write them on the board or to pass out printed sheets rather than to dictate them. If you must give an oral assignment, have a student repeat it after you. Try to determine each day the actual time required on the previous day's assignment.

LABORATORY INSTRUCTION

A COHERENT COURSE of laboratory instruction first tries to introduce the student to the scientific method and the use of apparatus and then, as he becomes acquainted with the techniques by practice, attempts to allow greater and greater freedom to apply his knowledge to individual problems of his own choosing.

Adequate preparation is required of both student and instructor. In the elementary laboratories, where it is difficult for the student to see why he is doing his particular set of experiments, the instructor has the greatest responsibility to show the student where his experiments fit into the general pattern of the subject matter in which he is most interested. The laboratory courses are usually arranged so that if

the instructor spends his whole time and effort during the laboratory period talking with the students, he will have time to discuss these general problems with each student individually, as well as the specific problems of detail which come up in the particular experiment at hand. In the more advanced laboratory, where the student is in general performing experiments of his own choosing, the instructor's natural enthusiasm for his subject should be sufficient to maintain the student's necessary interest and attention to detail.

V
Testing

ATTITUDES AND OBJECTIVES

FROM THE STANDPOINT of student-instructor relations and the cultivation of a cooperative team spirit, our examination system is a *potential obstacle.* Just when the instructor has established himself as the student's best friend, he is obliged to examine the student critically. In this examination, he composes the questions and acts as both jury and judge regarding the student's performance. At this stage, particularly, the instructor must seek means of preventing his own metamorphosis into a taskmaster in the eyes of his students.

It is essential that both the instructor and the student be fully aware of the objectives of the examination and of the interpretation to be put on the results. An examination is merely a quantitative observation

on a process — the process of learning. Really, both the instructor and the student are being observed. The examination is an observation on their progress as a team.

The principal *objectives* of examinations are:

1. To evaluate the level of each individual student's achievement on a scale relative to that of his colleagues and of his predecessors.
2. To evaluate the effectiveness of the instructor's teaching.

If the examination is to constitute a trustworthy observation of the student and of the instructor, it must be very *carefully formulated*. It is the instructor's responsibility to compose the examination. But much is often learned by having the students participate in the creation of an examination. One reasonably successful mechanism is to have each student submit one question (including his own solution to the question) about a week before the examination. From the possibilities thus submitted, the instructor can pick out a predetermined number of problems to be included on the examination. This type of *student participation* in the preparation of examination questions is occasionally useful, especially in advanced courses, for neutralizing a potentially antagonistic atmosphere between examiner and examinee. It may help to preserve and to enhance the cooperative team spirit between the instructor and the individual student. Usually the problems submitted by students will be much too difficult for direct use on examinations. They will often need to be modified and recast by the instructor. The method provides

some variety and stimulation and is helpful to the student in focusing his review work on definite objectives. The preparation of examination questions is an effective aid to learning.

There will be some situations in which the instructor can call in a professional colleague to be the examiner. This method has the advantage of preserving the unity of the instructor-student team and has the disadvantage of placing a heavy responsibility on a guest examiner whose viewpoint, knowledge, and emphasis may differ markedly from that of the instructor who actually worked with the students.

PROPERTIES OF A GOOD EXAMINATION

AN EXAMINATION is an observation on the learning process. It is analogous to an electric meter used to make an observation in an electrical circuit. We must use a type of electric meter which is appropriate to whatever characteristic of the circuit we wish to test. If we desire to know the current, we will do better with an ammeter than with a voltmeter. Similarly, an examination must be adapted to whatever we wish to measure about the learning process. Almost any examination will measure something, but it is not always obvious just what is being measured. An examination which was intended to measure knowledge may turn out instead to measure speed of writing. One which was intended to measure thinking ability may turn out to depend more on memory. Great care must be taken in the preparation of an examination to make sure that it measures what it is

supposed to measure, or, in a word, that the test is *appropriate.*

A second necessary condition to be met by a satisfactory examination is that it must be *reliable* in its measurement of whatever it does measure. The readings on an electric meter may be unreliable if the bearings stick, if the terminals are loose, or if the observer fails to eliminate parallax. Similarly, some examinations are more reliable or more reproducible than others.

