Both agricultural engineering and home economics deal with biological material. My specific job is to mechanize the farm and the farmstead; two of your many important jobs are to sanitize the home and feed the family the food my machinery harvests.

The development of a meaningful graduate program for the international student is an important and challenging task for the major professor. It requires deep insight and understanding of the needs of the student and his country. If the program is trivial, the student is not only robbed of his training but, worse yet, allowed to establish a false set of values concerning the responsibilities of the intelligent person.

If his training here does not fit him so he can make a contribution toward helping his country when he returns, he may take a non-productive job and become frustrated because he feels that his knowledge and training are not being used and appreciated. He then returns to the United States, leaving the country worse than it was before. His country has lost not only time and money, but an intelligent individual which it can ill afford to lose. True, it is a gain for our economy, but it is a tragic loss of major proportions to the student's native country.

Dr. J. Boyd Page, vice president for research and dean of the Graduate College at Iowa State University, says, "We need to instill into the graduate student the basic principles of research so that he can go back and creatively adapt his newfound knowledge to improve the conditions of his native country."

The objective of graduate training should be to maximize the individual's ability to solve problems that he will probably meet when he returns. Such problems are usually beyond the scope of people who have not had advanced training.

The academic courses should be selected to provide a background of all organized knowledge in his area of interest as well as to provide him with the mathematical and statistical tools to competently attack the research problem and analyze the data.

How does the program for a student from an underdeveloped country differ from that of an affluent country?

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It differs in two ways:

First, the undergraduate education is usually considerably different. To be specific, in agricultural engineering we receive foreign students trained in agriculture or trained in traditional engineering courses.

I imagine that few foreign students arrive for graduate study in the United States who have been trained specifically in home economics.

If our students have an agricultural background, they will have missed a good portion of the fundamental engineering education; that is, courses in thermodynamics, engineering mechanics, mathematics, and machine design. Students are required to take these courses before they can proceed to advanced engineering courses.

On the other hand, if students come up through the engineering program, they will have a strong background in the classical engineering subjects but will probably not have had much laboratory experience in engineering subjects because of the high cost of the equipment. Here, too, they will lack the training for translating ideas into practical machines through machine design.

To remedy this, our students are exposed while on campus to a number of laboratory courses in engineering and agriculture as well as machinery manufacturing courses.

Secondly, the problems the students from the underdeveloped countries will meet are considerably different. The four most obvious differences are as follows:

a. Most underdeveloped countries are in the tropical zone.

b. Engineers are scarce; therefore, they must be capable of solving a wide range of problems.

c. Farms are smaller and energy sources different.

d. The economy is socialistic rather than capitalistic.

Since most of the underdeveloped countries are in the tropical zone, solutions that have been developed for the temperate zone do not necessarily fit the tropics. For instance, land is plowed dry in the U.S. and wet in the Philippines.

The trained engineers or home economists of the underdeveloped country need to be capable of solving problems to improve conditions over a wide range of subjects. They are expected to provide "off-the-cuff" answers to a variety of questions. It may not be possible to "refer them to the proper authority" because it may be a long way to the specialist.
The equipment needs are different because the average size of farms is approximately five acres and the energy sources are human and animal. Because many countries are developing under socialist economies, the practicing engineer will need to be especially conscious of the economics of manufacturing, value engineering, and cost accounting. This is because, in a protective situation, there is little competition or sales feedback which would indicate an uneconomical design or distribution system as there is in our competitive, capitalistic society.

Thus we note that the technology of these countries requires the services of the general engineer or home economist rather than that of the specialist.

For example several years ago, I sat in on the master's oral examination of a student from India. He had done good work on the effect of the shape of the steel moldboard plow and the force required to pull the plow through the soil. He was asked what good this research would do him in his own country. For a moment he was dumbfounded. Then he replied, "We don't even have moldboard plows. We use a country plow, a pointed wooden stick with a steel tip." His reply left me wondering if his training had prepared him for his threefold task, which is to (1) develop the specifications, (2) design, and (3) manufacture the plow.

Some of you may be wondering if we might be conducting second rate programs for students from underdeveloped countries. We emphatically are not!

Because of the differences in education and the problems between the affluent countries and the underdeveloped countries, we emphasize plant physiology, soil physics, economics, machine design and fabrication courses rather than the final series of the theoretical courses in mathematics, statistics, and applied mechanics. We feel that these courses can be taken later if the student needs them.

**Educating the Major Professor**

We have said that the student must learn the basic principles so he can apply his new-found knowledge in his native country. How can this best be accomplished?

The major professor needs to know the student and his country before he can help him plan a program of study. The weekly conferences won't do the job. Because of the language and cultural barriers, the major professor does not realize that the foreign student does not understand, and vice versa.

