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THE FAILURE OF THE UNIVERSITIES—I:  
SCIENTIFIC AND TECHNOLOGICAL

Richard Bellman  
Mathematics Division  
The RAND Corporation

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SUMMARY

A discussion of the lack of universality of the university, of the artificial images of the "intellectual man" and the "practical man," and, generally, of life, liberty, and the pursuit of knowledge.

THE FAILURE OF THE UNIVERSITIES--I  
SCIENTIFIC AND TECHNOLOGICAL

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1. Introduction

There is a sad and yet quite useful, in a sense we shall make precise below, story which runs as follows. During the Black-and-Tan difficulties in Ireland, it was quite common to have agent provocateurs spotted in the taverns. If these enterprising individuals could induce some Irishman, emboldened by whiskey, to shout "To Hell with England," or "Down with the King," they collected one-half of the fine of one pound--a sizable amount in a poor country like Ireland.

The story goes that one evening one of these agents spotted an old man sitting in a corner muttering to himself, "To Hell with--," and then again, "To Hell with--." Practically feeling the half-pound in his hands, the agent sidled over and engaged in conversation. From time to time, he asked "To Hell with what," "Down with whom?"

Each time, the old man changed the topic, but the agent kept persisting. Finally, the old Irishman fastened him with a piercing look and said, "Finish it yourself. It's too damned expensive for me."

Often I have gone over this story in my mind to brush off some trifling incident or some petty person. It has been extremely useful in this way. But there are some matters which cannot be disposed of in this simple fashion, and one of

these is the state of our universities. The Brahmins they produce, the couth coterie they retain and the myths they propagate alike cannot be thus dismissed.

These are the topics we wish to discuss in the following pages, concentrating in this article on the technological and scientific consequences. In subsequent articles, we shall consider the effects upon our political and social systems, of the type of citizen produced by the universities, the effects upon our culture, and other dismal subjects. In the concluding part, we shall attempt to outline various programs designed to improve the situation.

## 2. The Purposes of the University

It is appropriate to begin by stating the responsibilities of a university in a free society. It must, first of all, be a self-reproducing mechanism in the sense of continually turning out scholars who glory in the freedom of the creative imagination, who honor the human spirit, and who believe in the full man. Concurrently with this, it must produce the trained personnel who will maintain and advance our technology, who will endeavor to cure us of our bodily and mental ills, and who will protect us against our enemies.

In both of these aims, the universities have been dismal failures. Furthermore, they have been failures in almost all

possible ways.\*

### 3. Prologue

This is a serious indictment and should not lightly be levelled. Although it would be preferable to have it shown to be a rash and ill-considered judgment, I am afraid that it is all too easily documented.

This judgment has been accumulating over the years as a result of the usual experiences as an undergraduate at reputable colleges, as a graduate student at universities of high repute, and finally, as a faculty member at two of the highest repute. Add to this a few years of wartime service on crash scientific projects, and a number of years as a mathematician outside of academic life, and I feel that I have had an adequate opportunity to evaluate the educational philosophy of the universities, the manner in which the students are trained, the effect of both of these factors upon the output as far as scientific work is concerned, and finally, the type of citizen that is produced.

Despite my strong feelings in this direction, reinforced by countless discussions over the years with others equally critical, there has been a great reluctance on my part to

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\* In all fairness, it should be pointed out that college football has improved enormously over the last twenty-five years, due in no small part to the superior prestige and salary accruing to a football coach at a major institution. It is generally conceded that the best Midwestern teams are on a level with the professional clubs.

write articles of this nature. This is due to my belief that in recent times, the universities have been on the whole attacked by the wrong people for the wrong reasons. Badgered as the academic world has been by bigots, fanatics, and political oppertunists, I felt that it was inadvisable to add to this random bombardment.

Since, however, the problems that our society now faces are of such a critical nature, and since the universities occupy such a central position and play a crucial role in their solution or lack of solution, I feel that open discussion of these matters cannot in clear conscience be postponed.

