International Research Journal of Engineering Science, Technology and Innovation Vol. 1(1) pp. 14-25, April, 2012
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Full Length Research Paper

Engineering science and philosophy

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Accepted 02 February, 2012

Engineering services and structures are among the cornerstones in any civilization growth and development for the social harmony of the society. In the planning, design, construction, maintenance and operation of these structures, engineers had innovative practical and creative artistic abilities in the past, but systematic education and training programs led them to get away from such abilities with more emphasis on the analytical and numerical ability improvements with deductive inferences leading to standard solutions. Although analytical intelligence and ability are indispensible gradients in mass production, their crisp and hard rule applications do not provide creative bases in engineering career. It is the main theme of this paper to emphasize the significance of science philosophy entrance into the engineering education and training. Without such a basis engineers expect case study solutions and ready software or formulation matching in their problem solving stages and hence creative abilities are not cared for future improvements and advancements. Philosophy of science provides dynamism into the creative intelligence of engineers.

Key words: Apprentice, deduction, education, philosophy, master, memorization, science.

INTRODUCTION

Engineering career evolution has gone through many stages even during extinct civilizations and a specific evolution is taking place today. It is not possible to think of any civilization without engineering works such as bridges, roads and highways, dams, airports, water distribution systems, construction material, earthquake resistant structure design, and weaponry. Initially, engineers had their trainings in the form of master-apprentice information transfer with linguistic (verbal) statements, which had logical, rational and philosophical (uncertainty) aspects all together for the problem solution. Engineers were in the domain of art rather than science and there was hardly a distinction between an engineer and architect. Today, although architects are still in the linguistic and aesthetical domains but engineers shifted towards more crisp ideas, numerical methods, procedures, algorithms and ready software for the problem solutions. Hence, rather than creative thinking and specific production, similar case study and formulation solutions become fashionable, which decelerated the creative and productive aspects of engineering education and training. Old fashion master-apprentice relationship broke and gave way to academic dependent only on the mathematical equations without master degree and in the meantime apprentice side either faded away or ignored completely.

Prior to detailed information about the importance of the science philosophy, engineering reflections on the sayings of several scientists, philosophers and engineers are assessed.

"*It is the mark of an educated man to look for precision in each class of things just so far as the nature of the subjects admits*" (Aristotle, 384-323 before Christ).

Today engineers as educated men and women should look for different classifications that are rather subjective but have common information about other engineers to criticize and try to improve the available knowledge.

"*Scientists explore what is; engineers create what has never been*" (Theodure von Karman (1911).

This implies that engineers are not scientists but they should benefit from the exploration of the scientists for creative ideas in improving the comfort of the society. Present day engineering education systems try to empower candidates with physical and scientific findings without practical use and the philosophical bases. The statement “engineers cannot be scientists”, becomes true if he/she is not aware of philosophical thinking but

critical views. For an engineer to become a scientist, he/she should empower himself/herself with
principles of philosophy, subsequent logical propositions and inferences. Philosophy and logic necessitate linguistic (verbal) means, which are missing in engineering education systems, instead present day engineering trainings are full of numerical formulations, symbols, equations and software. The first intensive contact of engineers with logical principles is due to software writings, where any slight logical error causes mistakes and the software do not produce desired outputs. Debugging in any software development requires science philosophy and logical principles more than any other numerical calculations in engineering domain.

"*The origin of the science of classification goes back to the writings of the ancient Greeks but the process of classification, the recognition of similarities and the grouping of objects based thereon, dates back to primitive man*" (Robert R. Sokal).

Systematic scientific writings that started with Old Greeks were based on the philosophical thinking and rational bases. Original and creative ideas have started with philosophical thinking in deductive and to a lesser extent inductive ways. Ideas are criticized, discussed and rendered into improvements for the service of the society. In ancient times, there was no distinction between a philosopher, scientist, engineer and an architect. Any individual had philosophical thinking, logical deductions and rational bases at different grades and consequently, according today's criteria he/she can be specified as an engineer, scientist, philosopher or an architect. As a trend from the engineering history, engineers should have philosophical bases in their creative works, but not pure philosophy, instead science philosophy. One should ask at this stage, which type of philosophy should be given during the engineering education today? Is it pure or science philosophy? Since, engineers are concerned with the comfort of the society in general leading to objective solutions, science philosophy is necessary in their basic education program so that they can adjust ideas linguistically in a qualitative way prior to numerical solutions. In this way, engineers will be empowered to suggest not only a single solution similar to case studies or problem solutions in text books, but several alternatives, in which case the engineer then tries to select the most rapid, cheap, secure, and optimum solution by reserving other features for future use.