The major professor could best become acquainted with the graduate student's country and its people by traveling and studying in the country. I think that six weeks would give him enough time to observe the major problems facing the nation. The country or foundation supporting the student
should assume the obligation of giving the professor this opportunity. (His travel expenses would probably be about equal to the salary he receives from his university.) The cost of educating the major professor is small compared to the support of one or more graduate students.

With proper arrangements, the professor could visit two or more countries during a summer. At this time, he could interview potential graduate students as well as the political, educational, and industrial leaders of the country to determine what problems need to be solved.

I learned more about the problems of Ethiopia in a three-day visit than about Surinam in two years of weekly conferences with the Surinamian student. These visits would help break down the barriers in communication, and the professor would develop a profound personal interest in the country.

In addition to Ethiopia, I have visited India, Ireland, England, and the Philippines prior to having graduate students from these countries. My visits were much shorter than six weeks, but the insight I received has been extremely valuable.

For instance, I learned that the seedbed prepared by the Ethiopian farmer doesn't allow a good stand of teff, their main grain crop, to emerge. The seedbed is rough because the Ethiopian farmer has neither the equipment nor time to make it better. I know that the dry soils of India require six to eight plowings by the "country" plow -- the pointed stick with the steel tip.

Probably some of you are recalling similar experiences in the home economics area which would provide a basis for developing a research program.

The university personnel participating in the contract programs of AID, in Fulbright lectureships and similar programs are gaining excellent experiences in identifying problems in foreign lands. Under the Iowa State University contract with Peru, professors of economics living in Peru guide graduate students who have completed their course work at Iowa State and have returned to Peru to do their research.

The Research Problem

We've said that we need to train the student to apply his knowledge and to educate the major professor to help the student identify the problems of his country.

From the problems existing in the country should come the research problem. The selection of the research problem is important because the concentrated study in the selected area will lead him to the frontier of knowledge. It should make him one of the world's authorities on the subject and provide the momentum that will carry him forward in his laboratory for the next 10 to 15 years.
A Danish graduate student of mine worked on the drying rate of conditioned hay for his master's problem. When I visited him last year in Denmark, he showed me his hay drying laboratory and five years of data on the efficiency of hay harvesting systems.

If the student goes into teaching and becomes a major professor, the problem selected may also seriously influence the areas in which his own graduate students study.

Research may be divided into three types as follows:

1. Basic research, which includes pure research.

2. Applied research, which includes development research.

3. Consumer research.

Basic research is thinking or experimentation aimed primarily at the extension of the boundaries of human knowledge. Since it cannot immediately influence the economy of the country, it should be conducted primarily by graduate students from affluent countries.

Applied research is the application of known knowledge to the solution of existing problems. More money is spent on applied research in the United States than on all other types of research.

Consumer research determines how successfully the problems have been solved. Mailed and personal interview surveys determine how well equipment and services are accepted by the people. The behavioral scientist spends considerable time conducting this type of research. Simply stated, consumer research determines how well applied research solved the problems by using basic research information.

Basic information is normally originated by the scientist conducting basic research. He seems to be doing a good job. In fact, Eric A. Walker, president of Pennsylvania State University, in a recent Sweeney Memorial Lecture at Iowa State University stated that, "Today, the scientist is filling the world with an abundance of new knowledge at a fantastic rate." Dr. C. Zenor of the Westinghouse Research Laboratories, has reported that,"The scientific and technical knowledge of the world doubled during the past 12 years and it is estimated it will double again by 1969." Let me repeat, the knowledge gained in the next five years will be equal to that gained by all previous generations, including the present one. This knowledge is printed in scientific journals and books that have inundated our libraries.

Because the accumulation of knowledge seems to be in such good hands, I believe the graduate student from the undeveloped country should conduct applied research on a problem that is meaningful to him and is useful to improve the health or the economy of his country.
Should he wish to do basic research when he returns home, he will find the transition from applied to basic much easier than from basic to applied. While doing the applied research, he will observe many phenomena that cry for an explanation. It is interesting to note that General Electric and Bell Telephone laboratories, our largest commercial research laboratories, both started out conducting applied research.

Selecting the Problem

When the international student arrives on campus, I assign him a reading list of recent Iowa State University theses based on what I think will fit his needs. These theses reflect our current research thinking and give the student an idea of what has been done and what a thesis actually is.

In conference, we discuss his area of interest and the problems facing his country. This is easier to accomplish if I have visited his country, as I previously noted.

It is my experience that the student will work hardest and will be most creative in an area in which he has a strong interest.

After a number of conferences, we mutually agree on a problem that has a chance of being solved within the time, space, and facilities available. It is hoped, of course, that the information gained will be of some value to Iowa, but this is not a necessary prerequisite for the outside supported student.

If a problem within his country cannot be identified or he wants to work in a fundamental area, he is encouraged to work on some component of the soil-plant-man-machine complex. Since some of our foreign students are born in large cities and educated in engineering, they are unable to identify the problems of agriculture.