These are not new matters. I am sure that no reader of a trade journal such as the Bulletin of the American Association of University Professors will find them of any novelty. But the fight has been kept a family fight, restricted to "sisters and cousins and aunts," and resolutely kept from the public.

There is, of course, some justification for this, and ample precedent. The medical profession does not like to air its qualms about fee-splitting and hysterectomies in public, nor does the legal profession engage in open debate concerning the type of training suitable for a criminal lawyer.

Nevertheless, this private debate in the academic ranks is a serious mistake. If we believe in democratic principles, we must believe that when the lay public comes to understand the basic problems confronting the universities, and the magnitude of their difficulties, it will become more sympathetic.

This understanding and sympathy will furnish the proper shields against vicious and unwarranted attack, and the correct foundation for positive support.

#### 4. Interlinking of Aims

In the foregoing lines, we have stated two of the fundamental objectives of university training. We do not wish to imply that one purpose is superior or "nobler" than the other. Only because it is impossible to state both simultaneously, have we followed one order or the other.

Our society vitally needs both outputs. Our fundamental thesis will be that not only is there no contradiction between these aims, but that one reinforces the other.

In other words, the closer the creative mind is to the real world, the more productive he will be, and the more that the real world calls upon the imagination and the intellect, the better the results.

#### 5. Survival--Pro and Con

Let us begin with the primary question of survival. In view of some of the prevalent academic attitudes we shall examine, it is a topic that requires some discussion.

It is essential that we stress the fact that survival against the barbarian hordes is necessary for any society. Without existence, no other aspect of a society is of any significance, except to historians and archaeologists.

Survival, however, is not enough. There is the double

task of defending our civilization against its mortal enemies, and of maintaining the ideals of our civilization. Without survival, there is no point to ideals; without ideals, there is no point to fighting and dying for one type of tyranny rather than another.

#### 6. Reasons for Survival

That we have survived as successfully as we have over the tumultuous period of the last thirty years is due to a combination of four factors--geographical isolation, inefficiency and shortsightedness of our enemies, the sacrifice and devotion of a few, and luck.\*

Of these attributes, let us observe that geographical isolation has all but vanished, and that the goddess Fortuna is notoriously fickle with her favors.

Sacrifice and devotion can work miracles as long as the technological gap is not too great. Even the Kamikazes could not save Japan from the power of the American naval armada. Scientifically, over the last twenty years we have been coasting, using up a reservoir of talent and training from Europe.

Finally, we must recognize that unlike the Westerns on TV,

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\* As an example of this, consider the fact that the most idealistic European physicists and mathematicians of the past thirty years were also the best. It is interesting to compare the level of those self-exiled scientists who joined the fight against the Axis by working at Los Alamos on the A-bomb with that of the German scientists who worked for the Axis at Peenemunde on the V-2.

there is no necessary correlation between a pure heart and accuracy of aim. Regardless of what we think of the political structure and moral framework of our principal and formidable rivals, we must face the fact that they possess the scientific potential and the political savvy to render us extinct if we keep on coasting.

### 7. The Grandeur that was Rome

Two thousand years ago, when Pax Romana ruled most of the civilized world and all roads led to Rome, it was easy to recognize barbarians. Crudeness of dress, crudeness of speech and crudeness of weapons distinguished the primitives.

Today, the distinctions lie deeper. Over the years, we have learnt painfully from the Fascists, the Nazis and the Communists, and elsewhere, that barbarians can possess Ph.D. degrees, manipulate electronic gadgets, and build excellent V-2's. They wear business suits, and formal attire on occasion, and deliver talks over television. They have learnt to mask their thoughts and ambitions with pious platitudes and to sugarcoat their designs with all the resources of modern psychology.