There are many variables involved in the examination process. The instructor is a variable, the student is a variable, the particular examination is a variable, and the grader is another variable — even if he happens also to be the instructor. The objective of an ideal examination is to *minimize the fluctuations* due to all variables except the characteristics of the student, including his state of knowledge and his ability to use knowledge. Everyone has off days. The result of a good examination given to an ill, fatigued, or disturbed student will not be a reliable observation on his ability. Don't be impersonal about examinations. Win the confidence of your students so that they will feel free to come and tell you when they have had bad days; then try, in-so-far as is practical, to take these facts into consideration in the final grade.

To smooth out these fluctuations, it is desirable that *several tests* be given each term in each subject. The instructor must devote a considerable amount of time and thought to the preparation of examinations so that they will come as close as possible to being

appropriate to the measurement job at hand and reliable in their results.

No examination can cover all the eligible material. Every examination is a spot sampling of the entire material and of the student's abilities. The examination is a *teaching aid* in-so-far as it picks up the more important points and focuses the student's attention on them. It is also a *learning aid* for the student in-so-far as it stimulates review and correlation of ideas.

An examination which is to be fair to all must be difficult enough so that no student gets a perfect score and easy enough so that no student gets a zero. In terms of the electric meter, reliable readings are best obtained in the middle and upper half of the scale. If the pointer is against either pin, at full-scale or at zero, the readings are less significant. The student who gets 100 per cent in an examination has in fact been cheated, because he has not been permitted to demonstrate how much more he can do. Few students object when they get 100 per cent; but they should, unless the examination is of the "minimum essential" type.

TYPES OF TESTS

TESTS MAY be divided into two very broad and obvious classifications — *open-book* and *closed-book.* When the student is permitted to use his text, his notes, and any reference material brought to the examination room, the questions can be more genuinely representative of matters met in practice. Memory for

details — spontaneous recall — will play a minor role. The student is confronted, as he would often be professionally, with a problem requiring solution, and the only issue is whether or not he can produce. This applies not only to the time-restricted open-book examination but also to the *home-quiz*. The home-quiz which lasts for a week or more tests the student's ability to arrive at an answer when essentially going at his own pace. However, the open-book examination is not always the prototype of professional practice. There are plenty of professional circumstances where the engineer, scientist, economist, administrator, or physician must respond and act without benefit of his library. The choice between open-book and closed-book in any particular examination will depend therefore on which type is more appropriate — that is, on what types of abilities are being tested.

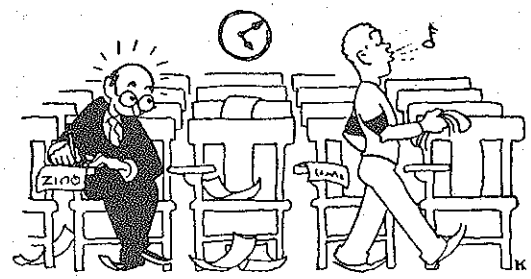
Essay-type tests have their principal usefulness in the liberal and fine arts, where opinion, organization of material, and forcefulness of expression are important variables to be tested. In engineering and the sciences, *objective tests* are used almost to the exclusion of the essay type. Among the objective tests there are many individual types, of which the most common are:

True-false
Multiple choice
Completion of sentences
Matching of scrambled pairs
Correction of errors
Computations
General derivations from given premises

Most of our examinations tend to concentrate on the last two types. Experimentation with other types is often fruitful.

In objective questions involving several computations, *inter-dependence of answers should be avoided.* This is as much a favor to the grader as to the student.

Above all, each question should be *clearly and unambiguously stated.* It is desirable to have each examination "guinea-pigged" in advance by a teaching colleague, in order to locate inadvertent ambiguities and to get an estimate of the time actually required to complete the examination. Students will generally need two to three times as much time as is required by a competent instructor in the same subject.



VI
Grading

KNOWLEDGE AND INTELLECTUAL ability are qualitative phenomena. The grading problem, which seems at first glance to be quantitative and statistical, is in a more profound sense *qualitative* and intuitive. The number of right and wrong answers in a quiz can be counted, but only the teacher's intuitive judgment can establish whether a given student is of "A" or "B" calibre or set the boundaries of other categories of human excellence.

A teacher who has only a few students and knows each one well needs no marking system to compare them or to describe their capabilities. When, on the other hand, students are numerous and personal acquaintance is very incomplete, marks become necessary as a short-hand means of comparing the excellence of individuals. Such comparison is a practical necessity to establish standards, to apportion honors

and scholarships, and to aid in guidance — for example, by deflecting those who are unsuccessful into activities for which they may be better fitted.

