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Quality of the Engineering Academic Faculty

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The highest level of quality of engineering education at a university (the transfer of knowledge) occurs when each of the three fundamental elements of a university are at their optimum. If any one of these three elements, the *body of faculty*, the *student body*, and the *learning and teaching environment* is less than excellent, the quality of the education, the knowledge transferred, will be degraded accordingly. The quality of the faculty is a result of a collection of intelligent individuals who have the appropriate personal make-up and background preparation and experiences to stimulate their students toward absorbing and understanding the knowledge that is transferred from the professor to the student. Students learn to the maximum of their ability when the individual and collective faculty's personal characteristics are such as to utilise the learning environment to inspire the students to do their very best.

INTRODUCTION

The quality level of an engineering education faculty is a vital component of the educational environment, but it is only one of the legs that must be in place to support the *academic chair* if a recognised programme of excellence is to be presented to the student body. The students represent the first leg of the chair. For a successful academic programme to be absorbed by the students, they must be enrolled in an academic environment that causes/encourages all students to study and to learn to the maximum of their ability. The faculty is the second leg of the *academic chair*. The academic environment must also be as close to optimum as possible to cause/encourage the faculty to teach and grow intellectually to the maximum of their ability. The third leg of the academic chair, the administrative and support personnel, have the responsibility to provide the optimum learning and teaching environment. The fourth leg of the academic chair is made up of the physical facilities. The physical facilities of the engineering unit must include a quality library and the many laboratories necessary to present students with first hand experience of the natural laws of science and engineering and how they are *put to work* through the practice of engineering.

The age-old truism that *a high quality college consists of an excellent faculty, an excellent student body, and an excellent library* is no longer adequate. Physical facilities, including the libraries and the laboratories, must be up-to-date with state-of-the-art of technology and they must be rigorous and of high quality with appropriate comprehensive coverage of the curricula topics. The administrative staff must be of such high quality as to provide as much as possible the optimum learning and teaching environment on the campus.

This paper will discuss the chair leg that consists of the faculty, and more specifically the various components that make up a high quality academic faculty.

PERSONAL CHARACTERISTICS

Faculty individuals are the role models, counsellors, and often the de facto *parent* of young students who are often away from home for the first time. These various possible roles are an integral part of the faculty responsibility in addition to the transfer of knowledge and the building of the learning skills within each student through the every day teaching routine. This is a very great responsibility. A negative experience between a student and a faculty member, which is not handled well by the faculty member, can leave a student *scarred* for life. Of course, if a negative experience is handled well by the faculty member, it can be a valued learning experience for the student. Not all individuals have the personal make-up and personality to have a fulfilling career as a faculty member helping and leading students in their preparation for a lifelong career. It is important that individuals who are selected for faculty positions be of the appropriate caring temperament and sensitivity as well as being dedicated to this faculty responsibility.

It is also important to recognise that faculties are collegial bodies and, as a consequence, a vital component of a strong academic faculty is the mutual and co-operative support for one another as each grows their individual academic career. It is necessary that individuals who join a faculty be of such a personal make-up that they will be able to earn acceptance by faculty colleagues as a productive and integral part of the faculty family. Acceptance of an individual into the tenured faculty ranks is not merely a routine of having a set number of publications of accepted quality, having acceptable teaching and having student support; it also requires that the candidate faculty meet the collegiality test and be accepted by the faculty family. Without this acceptance tenure is not granted and hence the unsuccessful candidate must leave the faculty. When a faculty member does not meet the requirements of tenure there is a great loss, since the permanent tenured faculty has invested several years time and effort toward including the unsuccessful faculty member into the tenured faculty. With the loss of the individual faculty member the tenured faculty must begin the building process all over again, starting with a search for a new member of the faculty.

ACADEMIC CREDENTIALS

The level of academic education for the faculty should in general be at the terminal degree level. This means they should have the PhD degree tagged from their specific academic field. It is argued that having the PhD degree does not make a person *smart* and this is perhaps a reasonably correct argument. However, the collegial faculty family in engineering will have PhD degrees as this degree suggests that the individual, at one time at least, did do some original research work that generated new knowledge and was of considerable depth. This demonstrates an intellectual level required of a faculty member. A pre-selection has already occurred and this suggests adding new faculty with the PhD degree is a relatively safe action.

Many individuals who have terminated their formal education at the Masters level are no doubt as bright as many of those who go on to obtain the PhD degree. They may be of superior teaching abilities. However, these individuals do not have the technical tools of the more in-depth sciences and mathematics and of the focused engineering principals and concepts. This disadvantage causes a disparity with regard to teaching assignments and advancement in rank in a timely manner. Mixing individuals with the Master's degree with those with the PhD degrees on a faculty more often than not causes personnel problems. While salary levels are based upon performance, the individual with the Master's degree often uses the different degree level to account for discrimination and unfair treatment. A carefully selected mix of different degree levels can work, but it is important to be sensitive to the probable people problems that will arise.