Two thousand years ago, the tribes that menaced Rome on all sides had little to supplant that of the mother of nations. Their leaders were overjoyed to proclaim themselves Caesars and to assume the purple that signified the majesty of Rome. Today, we are menaced by civilizations founded upon principles different from and opposed to ours, willing and eager to sweep

us into oblivion.

We have dwelt upon all of this to emphasize the fact that we are in a technological race for survival, not only in the field of weapons, but in many other areas.

This deadly conflict of cultures also makes it imperative that we educate our citizens to the true values of our civilization. What we have to offer to the human soul must be clearly apparent. One has the feeling that apple pie and refrigerators are not enough.

It follows that in addition to exposing the failure of the universities in the area of technical training, and hence defense, it is imperative to analyze their failure to turn out the type of citizen required by a dynamic democracy. This we shall discuss in the second part of the series. It is worth observing, however, that certain basic faults result in both deficiencies.

Let us now climb down from the eyrie from which we have been contemplating the decline and fall of empires, and examine the modern university.

#### 8. Survival Depends upon the University

The bridge that we use to go from one topic to the other is the observation that the university is our principal, and almost exclusive, source of scientific personnel, teachers of science, and research scientists. It follows that if our survival depends upon the level of our technology, then our continued existence depends upon the correct functioning of the university.

## 9. Myths and Mythology

In discussing the operation of the university, we must begin by disposing of the image of the "academic type." The people who inhabit the monastic walls of the modern college are no more of one breed than the products of West Point or Annapolis, the members of the Stock Exchange, or the members of a labor union.\*

Despite the extreme divergences of the members of these groups, there are certain myths and "mystiques" common to these groups which have significant effects upon the behavior of the individual members.

Of the fantasies that harass our society, none probably is more dangerous than those of the "intellectual man" and the "practical man." One has its roots in the academic world; the other in the world of affairs.

Let not the reader think, however, that the universities are not afflicted with both. In the Engineering schools, and in the Dean's office, and usually the President's office, we

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\* It is rather interesting to see how the popular conception of the university professor has changed over the last twenty-five years. One way to trace this is to compare the characterizations in the movies and in the leading women's magazines, then and now. Twenty-five years ago, the university man was a lovable absent-minded "prof" never without his bumper-shoot--something of the order of Mr. Chips played by Robert Donat-- , or, on the other hand, an evil genius such as Professor Moriarty (a mathematician, incidentally). Today, he is young, vigorous, and handsome, say Ray Milland in the television series, or as pictured in the romantic stories of McCall's.

find a plethora of practical persons.

Perhaps the largest group living in the academic world is comprised of those who feel that a Ph.D. degree is akin to a vow of chastity. To be more skilled and productive academicians--so their argument runs--they must divorce themselves from the temptations of the society that surrounds them. Not content, however, with stuffing their ears to drown out the Siren song, and lashing themselves to their desks, they must also reject their society, despise it and ignore it. Although they go by various names, let us call them, for want of a better label, "intellectual men."

Their status symbols are many, but as is most sad, they are mainly rooted in rejection, a rejection of life, a rejection of vitality, a rejection of adventure.

Their counterpart, found in sizable numbers in the business and political spheres, but also in the university itself as indicated above, accepts only the obvious, the "tried and true." Their status symbols are also many, but again founded upon rejection, a rejection of the mind, of the spirit, of faith and hope and charity. Although they are found under many guises, let us call them the "practical men."

What is both amusing and sad is that each believes devoutly in the mythology of the other. Thus, the intellectual man is perfectly willing, although he has long ago given up a belief in Santa Claus, to believe in the devils that inhabit

the outside world--cold, ruthless, ignorant people, motivated only by power complexes. Similarly, the outsider who has long ago ceased believing in a personal Devil is perfectly content to accept the image of saintly, unworldly characters living and teaching within the academic cloister.

That examples of each category can readily be exhibited makes it quite easy to extend blanket indictments. Needless to say, these mental images are not conducive to any free and easy interchange of ideas and goals between these groups. Each enters a discussion with the other with chips on both shoulders and one finger firmly planted on the panic button.

