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IMPACTS OF PRACTICAL TEACHING IN ENGINEERING EDUCATION

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Abstract:
Engineering has contributed enormously to the comfort and well-being of individuals, as well as to communities and societies. Engineering works need to be carefully designed and implemented, since any failure will lead to serious consequences and great suffering. As in medicine, law and the other professions, a rational teaching system is also necessary for an effective engineering education. It was understood that engineers are likely to obtain great benefits through effective practical training and observations for a fruitful engineering career. Better efficiency was thought to be obtained if more practice-oriented activities were included within the current teaching system related to engineering.

Keywords: engineer, engineer education, curriculum, practical teaching

1. Introduction

The importance of science has long been understood by human beings for thousands of years. Remedies considered to solve real-life problems, as well as the search for a better, more prosperous life for communities and for the well-being of individuals, have always been seen to be based upon scientific thoughts and principles. Science may be said to be one of the important factors which has a great influence on the processes of development throughout the life of a human being. It was not until the past two centuries that drastic changes in human life have taken place, i.e., since the inception of the Industrial Revolution, which started with the discovery of steam power. The dreams and the expectations of human beings have all been realized ever since then. Life has been more comfortable and convenient ever since the replacement of manpower by the continuing development of machines, sophisticated devices and instruments. The dream to fly and the desire to communicate at very remote distances have all been gradually accomplished and realized. All these achievements have, by all means, been acquired through scientific

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thought and considerations; however, a question may arise from this point, in that what kind of scientific thoughts were behind all these achievements? Engineering would probably be the most realistic response to this query.

It is inevitable that with all professional activities, one of the primary aims is the well-being of human beings and other entities. Among all professions, engineering holds great significance with its duties and obligations. As an example, the security of people crossing bridges or the life of those who travel by airliners with hundreds on board, depends upon a very sophisticated, delicate and rational engineering design. A device or machinery may be so sophisticated and cost-effective, but it is not of any use if it poses threats to both the environment and public safety. Fruitful engineering skill and competency, therefore, have to be in harmony with sound and rational judgment. Therefore, there is always a trade-off between safety and other engineering issues in a design, requiring discretion on the part of the engineer to ensure that the design serves its purpose and fills its market niche safely (Fleddermann, 2012).

This paper emphasizes the impacts of practice-based teaching in engineering education. Fundamentals of engineering tasks and duties are outlined, and the significance of the engineering profession is defined. Contributions of practical teaching to a successful engineering career are explained with actual experiences gained in a particular field of engineering discipline.

Engineering is a profession that designs the physical components necessary for the well-being of individuals and societies, and contributes to technological and economic development by ensuring the production, continuity and prevalence of these components. Along with the technical knowledge and skills, the engineer follows the technology, adapts to changing conditions, and takes part in teamwork. Moreover, a good engineer has leadership qualities, creative thinking and communication ability, and is always ready to take risks. Engineers explain and evaluate research issues through scientific evidence, and provide sound reasoning when deciding on whether a scientific finding can be physically realized in practice or not (Bybee, 2011; Lederman & Lederman, 2013). Today's engineers are expected to have good leadership qualities with creative thinking and communication ability, being self-confident and not hesitating to take risks in consideration with the economic, social and legal framework of the society. Engineering applications, therefore, require continuous education and research since it has direct impacts on the lives of individuals.

The purpose of engineering education is to encourage students to bring analytical and practical solutions to engineering issues that they are likely to encounter, and to develop the most efficient design techniques within the limits of the available conditions. The future engineers should, therefore, be trained in different ways than those adopted currently in an effort to increase the above-mentioned engineering qualities.

The following points may be considered to be important in engineering education:

- to encourage the students to develop analytical solutions and alternatives for engineering problems.
- to develop general design principles that can be applied in all conditions.
- to focus on the experimental methods in laboratory lessons.

- to gain the ability to employ alternative technologies, along with the available ones, when designing a particular engineering work.
- to prepare graduates for postgraduate education (Gençoğlu, M. T.; Cebeci, M. 1999).