The academic experience of the faculty requires that they have excelled in programmes that have wide recognition as being of high quality. To experience less than a high quality degree programme places a particularly heavy burden on an individual as their experience suggests that they may be inclined to require less rigor and in-depth knowledge and understanding from their curriculum than is the accepted norm in the high quality programmes in science and engineering education. Academic credentials and degrees should be obtained from programmes and institutions where the quality of the faculty and the academic programme is well recognised for excellence.

It is important to recognise that within a specific academic discipline, even in widely recognised institutions, there exist strong as well as less prominent faculty and degree programmes. The use of peer review and references usually provides insight regarding quality level of the specific programme.

There exists the extensively discussed industrial experience requirement for a prospective new faculty member. The argument that most engineering graduates leave their engineering degree programmes and build careers in private and public industries and not in academe is a valid argument. This suggests that teaching faculty should have some industrial experience in deference to the more common practice of pursuing and obtaining the terminal (PhD or ScD) degree and then joining a teaching faculty immediately. This approach provides *real world* experience that the faculty member can call upon to support the content of the curricula. While this is a good, sound argument suggesting that excellent and qualified individuals should gain some industrial experience prior to beginning a teaching career, it in fact does not work well in practice. The larger salary in industry makes it very difficult to leave industry at a later time. The industrial engineer may begin a family along the way and acquire a living style that precludes taking the financial cut inherent in moving to an academic position.

What is a more practical approach is to encourage the faculty to spend time in non-academic industries during off semesters from their teaching duties and to utilise sabbaticals from the campus to gain industrial experience. In addition, co-operation between faculty and colleagues in industry pursuing research and development (R&D) projects provides an excellent opportunity to gain experience and an understanding of the industrial environment into which the graduates move following graduation.

As a consequence of the above arguments it is probably unreasonable to require new, young additions to the faculty to have an industrial background. Instead it is desirable that the total faculty have, on balance, some extensive experience in non-academic industries and that this experience can be gained whilst being a member of the faculty or through direct employment of individuals from non-academic industries.

KNOWLEDGE/SKILL LEVELS AND BACKGROUND

Faculties of Engineering Education programmes have experienced, through their many years of being on the receiving side of the transfer of knowledge, just what makes an effective faculty member and also just what constitutes a poor faculty member. As individuals progress toward the PhD degree they gain some experience teaching laboratory courses, and many teach lecture courses at the undergraduate level. During this process they gain in-depth knowledge of the science base of the engineering curricula and they reinforce the engineering principals and approaches of applying this science toward problem-solving. Problem solution focuses on some aspect of a marketable product designed to enhance the quality of life for the consumer. This is the corner stone upon which an academic career rests.

This starting point for a faculty career is not optimal when one considers that one product of the faculty's effort, the student graduates, leave the university and go into a non-academic industry. Student graduates who enter a manufacturing company are employed with the expectation that they will contribute to the profitability of the company. This means that it is important that they be ready to *produce* within a very short time and without too much additional education provided by the company.

This suggests that it is important that the faculty be knowledgeable and well acquainted with the industrial environment and that the faculty be actively involved with non-academic industries through private consulting arrangements, through co-operative research and development programmes, and through utilisation of off semesters to work within the various companies. There are also other creative approaches to facilitate faculty involvement with industry. The non-academic industries compete strongly with one another and as a consequence they must stay as close as possible to the state-of-the art of their particular business if they are to continue to be successful and remain profitable. This provides a real challenge to the engineering faculty to also remain up to date with industry and, if possible, to be a leader in the application of engineering utilising the latest technologies. If the faculty is up to date and is, in fact, a leader in technology, it follows that the graduating students will bring new knowledge to the industries and help them to be competitive in the World Market. This aspect of technology transfer knows no bounds and is important for industries in all countries of the world.

The above discussion points out that the faculty must be expert in transmitting existing knowledge to their students. They must be experienced and expert in generating new knowledge. They must know how to apply this new knowledge so that it will be economically useful to practising engineers in the non-academic profession. They must also be expert in transmitting the techniques of building this new knowledge base and its applications to their students. As the faculty member's career progresses, the knowledge and skills to fulfil this role must also grow to a level where wide recognition is received from those who utilise the academic products: the student graduates and the R&D results of new knowledge and new applications.