Where, when and how it came about that in our society it should be believed that intelligence and professional training are a detriment to the successful handling of the affairs of the nation and the market place are themes that are too difficult to explore here. It must be pointed out, however, that these matters are far too important to be left in the hands of "practical men."

Equally deadly is the strongly held belief that the creative mind should get himself to his monastery, and keep his educated nose out of world affairs.

It does not require a particularly acute observer to see that unless this schism is ended, our society will founder, if not upon one shoal then upon another. Either myth is dangerous in itself, and the combination is deadly.

There are, and always will be, "shadow men," one-dimensional individuals with the same bloodless face always turned towards

the world. That these half-people should have any large say in the administration of business or government or the university is indeed absurd.

A delusion which feeds the myth of the "intellectual man" is that the best creative effort requires a sterile solitude far from the madding crowd. One has to only think of the lustiness and vigor of the Italian renaissance or the Elizabethan era in England, to see what a misconception this is. Nonetheless, there are always patrons who wish to establish "Institutes" to pluck the genius from life, and life from the genius.

Think, for a moment, upon the merits of a plan which wishes to protect the creative mind from the hurly-burly of academic life! The next, most logical step is to feed the members of these institutes vitamin capsules in place of ordinary food.

#### 10. Academic Snobbery

If there were any natives of the South Sea islands rude enough to intrude themselves upon our culture the way we do upon theirs, one of the aspects of university life which might most pique his curiosity is that called "academic snobbery."

This bold native, complete with psychological questionnaire and pencil, would observe that any inmate of a university--excepting, of course, the janitorial staff--considers himself superior to any outsider. Furthermore, he would observe a peculiar "pecking order"--or, as they say in the

South Seas, "monkey-cocoanut-throwing order"--in which the social scientists defer to the physical scientists. Within the physical sciences, the chemists bow to the physicists, and the physicists to the mathematicians, although there is occasional controversy on this last point. Within the mathematical sphere itself, those who work in fields most removed from human experience consider themselves most advanced. This will be discussed again below.

At night, within the confines of his comfortable outrigger canoe, the native might at first sight be puzzled by this apparent contradiction. How is it that a depressed group, poorly paid, with little prestige, retains this feeling of superiority?

Thumbing through his cocoanut leaves which contain notes on a course in intellectual history, he will soon perceive that this is a quite common phenomenon. Let society reject a particular group, treat them shabbily, and the first thing you know, as a defense mechanism, this group has a "mystique" which enables it to feel superior. History is full of examples.

#### 11. Why Should the Reader Care?

At this point, having plowed through several pages of verbiage, there may be a certain tendency on the part of the reader to shrug his shoulders. Why should these local wars and batties over status interest him?

Why should he care whether or not a professor of mathematics knows or cares about engineering or history or the

deplorable state of West Coast football? If none of these affect the immutable fact that  $2 + 2 = 4$ , how does this separation of the academician from the outside world affect the fundamental task of the mathematician, or the jobs that the university has to perform?

Unfortunately, as we shall see, in this technological world, it affects practically everything. We shall analyze below what effect this has upon the teaching of mathematics. In this world of swirling ideas, this idea of aloofness wreaks havoc.

## 12. The Non-universality of the University

Before examining the case of mathematics in detail, let us study the university in general outline.

The university presumably derives its name from the concept of an organization devoted to the study and development of all branches of human knowledge. It is a noble conception, an institution within whose halls it is possible to obtain a knowledge of Sanskrit, a thorough grounding in French history, or an ability to synthesize protein molecules.

There is a well-known Latin proverb which reads

Mons laboravit et parturit mus.

Roughly translated, this states that the mountain anguished in labor pains and gave birth to a mouse. What an apt description of the workings of the modern university!

With all the fabulous resources that it contains, the cultural heritage of all past civilizations at its command as

well as the modern genie of our mechanical and electrical age, does it produce the well-trained, well-rounded scientist, eager and vital?