If the student selects a fundamental area, he must seek ingenious ways to build and use simple instruments and equipment for his experiments. These are made from easily purchased or fabricated parts. It would be an injustice, I believe, to train him on the use of little used, expensive instruments that his native resources would never be able to provide.

During the past nine years, five of my graduate students have studied the pressure that the planter wheels exert on the soil and the effect of such pressure on the germination, growth, and emergence of plants. One student was from Egypt and another from West Pakistan. Each student constructed new instruments from standard parts and made a contribution to the understanding of the relationship of soil physical conditions and plant emergence.
The understanding these students got from learning how pressing the soil over the seeds affects plants coming up is just as applicable to the Egyptian engineer studying cotton planters in the Nile delta as the American engineer studying corn planters in Iowa.

Our machine design projects provide a lucrative training ground for agricultural engineers. Our student selects an operation in plant or animal production that is being done by hand. It is then a test of his observation abilities, deductive and inductive reasoning, and creative powers to invent a mechanism that will carry out the hand operation. Once the hand process is mechanized, it is a test of his design, construction, and development abilities to create a field-worthy, economical machine.

The designer makes many hypotheses about his mechanized process and his machine during the design and development stage. Some of these hypotheses are tested when the machine is run empty in the shop and others are tested when the machine is operated in the field.

I remember during the recent field tests of our strawberry harvester, my Ethiopian student became fascinated by the daily improvements that we were able to make in the operation of the machine. In one season we were able to progress from stoppages due to break-down or clogging every two feet to picking an entire row without stopping.

During the creation and development of a machine, information similar to that gained by basic research is recorded about the material being handled in the mechanized system.

For example when we were working on a cucumber harvester, we gained basic information when we measured the force required to pull the vines out of the ground as well as the force required to pick the cucumber. We also determined the length-diameter ratio of cucumbers and wrote equations expressing this relation. Thus the student gained experience in basic as well as applied research.

The desire to do basic research is strong. A great deal of status is attached to doing something new. I recall that in one institute I visited in India, one of the projects of the research program was the development of new metering systems for seed. New metering devices for seed have been under design and development for more than 150 years in the United States and Europe. The desire to do original work should have been shifted from research in metering systems to selection of materials, the redesign, for local manufacture, of already known systems.

Another institute was studying a new system for threshing rice because the cylinder and concave of the threshing machine broke the straw up so much it could not be used for manufacturing hats, purses, and sandals. This was a real
problem, but the approach to the solution should have been to study the harvesting method to determine if the major portion of the straw could not have been saved at the time the grain was cut rather than at threshing time. Of course, new principles of threshing rice will be discovered, but they will probably be expensive in time and money to develop. The sale price of the new harvester may be higher than that of the conventional machine.

Both in seed planting and rice threshing, India can ill afford to use the time, money, and facilities to develop the new systems.

On the other hand it is valid to conduct research on the use of native materials and craftsmanship in the construction of new devices or structures. One American engineer working in Ethiopia observed that native carpenters were familiar with the handling and installation of steel corrugated roofing. He designed a rodent-proof round grain storage bin using corrugated sheet metal that is now being constructed with native labor.

Just as the American technology of the 19th century was developed on information from Europe, the 20th century technology of the undeveloped countries will be developed on basic information from the affluent countries.

**Conducting the Graduate Program**

The concept of the graduate college grew out of the German tradition in which the thesis was an original contribution to knowledge in a basic science. In some areas the graduate student cannot sufficiently master the field in two or three years to the point that he can make a contribution to knowledge. Thus this requirement has been modified in the United States so that the program provides training in research techniques and procedures and the opportunity for experiences in the creative process.

Since the foreign student may have developed strong opinions at his undergraduate university concerning the traditional view, the major professor may have to explain the need to solve existing problems by applying basic research. His job is not to develop new knowledge during his graduate program, but to develop new ways of applying already known knowledge to problems of his country.

Solving existing problems can develop mental tools and techniques and associated skills to do research which will enable the foreign student to contribute to his country when he returns. He will gain status from the contributions he makes.

He has the same opportunity in applied as in basic research to form his hypotheses, search the literature, organize research, have a creative experience, conduct experiment, perform statistical analysis, write report and, yes, to "stick his neck out," that he has in basic research. The research program may be his first and last chance to be creative.
Creative thinking is needed to solve the vastly different problems of the undeveloped countries. The student should be encouraged to think creatively, not just memorize meaningless facts and figures. Of course, the major professor must first be versed in the creative process. Allowing the student to be creative isn't the easiest way to get research done, but one must always keep in mind that the important product is the student and his training.

The professor should set the stage for a creative experience. It's an awful temptation to blurt out the answer to a problem when you know it and you also know that the student won't conceive of the answer for at least another half hour or more. But he must be allowed to think for himself. Getting an idea is like getting olives out of a jar. The first one is the hardest, but when it is shaken loose the rest roll right out.