"*The mere formulation of a problem is far more often essential than its solution: to raise new questions, new possibilities, require creative imagination and marks real advances in science*" (Albert Einstein)

Engineers after their four year Bachelor of Science education, depending on their analytical thinking abilities, try to solve problems according to readily available formulations or software, without creative thinking capability. The above saying indicates that none of the formulations provide a unique solution of the problem at hand, but approximate results. This implies that any formulation has improvement possibilities provided that the scientist or engineer wants to think analytically with the support of science philosophy. Here philosophical thinking means, for an engineer, to understand foundations of engineering problems not through the symbolic logic and symbols as in the formulations, but their logical rules (Şen, 2011).

"*If you can measure what you are speaking about and express it in numbers, you know something about it*" (Lord Kelvin)

This statement suits to quantitative physical and engineering aspects, but it also implies that prior to numbers, the mathematical expressions should be in verbal information. Any instrument provides measurements, but without knowing the possible scale domain of the measured variable, it is not possible to accept the measurements straight out as accurate and useable in engineering problem solutions.

Recent movements towards the philosophy of engineering indicate that engineering career started to face in an increasing manner a global crisis that spurs although temporarily, a turn to philosophical fundamentals, principles, logical propositions and inferences prior to any quantification.

Almost all the engineering methodologies are heuristic in nature, which require accuracy and justification characteristics. Additionally, these methodologies are crisp and based on a set of unrealistic or approximate assumptions and hypothesis, which provide a philosophical basis for further criticism and debate, which are all in verbal domain; their proper and effective uses necessitate philosophical grounds.

In classical engineering training, scientific knowledge generation is not possible without philosophical bases. Philosophy triggers desires for generation of innovative inventions and knowledge. However, heartily thoughts (based on religion, ideology, patriotism, etc.) are different from person to person without common objectivity, but their support to rational thinking may provide additional internal energy and excitement. Many individuals, institutions, associations and establishments may mention differently about critical criticism, analytical thinking, global approximations, science and topics like understanding the nature, but they do not mention about the common base of all these points, which is philosophy.

If philosophy is exempted from these as cement, the research spirit of human might be boring again indulging to repetitive and ready memorization rules. For instance, many may think that for critical debate, internet connection may be useful, because it is information technology for knowledge transfer. Anybody can think that he/she can draw useful information from internet and may print them on paper keeping in mind that later he/she will read. In this manner piles of paper lay next to him/her. Is it possible to deal with them without

philosophy and critical assessment? Or is it better to intake knowledge simultaneously with philosophical and logical foundations by giving rise to their accumulation in minds rather than on papers? It is a personal experience that after some time, the accumulation of papers are useful only to use their reverse sides as scrap papers. Internet information cannot be safe completely, and therefore, it is necessary to verify their validity by philosophical, rational and logical means. In order to keep critical thinking on line and alive, one should make critical revisions frequently. Philosophy teaches the principles of critical thought. An engineer empowered with such critical view abilities can revise the coming information with rational, philosophical and logical rules and renders the intake of information into useful forms for the society. This information remains in his/her memory linguistically for any future verbal, symbolic and formulation generations. Convenient forms may be given to logically base engineering philosophical knowledge in any problem solution. If the thought is critical then reading, writing and productions also become critical and alive. One cannot say that there remains no memorization, but engineers equipped with philosophy and logic can reserve them in their mind even after their repetitive usages with dynamism and triggering at times of need. Another property of an engineer is practical thoughts and solutions and these are also provided by philosophical approaches. After raising philosophical engineering knowledge to the level of practicality, it can be employed by the engineer in convenient cases for solutions. Such practical knowledge can be transferred to new engineering adults as simple as possible with principles of philosophy of engineering. This gives to engineers the ability of feeling that he/she can also generate information and can use knowledge at proper times and locations for problem solution.