It produces, nay bends every effort to produce, the narrow, specialized robot. Highly trained in one direction, over-trained in one spike of knowledge, and ignorant of most everything else--this describes the typical product of our graduate schools. The typical product of our undergraduate schools is merely ignorant. He is not overtrained in anything. Both of these are on the whole desperately ignorant of human values, precisely the most important values of our civilization.

Think for a moment, vistas of 1984, of this situation in which the new elite, the scientific cadre, is becoming more and more powerful with less and less humanity and understanding. For those who like horror shows, I recommend fifteen minutes of contemplation of this as an adequate substitute for Dracula and Frankenstein. And for those who have no projective imagination, I recommend that they read about what is happening in Communist China at the moment in connection with the new Commune system.

We have agreed, however, to restrict ourselves to the scientific scene here. We see doctorates in mathematics who may never have taken more than a freshman course in physics--if that--to say nothing of chemistry or biology. In return, we see summa cum laude's in Physics, up to the Ph.D. level, whose only experience in mathematics has been on a level with follow-

ing cookbook recipes--and not particularly esoteric cookbookery either. What is worse, they don't even know this.

What is perhaps even more surprising to the uninitiated is that the great majority of Ph.D.'s in the same field--say mathematics, where it is easy to document this--cannot discuss their theses with each other. Furthermore, this will be the case with students from the same school, the same department, and often the same senior professor.

Each of these students is encouraged by his professor, and his department, to consider his field and his thesis topic as the most important direction of human culture. This is reasonable and pardonable in the young, who must be sustained by enthusiasm to endure the cruel initiation rites of the university. But when the student is encouraged to consider his field as the only proper study for a brilliant man, and persists in this belief past the age of maturity, then we are entering the dangerous areas of snobbery.

I recall an incident involving a product of a very famous university and an equally famous professor who came to see me concerning a position in one of the electronic laboratories in Southern California. Upon being asked what his major specialty was, he replied, "Algebraic Geometry." When I pointed out that employer's eyes did not light up with glee upon hearing this, he added that he was also an expert in Algebraic Topology.

I agreed that these were fascinating areas of mathematics, but that some experience in the fields of ordinary or partial differential equations would be desirable.

"Oh," said he, disdainfully, "I've never taken any course in applied mathematics!"

What a terrible set of words are these, "pure" and "applied." How well they sum up so much of the academic attitude that now exists. What a wonderful pejorative quality to the word "applied" and how richly satisfying is the adjective "pure." Oh, Vestal Virgins, guarding the sacred flame of Truth!

One wonders if the thought ever occurs that such immortals as Archimedes, Newton, Gauss and Poincaré all could be classified as "applied."\*

What these selfsame attitudes do to the training in the social sciences, and to the relations between the physical scientists and the social scientists, will be discussed in the second of these articles. It may be surmised that the situation is not what might be desired.

One of the worst effects of this academic snobbery, and of the battle between the "intellectual man" and the "practical men" is the cleavage between the mathematicians and the engineers. In practically any university, we can observe the spectacle of one set of courses being given in the mathematics department and another set of courses, with very much the same titles, being

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\*Scientific and cultural historians of the future will perhaps be intrigued by the fact that the leaders of the ultra-abstract clique, the Bourbaki, who would like to have mathematics secede from everything else, are French. Perhaps they will be able to trace a connection between the political and cultural difficulties of the French nation and such manifestations as Existentialism and the Bourbaki.

given in the engineering school.

It is clear that it is the student who is cheated. If mathematics courses are taken in engineering, he suffers from lack of contact with the best mathematical thought and training; if he takes his courses in the mathematics department, he suffers from an abstract approach that is unmotivated and divorced from the field of application. One has the feeling, quite often, that the courses are deliberately slanted to repel the engineer and the physicist. The keepers of the sacred flame do not wish to be contaminated.\*

### 13. The Universality of Problems

What is delightfully ironic, to one who has a cosmic sense of humor and is not particularly worried about such minor perturbations in the pattern of culture as may occur in the next hundred years, is that as this emphasis upon narrow specialization increases, the problems that we face become of broader and broader aspect.