Each year, I give five lectures on creativity and patents to my undergraduate and graduate classes. I am interested in my students knowing the steps in the creative process -- how to conceive the idea, what to do with the idea, and how to protect the idea. I get as much benefit from it as the students do. I need to be reminded of the steps leading to a creative encounter with the unknown and to be a good listener.

The major professor has the obligation of leading the graduate student to the frontier of knowledge in his area of interest. He should be currently aware of recent unpublished research articles and should personally know the research workers in his field throughout the world. He should direct his graduate students to correspond with them so he can become acquainted with them and learn about their latest work.

The literature survey brings the student to the frontier of knowledge in his area and gives him practice in information retrieval. We apply the following three tests to determine if he has actually reached the frontier of knowledge.

1. A canvass of current professional research workers turns up no new literature.
2. Recent articles, bibliographies, and abstracts contain no new articles or citations of new articles.
3. The hypothesis advanced by the student or his advisor remains unexplained or unexplored by the literature survey.

After the literature survey comes the actual experiment or testing of the hypothesis.

To gain experience in working with his hands, each of our international graduate students constructs an instrument or machine and conducts tests with the device. I make it a point to be there when he runs his first test. He needs lots of encouragement at this point; otherwise, when the device fails to
perform as he thinks it should, he will quit. My trouble shooting gives him the help he needs to understand the actual function of the device, and to improve it until it works.

Observations in Home Economics

Just as mechanization has been one of the vehicles of graduate training in my field, so sanitation, nutrition, environment, behavior, economics and etc., are your vehicles. When rural America was electrified during the 1930's, the home economist used the advantages of electricity as a vehicle to advance the home 20 to 30 years almost instantaneously. They used it to teach better diet through preparation of food, refrigerated storage and the electric stove, and better care of the home with the electric sweeper.

The Unva-Ram adobe brick machine appears to be a device that can be used as the vehicle for improving the rural family life and home of the undeveloped countries.

In like manner, the changing of the type of power used on the farm can have a profound effect on the family. Professor of G. Wallace Giles, consultant in agricultural engineering to the Ford Foundation concerning India, had this in mind when he reported to a recent meeting of the American Society of Agricultural Engineers:

The agricultural operations now used in most of the undeveloped countries were developed using animal and human power many centuries ago, and have remained practically unchanged to the present day. These operations need to be evaluated in the light of a new type of power -- mechanical power.

The lack of power is one of the most fundamental problems facing these countries in agriculture. More power is essential in carrying out operations effectively and at the right time. More power is a catalyst for changing the attitudes and uplifting the social status and dignity of those who labor in agriculture. Farmers who have at their command mechanical power raise their sights to new horizons. It provides for an open and a more dynamic and exciting profession. And lastly, more power provides the opportunity for using a whole new array of modern implements. Implements that perform their function better and quicker invariably require more power per hour or per acre.

I have observed that the job of the home economist in underdeveloped countries can be compared to the work of the extension worker in the U.S. during the "roaring twenties." Back in that era the home economist was concerned with child care, nutrition, and clothing in the home rather than the problems of today's industrial home economist. More home economists
of today are working in industry and have made rapid strides in prepared frozen and dried foods. The housewife of today can serve better meals to her family in less time than her grandmother because of the "built-in maid service."

This brings me to my point that every culture exists in a time relation with other cultures. The problems of the Australian and Argentina livestock rancher today are similar to those of our west during the 1880's. As I travel, I see situations that appear like the rerun of an old movie on the late TV show. It is our hope for everyone that the experiences of advanced cultures will render the solutions less costly and painful the second time.

While I was traveling in other lands I made a few observations that raised questions in my mind:

Such as, why is the chicken an important meat source in warm climates? Could it be because it is "meal size" and can be kept alive until it is needed for a particular meal and then consumed by the average family.

Why are foods served highly seasoned in warm climates? Were hot seasonings originally used to retard spoilage or mask putrid odors and flavor in the food associated with decay?

How does this affect the food value? When refrigeration becomes available are the hot seasonings justified or just habit? What is the effect of the spice on the children? How does it influence their eating habits? Do they eat solids as soon?

The tropical countries can grow vegetables the year around. Why, then, do they only grow them in the off season when they can't grow rice? Should not the need for a year around supply of vegetables be stressed?

There are many more questions in my mind, and it's fun to speculate on the answers. Maybe some of you know the answers. I don't, but it would be interesting to find out.

In summary, the training of a creative graduate student is more important than the research that he may do. The research problem is the means for creative training.

The role of the major professor is many fold if his students are to be productive. He must foresee their needs and the needs of their country. It is then an easy matter to guide them so they will have a rendezvous with greatness in their pursuit of excellence.