2. Theory and Practice in Engineering

Faculties are inevitably the first places where engineers begin to gain their professional skills. On top of it, internship education substantially provides a very important opportunity for prospective engineers to combine theoretical knowledge with what they have gained in practice. Such adequate practical knowledge greatly helps the students to adapt to the business environment and to foresee challenging engineering issues when they step into the industry. Within the process of the current education system, universities or other higher education institutions are the first place where the students gain their engineering skills, i.e. the students are bound to be educated and trained within a limited period of time. It would, however, be very useful to start engineering teaching gradually during high school education, prior to university. It is obvious that an engineer who started his engineering education in high school and continued it at university would be more qualified than someone who gained his professional skills only in a faculty. This concept has, therefore, been adopted in some parts of the world where certain engineering disciplines were taught in high schools and then gradually resumed through universities, since it is not possible to contain all engineering subjects within a limited period in universities. This process is commonly practiced by some established corporations that prefer to employ engineers of this kind specifically trained for their needs. In this context, the student will be reasonably well-prepared for business life immediately after graduation.

Theoretical teaching obviously forms the base for education. It would, however, be best to include practice-orientated programs in engineering education, since the main goal of engineering is focused on the practical application of ideas and concepts. The inclusion of research and development laboratories in concurrence with advancement in technology was claimed to urge engineering students to combine their theoretical knowledge with practice (Husen, 1990).

The content of teaching is one of the important issues in engineering education. Students are, of course, enrolled on a particular subject of engineering where the education is solely based upon a specific engineering discipline. Rapid development in technology has, however, indicated that knowledge gained in a specific single subject may not suffice to solve complex engineering problems, inferring the need for interdisciplinary knowledge and information. With the interdisciplinary teaching in engineering education, students are given the opportunity to explore relationships and structures that go beyond a particular discipline and systematically combine different aspects of engineering. It was reported that organizing and integrating the contents of different subjects around a theme leads to higher-order thinking and meaningful learning (Drake, S. M., & Burns, R. C., 2004; Ericsson, 2006; Roblyer, 2005).

It is important to focus on the methods of explanation in teaching. The classical method, in the form of classroom teaching by lecturers, may not sufficiently develop students' problem-solving skills and may not require the creative and critical thinking that students need to solve the problems they will encounter in their professional lives. A differentiated instruction system for individual learners emerges to be important and to be considered in a teaching curriculum due to the fact that all students are not the same. It was reported to be imperative to adapt a teaching system which is arranged with respect to individual differences (Hartman, 2009; York-Barr, Sommerr, Ghere & Montie, 2006). Accordingly, the lessons should be tailored to the needs, abilities, backgrounds and experiences of the students in order to train a good engineer. The academic areas where people with different learning styles can be classified as strong, weak, talented and interested (Felder, Felder & Dietz, 2002). The most important factor in increasing the success of people with different learning styles in engineering education is to develop new education strategies by discovering the differences in learning styles (Felder, Felder & Dietz, 2002).

In engineering education, developing the skills in observation, classification, measurement, prediction, communication, interpretation, and using numerical relationships were noted to be important in the learning process of engineers (Cothron, Giese & Rezba, 1993). Such a learning process is termed an active learning process, leading to effective and permanent learning by virtue of the personal effort of the student. The candidate, who learns effectively and permanently, constructs a new concept in his mind by dealing with objects, interacting with people, ideas and events. In other words, it is the source and master of the construction of its own experiences. Such a learning process contributes to the ability of the student in acquiring and evaluating information, solving problems, developing thinking skills, as well as participating in teamwork (Mayer, 2002).

It would prove to be useful if the content and programs of contemporary education were determined in collaboration with all parties (employers, unions, professional organizations, students, etc.).

3. Engineering Profession

For a sound definition of engineering, it would prove to be useful to differentiate the relationship between science and engineering in terms of various circumstances. Any scientific principle or finding which has the potential for a direct practical application may be said to be related to engineering. Furthermore, application of such a scientific principle to practice should be very cost-effective, convenient, ergonomic, safe and comfortable. In other words, any scientific principle having practical significance is said to be associated with engineering.

Engineering may, then, simply be defined as the implementation of scientific principles and findings into practice by using the most convenient and economical means. It may certainly be regarded as a job, since the engineers are paid for their services. However, it is more meaningful than just a job, since engineering requires extensive and sophisticated skills. The engineer uses judgment and the exercise of discretion within the whole extent of his/her knowledge and ability when performing his/her duty. Engineers also have responsibility for keeping their employers' or clients' intellectual property and related business information at a confidential level. Moreover, the engineer also bears moral responsibilities for the health and safety of the communities.

In essence, a methodology, an idea or a technological concept should meet the following basic engineering requirements in order to be considered engineering:

- **Practical significance:** it should be effectively used in practical conditions,
- **Cost effectiveness:** it should have an affordable cost in order to be largely available to the majority of individuals or communities,
- **Health and safety:** it has to comply with public safety and health regulations.