Thus, the problem of cancer appears to depend upon an understanding of some of the basic processes of living organisms. The more that it is studied, the wider the problem appears. Similarly, the problem of mental health which seemed completely resolved with the aid of three Viennese doctors, and a few New York doctors, now appears to have fundamental

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\* The situation is reminiscent of the medieval mysteries where knowledge was considered power. Newton was a prime example of this. When he discovered how to solve differential equations by means of power series, he sent the information out in the form of an anagram!

biological and chemical roots.

The fundamental questions to which we seek answers do not come neatly labelled as "Chemistry," "Solid State Physics," or, perhaps as exercises at the end of a textbook. Without proper perspective, it is very easy to miss the basic problem completely.

#### 14. Can We Turn Out Universalists?

At this point, it is appropriate that the objection be made that the vast extent of current knowledge effectively prevents any single individual from absorbing any appreciable fraction of it. Even a colossus can no longer straddle a single field. Gone are the days of a Swedenborg or a Helmholtz--and so the defense mechanism continues.

It is comforting to know that similar despairing remarks were made at the time of the Renaissance, and probably by contemporaries of Archimedes. Most likely, the first Cro-Magnon man who was forced to qualify in both bow-and-arrow and spear muttered similar sentiments.\*

What these remarks really signify is that facts are accumulating at an alarming rate. But theories are not increasing at the same rate. As a matter of fact, as research continues, we find a remarkable synthesis of theories. Those which seemed to exist in quite different domains based upon unrelated ideas, turn out to be special cases of more basic and

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\* For a further discussion of related ideas, see the charming book, "The Sabre-Tooth Curriculum," McGraw-Hill Book Co., Inc., New York, 1958.

powerful theories. A characteristic of these more powerful techniques is that their conceptual basis is usually quite simple, although a higher level of mathematical analysis may be required to go from fundamental concepts to analysis of experimental data.

It follows that if we pick up the theme enunciated above, "problem orientation" rather than "departmental orientation," it will not be too difficult to produce graduates well versed in the basic ideas of all the sciences, engineering and mathematics. This combination of basic training and mental discipline will enable a scientist thus trained to fill in the details in any particular field as needed.

After all, any tape recorder can compete on the basis of facts. It is the interpretation of facts that makes the research scientist. Of course, a knowledge of the multiplication table is handy, and one would not wish to derive this from first principles of arithmetic every time one encountered seven times nine.

#### 15. The Curse of Progressive Education

It must be realized that the university cannot carry out any sensible program of education without the cooperation of the public schools and high schools.

With the best possible integrated program and the most inspired faculty, little can be done with high school students who can't read, can't write, and have been trained in laziness, spoonfed with intellectual pap.

In order to lay the proper foundation for the university, we must break the death-grip of the self-styled experts in "Education." Some way must be found to root out these individuals who have made "Progressive Education" an obscene term.

The Education Departments and the schools attached to universities turn out by the thousands public school and high school teachers imbued with a desire for conformity and togetherness. They are devoted to the principle that anything can be taught by the Method. According to these people, it is not necessary to be well-grounded in a subject, the Method will light the way.

No sensible person wants to return to the classrooms of the 1850's, but it is a shame that the best of the old cannot be combined with the best of the new. It certainly must be emphasized that learning is fun, but also that it requires hard work and guts--a word that is perhaps not fashionable but which aptly describes and sustains a scientist in the face of many a bitter disappointment and failure.

Any youngster who has played baseball or tennis knows that no worthwhile skills can come easily, nor are the easy ones of any worth. Why should one expect that skill in the best game of them all, the play of the mind and the imagination, should come easily?