The proportion of failures is usually very small in any given subject. Failing grades, when they occur, may be an important guide to the student and his advisers. Equal talent in all lines is not a general characteristic of men, and each student needs to find his weaknesses as well as his strengths.

The use of "letter" grades, as practiced at M. I. T. and many other places, rightly emphasizes the essentially qualitative nature of the thing we are trying to measure. But the instructor, confronted with the practical necessity of grading his students, is faced with a dilemma. Essentially, the problem is whether to apply an absolute standard of performance to his class or whether to assign marks "on the curve." Quizzes in which nearly all the students fail — or in which nearly all get "A" — are examples of applying an "absolute" standard, perhaps unwisely.

In a class numbering only a few students, each of whom he knows intimately, the teacher must set his own absolute standard and decide whether the student measures up to it or not. With a large class, *statistical samples of performance* in parts of the subject must serve as substitutes for close personal knowledge, and accordingly "grading" becomes necessary. Thus a quantitative approximation serves as a substitute for the direct contact of mind to mind which is the essence of the teacher-student relation and which gives the teacher an immediate and intuitive knowledge of the student's progress. In practice, three or four

one-hour quizzes and a final three-hour examination must be relied upon to provide these samplings.

In grading a class, every instructor must strike what seems to him a reasonable compromise between the absolute standard implied in his knowledge of the subject and the practical necessity of establishing boundaries for the category of "A" students or "D" students. There is no inherent reason why the curve should follow the "normal" probability pattern; in fact, since the student group at M. I. T. is highly preselected, there is every reason to expect a skewed distribution. The instructor should not become so preoccupied with the statistical aspects of class grading as to lose sight of the real factors of intellectual calibre and growth in the student. On the other hand, it is essential for him to take some account of general Institute practice in these matters, particularly if he has a section in a large course where some uniformity in the distribution of grades is an essential from the standpoint of fairness.

It is widely asserted, and undoubtedly true, that students place undue emphasis on grades and on their term-by-term cumulative ratings. Grades, however, should be regarded as a necessary evil, not as ends in themselves. All must cooperate to see that grades perform their intended functions and that students and instructors find their real inspiration and motivation not in seeking grades but in the acquisition and use of knowledge and in growth in intellectual stature and wisdom.

VII
Counseling

NO INSTRUCTOR can consider his job properly done merely by meeting his classes. He should arrange his schedule so that students can find him easily and will therefore turn to him for help. This can be very time-consuming for both instructor and student unless the instructor budgets his availability. If you set up regular office hours for conferences and consider them as rigid a responsibility as meeting your classes, you will find that both you and your students take most efficient advantage of this mutual contact. Remember that students are complex human beings and that time spent discussing their *personal problems* may often be more important to their educational welfare than the algebraic intricacies of a particular class assignment.

The teacher's role includes counseling as an integral part of the educational process. Counseling in-

volves all the contacts between the teacher and the taught, in and out of the classroom. The good counselor listens to the student with complete acceptance of him and usually without passing moral judgment. He understands that for many questions there are no answers, and for many wrongs there is no one person to blame. As a rule he does not give advice directly. He realizes that the mere formulation of the problem will make it objective enough for the student either to make a constructive attack on it or a sensible defense against it.

The good counselor is *friendly* with students but does not become involved in personal relationships that encourage undue dependence. An important part of his job is to help a student free himself from preoccupation with personal matters so that he can devote his energies to his work with the least possible interference. His constant aim is *to help the student understand himself* and thus be able to solve his own problems.

The good teacher minimizes the difference between himself and his student. Both are students with the same aims; one is only more advanced than the other. The teacher and the taught are on the same side of the material. They are not adversaries.

If a teacher is to understand the student, *he must first understand himself*. This means that he must have a working concept of personality and that he understands the existence of unconscious mental processes. He is aware that humans handle their problems by such common mechanisms as shift and substitution, denial, and escape. He uses common

sense; but he realizes that common sense has limitations because of the student's conscious and unconscious attempts to make the best case for himself, and because of the blind spots in the teacher's understanding of himself. He realizes that immaturity in all its forms, including prejudice and ignorance, is the reason for his existence as a professional person. He is well aware of the good effects of genuine friendliness.