CRITICAL MASS – NUMBERS OF FACULTY

There exists a large data base that strongly suggests guide lines for the number of faculty that are required to present and carry out a high quality academic programme. These data have been utilised by engineering programmes in many countries to provide minimums for numbers of faculty required to offer a quality engineering education programme that exceeds minimum standards. The minimums have been determined through experience that reveals the magnitude of the interactions that must take place among the faculty to cause them not just to maintain their level of competence, but to grow and to remain relevant as the state-of-the-art of engineering continues to advance. The term *critical mass* has been used to describe the number of faculty members a programme must have before the internal interactions among the faculty stimulates them to present a dynamic, modern education programme.

Proscribing a specific number is somewhat complicated since it depends upon the organisation of the engineering faculty and the number of academic disciplines that are offered. There is considerable overlap among the engineering disciplines and this makes it possible for faculty from one discipline to provide service courses to other disciplines. If this is the situation, that is several engineering disciplines such as the so-called founding disciplines, Civil Engineering, Mechanical Engineering, and Electrical Engineering, then it is generally agreed that as few as five faculty members in each discipline can provide a curricula that will exceed acceptable minimum levels.

If these three academic disciplines are offering academic degrees, it is possible to build added degree programmes in designated disciplines, such as Chemical Engineering, with as few as three faculty members, provided that the faculty offices are within close proximity and that the faculty members interact closely with one another. In a number of countries there currently exist programmes with these small numbers under the above mentioned conditions and they have demonstrated that they can meet minimum requirements of accreditation according to the standards set in English speaking countries. However, they are usually considered marginal and questionable in regard to whether or not they meet the minimum criteria.

In summary it is correct to state that while there is no specific suggested number of faculty that must be in place if a quality engineering programme is to be presented, it is also correct to state that there is a well established minimum number that must be in place. This minimum number is the number that fits the human equation of people interactions. This number of faculty provides the necessary interactions that cause the faculty to remain stimulated to present an up-to-date programme with appropriate rigor and content to assure that the graduates of the programme are prepared to build successful careers in the engineering profession.

Balance: the age of the faculty and the orientation of the faculty toward being theoretical or experimental in their academic pursuits

Balance is often ignored in building faculties, as the practice is to employ the best people available when the need arises. This is particularly true with regard to the physical age of each faculty member. With regard to the orientation toward theoretical or experimental, the choice is often dictated by the economics of the times. Laboratory instrumentation is expensive. History demonstrates that the cost to a university on a per semester hour basis on average is twice as high for engineering programmes as for the general university curriculum. The cost of the laboratory instrumentation and the requirement for smaller classes cause this differential.

The physical age of the faculty is a potentially major problem when the faculty members are of a similar age. They progress through their careers and they may build an excellent academic programme with high recognition. But finally they retire over a short time period, meaning that the rebuilding of the programme and the faculty present horrific problems. Institutional memory is gone. The normal transmittal of collegial skills is interrupted. To avoid this it is important that there be some new, young people added to the faculty on a periodic basis to provide the influx of outside energies and ideas to stimulate the core tenured faculty. To accomplish this some programmes limit the percentage of faculty numbers who can be given tenure and hence become permanent members of the faculty. Those not on the tenure track spend a few years as visiting faculty and then move on to other universities. This also allows selective additions to the tenured ranks when the *right* person comes along to fit into the permanent faculty family.

The balance between faculty members who are most comfortable presenting the theoretical aspects of the science and engineering curricula and those more excited by the laboratory orientation is very important and must be given attention. External forces, such as economics, have had their impact on many programmes and these are real forces that must be dealt with and overcome. It is much more economical to present theory than it is either to demonstrate experimentally that this theory does indeed represent the laws of nature or how these laws are put to work utilising the practice of applying engineering principals. It is a very important planning consideration to provide the optimal balance within the curricula between theory and experimental practices and demonstrations to provide an in depth understanding in the student of these complex phenomena. Today, many of the very complex phenomena that historically have caused engineering students much difficulty so far as understanding and comprehension can now, through experimental demonstrations, be seen in multidimensional colour pictures. Hence, understanding is more quickly gained and the student is able to assimilate greater amounts of knowledge during their stay on the university campus.

The needs of the customer of the academic programme must be factored into the decisions regarding the ideal mix of individuals, that is, between theory and practice. The non-academic world that provides career paths for graduates is dominated by the need for professionals who can apply knowledge and the application of engineering principals toward improving an existing product or toward creating a new product. These people are important customers and their voice needs to be heard. The voice of this customer suggests that the balance of the faculty should be toward the experimentalist type. At the same time the lecture courses within a curricula impose a heavier demand for those who prefer the theory side, as most of the courses are theoretical, while the laboratory courses are organised to demonstrate the reality of the theory. This does not place the demand in terms of time as highly for the experimentalist as for the theorist.