The task of an engineering profession may basically be seen in the form of three broad categories:

- **Practicing (regular) engineers:** Engineers within this category conduct the implementation of an already designed project in a given branch of an industry. As an example, construction of a building, installation of a plant, building and operating a high-scale machinery system, setting up a mine, etc. Practicing engineers may supervise the course of production in factories and elsewhere, determine the reason for a process failure, and test output to maintain quality. They take the responsibility for a certain part of the project relevant to their branches of engineering discipline. The task in this category may lend itself to a management position, though not beyond the sub-management level. Practicing engineers generally report to senior engineers in upper positions. A practicing engineer mainly needs knowledge of the principles of engineering techniques, as well as personal skills, when performing such tasks. He/she may attempt to suggest ideas for development or the modification of the project to a limited extent.
- **Professional engineers:** Professional engineers are competent by virtue of their fundamental knowledge and experience to apply the scientific method and outlook to the analysis and solution of engineering problems. The task in this category involves designing and planning challenging engineering projects. The essence of engineering design is judgment: how to use the available materials, components, and devices to reach a specified objective. The crucial and unique task of professional engineers is to identify, understand, and interpret adequate solutions to engineering problems in consideration of existing or new technologies. They are team leaders who generally undertake the sole responsibility of the project, as well as serving in senior managerial positions. Possession of the full extent of knowledge, proficiency and immense expertise in their field, along with personal skills, is an absolute must for the engineers falling within this category. A vast previous experience in a particular engineering branch is substantially required for the successful accomplishment of the project. The innovative approach may also be needed, to a certain extent, though they commonly use existing technologies. Professional engineers make the decisions at

their discretion. Thereby, they pose technical accountability for highly complicated systems with significant levels of risk. The rank of engineers of this category is regarded as higher than that of those termed as 'chartered engineers' employed in some countries. Professional engineers are capable of closely and continuously following progress in their specific branch of engineering science by consulting newly published works on a worldwide basis, using such information and applying it independently.

- **Innovative engineers:** Engineers falling in this category are involved in bringing new ideas and solutions to highly challenging engineering issues by means of innovations and creations of new or noble technologies, as well as continuing development of existing technologies. Extensive knowledge and immense practical experiences in a very specific field of an engineering discipline is substantially required. They may also be regarded as scientists, but not in the sense of pure science, as they are primarily interested in the practical outcomes of solutions. In other words, they are engineering scientists. They, however, work in collaboration with pure scientists where necessary. The main objective of innovative engineers is to justify how scientific thoughts and ideas are applied successfully to practical conditions in the most convenient manner.

The most important factors to be considered in engineering education can be listed as follows:

- to equip students with the ability to develop analytical solutions and alternatives for the problems they will encounter.
- to provide general design principles that can be applied under all kinds of conditions.
- to emphasize the investigation of experimental methods in laboratory courses.
- to ensure that graduates use their practical and analytical skills in solving technical problems.
- to provide the ability to research and develop alternative technologies, in addition to using existing materials and systems when designing.
- to prepare graduates for postgraduate education

4. Engineering Education

Engineering education literally means the activity of teaching fundamental knowledge and essential principles related to the professional practice of engineering. Engineering requires extensive formal, theoretical and practical training. Methodology adopted in an engineering education is obviously based upon the engineering principles as mentioned above.

It is a common understanding that in any field of education, the learners generally try to use their ability of imagination to visualize the object that is described verbally. No matter how effective the verbal explanations are, the learning may, however, not be fully complete by such a verbal description unless the real vision of this object in the form of a picture is made available. Teaching with the aid of audio-visual materials, therefore, helps greatly to promote the quality of learning. Teaching with mere pictures may, however, not be as effective if certain physical properties of this material, e.g. surface hardness, toughness, smoothness, etc., are to be taught. In this case, the material itself, rather than the picture, is required for successful perception of properties since physical contact for close examination is needed for this type of learning. This situation, thus, indicates the necessity of hands-on learning inside or outside of the classroom. Some subjects can be learned in laboratories, as in chemical and physical engineering, while field trips are additionally required for others, like geology and mining engineering.

Learning on the spot or 'in-situ' learning is probably the most important education method, which greatly enhances the effectiveness of engineering education. This is basically a form of learning in a place where the subject is actually practiced in real life. Such places may be an actual production in a factory, in a mine-site or on agricultural land where the related operations are actively realized. The learner is able to observe and acquire all outcomes of the subject, i.e. the learners achieve the main idea along with all the details by living it. The degree and the effectiveness of learning are likely to become higher with a longer time span spent in a practice.