#### 16. No Royal Road

There is a possibility that this more rigorous training may discourage some university students whose minds cannot be

stretched in the desired fashion. Among these, there will certainly be some who could make contributions in special domains if allowed to enter a particular field and remain there.

Against this loss, we must balance the terrible loss sustained under the present system where some of the most creative minds are either discouraged or stifled.

We are not, after all, talking about mass education in discussing the type of training required for the scientist. Since the progress of a country depends upon its best minds, not upon its second best, we must design an educational system which stimulates these.

Such a system will not be an easy one, and even the gifted student will be forced to work hard. Since the research road is infinitely rockier than any university curriculum, no matter how demanding, this is certainly desirable.

#### 17. The Lure of Formalism

As we have pointed out, significant problems are generally difficult to solve, and sometimes difficult even to recognize.

Although many of these problems require a broad scientific and philosophic background, they are approached by the typical Ph.D. with "little knowledge and less philosophy." Instead of subjecting these problems to a penetrating analysis, there is a strong temptation to borrow machinery already in existence and apply it willy-nilly. Whenever a method is applied in a routine way to a problem because of a resemblance to another

problem, real or fancied, we say that we are indulging in formalism.

Formalism, this belief in the intrinsic content of symbols and intellectual structures, is one of the last strongholds of primitive magic. Since it has worked so amazingly well in various branches of science--as, for example, quantum mechanics--there is no reason to scorn it. But it must be used with care.

It is particularly tempting to invoke the sacred name of mathematics which enjoys a moderately deserved reputation for exactitude. We observe various fields of engineering and the social sciences going full steam ahead with masses of equations. One of the first things that one learns is that mathematical conclusions are no whit better than mathematical premises. Turning the mathematical crank in no way adds verity, although it does add verisimilitude.

This is not to say that there is too much mathematics in engineering and the social sciences. Quite the contrary! We wish merely to point out that a great deal of routine mathematical analysis is used to provide a false front of respectability for operations which might not stand the spotlight of common sense.

Two stories come to mind. At one university, the chairman of the philosophy department for a long while refused to talk to the chairman of the department of mathematics. It came about in the following way. One day, a mild little man came to show the mathematics chairman a mathematical model of theology in which God, the angels, the saints and the Devil all obeyed

certain mathematical formulas. With a perfectly straight face, the chairman of the mathematics department listened to all of this and dispatched the visitor to the chairman of the philosophy department, who, he was assured, was the appropriate and interested party.\* It was a long time before the philosophy chairman saw the humor of the situation.

On a more serious level, I recall giving a talk before a conference on engineering education in which I pointed out the many difficulties encountered in formulating mathematical models of physical situations, and the even greater difficulties met in economic and social situations. Here we meet the imponderables of emotion and psychology.

I questioned very strongly the validity of these latter models and emphasized the great care that must be exercised in using any numbers derived from these models.

No sooner had I finished my caveat when someone in the back of the hall raised his hand and wanted to know how to construct a mathematical model involving five hundred workers at a utility company and their use and misuse of water fountains and washrooms.

Truly, mathematica omnia vincit!

## 18. The Teaching of Mathematics

Some pages earlier, we promised to indicate why the teaching of mathematics is not a routine matter.

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\*The chairman was applying a technique made explicit by Bertrand Russell. If a vegetarian buttonholes you and informs you that nuts are the only sensible food, and cashew nuts best of all, agree with him on basic theory, but maintain resolutely that walnuts are better. It makes for amiable conversation.

As we progress up the mathematical ladder, we find that there is more and more to learn, with more and more interconnections. Consequently, there are many different approaches and many different starting points.

Here, the matter becomes quite subjective, and completely dependent upon the psychology and philosophy of the individual mathematician.\* Here we see the strongest resemblance to the other arts such as music, painting and sculpture.

As we know, much of mathematics has evolved from scientific investigation of the physical world, and one can make a good case for the claim that most of the theories of any significance have strong roots in the physical world.