In practice, most high quality, engineering education programmes have faculties quite evenly balanced between the theorist and the experimentalist.

THE OPTIMAL LEARNING ENVIRONMENT

Ideally, both students and faculty should be provided with a learning environment that is optimal for each to be inspired to do the best job possible. For the student, the objective is to accumulate and learn as much knowledge as their personal make up will allow. The faculty must be stimulated and inspired to be outstanding teachers for the students and to simultaneously grow professionally as rapidly as their personal abilities will allow. This is a complex environment to build as each individual involved will have different needs and hence different emphasis need to be placed on various components that make up the environment. No doubt it is impossible to provide the optimal environment for all individuals among the students and the faculty. It is important however to give considerable attention to this problem and to build the best environment possible with the financial resources available to the academic institution. Planning and faculty discussions make it possible to build learning and growing environments that are far better than would otherwise occur.

The students' learning environment includes all of the physical facilities of the campus, the availability of the faculty in and out of the classroom, and the off campus environment in which they spend most of the hours of each day. The university administration and faculty have an important influence on every aspect of the students' learning environment. Students need to have appropriate classrooms that are equipped with teaching aids, such as computers, to facilitate the faculty's teaching. The truism of the middle decades of the twentieth century, suggesting that the optimum learning environment was a professor in front of class of no more than 15 to 20 students and a blackboard and a piece of chalk, is no longer true. The optimum today includes the latest technology-teaching aids to facilitate student learning by simultaneously showing multidimensional views of the phenomena as that specific theory is being taught. Students can access the data to view it, repeatedly if necessary, during the off hours to solidify the knowledge gained. They need access to interactive computers connected to the library's database during time on and off campus. This also means that students must have access to one another via electronic communications, in particular from their on or off campus accommodation.

Access to faculty traditionally included faculty having office hours. This has been a continuing problem as it too often requires more time than the faculty has or is willing to give. Many students often have the same questions/problem and the faculty member traditionally answered the questions while talking with each student. This problem has been minimised by utilising the computer email systems that allow students to interact with the faculty by leaving questions and discussions of problems for the faculty member with the faculty responding individually or collectively in a timely manner.

Libraries have traditionally been the sites of the primary knowledge database, coupled with a friendly environment in which students could sit and study and/or browse. Often, through browsing, a student would find information that was unanticipated; this was and remains a great advantage of studying within the library confines. It also combined the people to people interactions that almost always occur. It must be emphasised that this library environment remains an important part of the student learning environment. However, its relative importance is much diminished as student access to the library's data base via personal computers from home facilitates their search for more extensive information and provides quicker access to greater knowledge than was previously possible. The student today has access via this electronic medium to much of the world's knowledge housed in data bases on campuses across the world, and in such places as the National Archives of data in the United State's Library of Congress. Electronic access to information is essential for a proper learning environment for both students and faculty.

The learning environment includes the many components and influences that impact on the magnitude of students and faculty's accumulation of and handling of knowledge. The university's administrative people and the support staff have a much more important influence on the learning environment than is generally understood. Without quality staff support of all aspects of the university's people, it would be impossible to build a proper learning environment. On the other hand, the same is true with regard to the administrative staff, as it is the administration that provides the support for all aspects of the academic enterprise. It is the administration that has the primary responsibility to provide the physical and mental facilities that are needed to provide the optimal learning environment. The administration must lead the efforts to locate and to provide the financial resources for the buildings and the instrumentation that is needed to equip the buildings and to provide the financial resources to pay the salaries of all personnel on the campus, faculty and staff alike. Faculty, of course, participate in building this leaning environment through their interactions with students, both in and out of the classroom, and through their building of co-operative relations with non-university entities that lead to supported R&D programmes that help to introduce the industrial environment to the university family. It is a complex and challenging assignment for all involved in building the campus learning environment. This challenge is better met when all of the components of the campus are co-operating and planning and working together toward the goal of providing the best learning environment that can be presented within the available financial means.

BIOGRAPHY

Dr Donald D. Glower's career in academia included teaching mechanical and nuclear engineering to undergraduate and graduate students while a Professor, and later as Department Chairman, of the Mechanical Engineering Department at Ohio State University. He served as Dean of the College of Engineering at Ohio State University, Columbus, Ohio, USA for 14 years and concluded his academic career as Vice President of the University for three years. He published over one hundred research papers and authored four books. He came to the university following four years of work experience with the Bell Laboratories and General Motors Corporation.