The 'in-situ' style of learning has resulted in tremendous benefits in engineering education. It was understood that students who completed their summer training studies were found to demonstrate greater perception of understanding the subjects better than those students who had not undertaken such an internship study. The degree of accomplishments of students was assessed through report presentations, giving a full account of their activities during internship studies. Moreover, the students who were understood to work diligently during summer training studies were seen to be much more creative with their project assignments than the others. They were able to develop better visions and solutions to engineering problems with realistic outcomes. Such competency and sophisticated skills exhibited by these students were attributed to the effectiveness of in-situ learning. The students can have a chance to observe all aspects of the subjects, ranging from technology to psychology, rather than limiting themselves to a single point of learning, since they are living with all activities and circumstances while working in an actual place. For example, they also perceive the psychology of all employees in the working atmosphere, behavior of workers, cooperation between employees, various ethical issues, along with the difficulties arising from engineering functions or technical methods employed there. Hence, the students will be able to understand that excellence and ethics go together, and they combine all of these different parameters together to develop rational projects in the future.

The above-mentioned explanations infer that in-situ learning or related practical teaching provides the engineers with a high vision, and significantly improves the skills with creative engineering approaches. It is believed that the inclusion of practical learning within the curriculum of current educational systems in engineering will be beneficial.

4.1 Collaboration between Universities and Industry

The connection between universities and industry should be strengthened, with a greater emphasis on joint research and design projects. These strategic partnerships foster innovation and economic progress through shared research, knowledge exchange, and resources.

4.2 Curriculum Development

To determine the structure of the engineering curriculum, councils representing various segments of society should be established. The resulting educational programs must then be shaped by the decisions of these councils. The curricula of engineering faculties must be designed to develop the knowledge, skills, and competencies expected of a graduate upon entering the profession.

In the implementation of an engineering curriculum, how subjects are taught is just as important as what is taught. The traditional lecture method, where faculty members deliver information directly to passive students, does little to enhance problem-solving skills or foster critical thinking abilities. Consequently, this approach leaves graduates ill-equipped to tackle the professional challenges they will face in their careers. Instead of one-way lectures, more effective methods such as project-based learning, problem-based instruction, and collaborative teaching should be adopted, as well as differentiated instruction, active learning techniques like reciprocal questioning and Think-Pair-Share, and inquiry-based learning.

4.2 The Importance of Practical Experience

As a fundamentally applied discipline, a significant challenge in engineering education is that many students tend to shy away from or hastily complete laboratory experiments. This often results in graduates lacking the essential hands-on skills required of a competent engineer. Therefore, engineering programs must be structured to ensure that students engage in a learning process that is predominantly experiential and based on "learning by doing."

In light of global advancements in science and technology, as well as each nation's specific needs, engineering education should shift from a purely generalist approach—or complement it—to include specialized training in specific fields (Ozsoy, 2001). This approach will cultivate the technical personnel that industry requires: individuals with in-depth knowledge, targeted training, and strong practical skills in defined areas.

It is essential to not only increase the number of practical applications in engineering education but also to ensure that these applications are realistic and closely aligned with real-world scenarios. Furthermore, it can be argued that "workplace training," conducted in cooperation with industry, holds significant importance in the engineering curriculum. Workplace training is a vital opportunity for students to bridge the gap between theoretical knowledge and its practical implementation.

5. Conclusion

The effectiveness of engineering works depends upon the degree of their viability and reliability in practical conditions. The value of engineering marvels is due to their practical significance with maximum comfort and safety. Practical learning, therefore, emerges as important in considering an engineering education, particularly with manufacturing and field-intensive disciplines. More effort may be needed for the adoption of teaching methods consisting of substantial portions of in-situ learning.

Focusing on the following procedures may be of very helpful in this respect:

- Intensifying auto-visual teaching in classrooms.
- Increasing hands-on education systems both in classrooms and out of the classrooms.
- Including in-situ teaching with prolonged time periods in the curriculum.

It is essential to equip engineering students with the ability to work across disciplines. Furthermore, fundamental engineering activities such as synthesis, design, and basic design projects—which form the core of engineering practice—should be introduced earlier in the curriculum.

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Conflict of Interest Statement
The author declares no conflicts of interest.

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