It follows that in presenting a particular subject in mathematics, one can motivate the methods and results by sketching the physical background. At the other end of the scale, one can employ a purely axiomatic approach, and completely ignore the origins.

There are advantages and disadvantages to each approach, with the result that the experienced and skilled teacher and expositor employs sometimes one method and sometimes another. It is certainly strange to find certain groups, of which the aforementioned Bourbaki stand at one extreme and various engineering departments stand at the other, wishing to follow one road completely to the exclusion of the other.

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\* Elsewhere, Simulation and Stimulation, RAND Paper P-1581, we have discussed the influence of philosophy upon the construction and interpretation of mathematical models.

It is the continuing battle between the "intellectual men" and the "practical men," with the well-balanced men the victims.

We see, then, that the teaching of mathematics does depend upon how the professor reacts to his society and upon his beliefs and prejudices.

### 19. University Teaching in General

What are the consequences of this combination of extreme specialization, indifference, and rejection insofar as the caliber of university teaching is concerned? This is one effect we cannot lay at the door of Education Departments, since, unlike public and high school teachers, university teachers have never been compelled to swallow the benefits (I use the term loosely) of Education courses.

We observe large numbers of university teachers who are illiterate, incoherent and uninspired.

By illiterate, we do not, of course, mean that the instructor cannot read or write. The technical proficiency is there. But, he is unable to express himself simply and understandably without jargon, either in his professional papers, or in communication relating to university administration. As a result of an education in the elementary schools and high schools which has been weakened and watered, due to influences which are beyond the power of the university to rectify, and as a result of a college education comparable to that of a surgeon who is trained to operate on the second joint of the index finger of the right hand--on Tuesdays--we have loosed upon the hapless

student a group of hillbilly Ph.D.'s.

By incoherent, we mean that these teachers have never had any training in the verbal communication of ideas. As we know, they are not too enthusiastic, in any case, about letting others into their sacred mysteries. The result is that they are totally unfit as expositors, and yet they are foisted upon those who need it most--the young student.

There are many universities where the most eminent and gifted professors reserve the right to introduce the new university student to the fascinating world of science. There are many other institutions, with equally illustrious names, where the undergraduate will never see or hear an eminent scientist. If he takes graduate courses, he will have this opportunity. Otherwise, he is doomed to teaching fellows and young Ph.D.'s. The freshman and elementary courses are used as an excuse for paying graduate students, and the intermediate courses are taught by hacks who spend all their time teaching these basic courses.

Is this not a form of cheating? Is the university that engages in this practice any better than the sideshow that advertises in garish terms, and then puts on a very prosaic show inside?

It should be added that there are college administrations that refuse to permit this and require every faculty member, no matter how famous, to meet at least one undergraduate class.

The illiteracy and the incoherence could be excused were there enthusiasm. But how can there be this necessary ingredient

when the Ph.D. himself has a limited understanding of his field and no knowledge of the broader implications of science? Add to this ignorance, a disdain for the "elementary" and a desire to retain the power that specialized knowledge appears to impart, and you have all the factors necessary to produce a bored instructor and a bored class.

## 20. Partial Conclusion

We can sum up much of what we have been saying in the following words:

1. There is a conflict between two myths in our society, the myth of the "intellectual man" and the myth of the "practical man."

2. One result of this conflict is the existence in the universities of large and influential groups of academicians who, consciously or unconsciously, reject their society.

3. As a result of this, and other influences, the scientific training that is given students is narrow and over-specialized, either in the direction of theory or in the direction of applications.

4. This specialized training does not properly fit the student to understand or tackle significant research problems or realistic applications.

5. This failure of the universities to produce an adequate supply of properly trained and philosophically oriented graduates is affecting our technological struggle with Russia. The effect will be even more pronounced in five or ten years.

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The further effects of these attitudes upon the type of citizen that is produced and the effects upon the arts and humanities will be discussed in subsequent parts.