In classical engineering education or even during the secondary school training, there may be some memorized information, which may be rendered into more active and the least static status by philosophy. The most significant separation of the philosophy from engineering is that, in philosophy, there is no end for solutions, whereas in engineering there must be ends for applications. Any mind acquaintant with philosophy tries to find not a unique solution to the problem at hand, but several alternative solutions. If engineering is defined as the practical application of available knowledge, then such a definition may lead to undesirable conclusions as if engineering does not need philosophy. This consequent may be documented on the basis of scientific philosophy, because science has more rigid rules compared to philosophy and philosophy of engineering, which is akin to the philosophy of science.

After all that has been explained in the previous paragraphs, it is the main purpose of this paper to reflect scientific philosophical aspects that are necessary in the engineering education. In the past, master-apprentice training for an expert engineer has become more involved in the universities as if apprentice stage corresponds to Bachelor of Science, master stage to Master of Science and finally expert level can be viewed as the Philosophy of Doctorate. In these three stages of modern education system, “science” and “philosophy” are emphasized even in engineering training. The graduates seem to have been empowered with analytical thinking capability, which helps engineers to memorize, transfer and readily use of knowledge according to past applications. It is emphasized in this paper that science and its philosophical foundations should be given to engineers for better problem solving and even personal emotional and intuitive comfort, which help to improve practical and creative intellects.

Basic engineering

Engineering and architectural thoughts are related to metaphysical and ontological issues such as imagination, description and visualization of a certain problem along the solution path, and therefore, philosophical and logical interpretations and inferences are necessary to reach at a final solution among many alternatives after an effective decision making process. No need to say that such philosophical ingredients in engineering are relatively rare compared to the methodology, epistemology, ethics and aesthetics. A common ground among the engineers and philosophers include topics of ethics, aesthetics, epistemology, methodology and ontology. However, these two groups of specializations have shown common interest during few decades only on ethics and since many centuries on aesthetics, but not so on other issues. Perhaps, the first impression in both specializations is towards looking onto each other as if the interests are different, but as long as verbal issues are concerned, engineers must shift towards the philosophical domain so as to increase their ability to draw deeper conclusions for their current problems prior to numerical solutions. Coupled with the preassembled linguistic (philosophical and logical) understanding, any formulation or equation appears as a matter of dynamic activity on the engineer’s behalf.

Engineering can be defined also as an art and ability of rendering available natural resources for the service of human after scientific inferences and their applications. In this statement, there are two words, “ability” and “art”, which can be explained only philosophically. Scientific theories and results are produced by scientists and as end product users, engineers cannot be scientists, but by acquainting themselves through philosophy of science principles, they can come along with scientists closely and with common and joint agreements. After all, scientists who are empowered with the philosophy of science and any engineer with background on the philosophy of engineering can find a common hinterland for discussion. Unfortunately, without philosophy of engineering, engineers are confined to blind and

restrictive applications of scientific outputs only. In order to avoid such a situation, engineers must be empowered with philosophical thoughts also apart from ethical and aesthetical implementations.

Classical engineering solutions do not consider the philosophical principles, which cannot be limited, indefinable and explain wholeness, and only on economy. Such solutions are not considered within wholeness, and therefore, may have harmful ingredients. Instead of trying to improve the occurrence of harmful cases afterwards, it is far better to search for solutions by considering philosophy of engineering principles from different facets and suggest an engineering solution based on linguistic information and subsequent logical rules. Mathematical formulations have logical linguistic information at their bases and hence the engineer must put forward their thoughts linguistically into action with a set of knowledge about the subject concerned. Philosophical knowledge provides reasonable distinction between the useful and harmful aspects of a problem, and hence, useful aspects may be selected rationally. Today engineering curriculums include socio-economic and cultural courses for linguistic training of engineers, but without philosophy of engineering such a desire may not reach its target successfully. In engineering all the symbolic and numerical results can be useful only if they find their linguistic fundamentals in engineers mind and memory. Additionally, philosophy of engineering principles is bound to provide a more dynamic basis for better understanding of socio-economic and cultural courses.

Luegenbiehl (2010) defines engineering as "the transformation of the natural world, using scientific principles and mathematics, in order to achieve some desired practical end". In this definition, the words "scientific" and "mathematics" as preliminary requirements for the existence of engineering implies "philosophy of science" and "logic", which is also a discipline under the philosophy. Unfortunately, many engineering institutions all over the world do not care for philosophy of science or logic. They drive away these two major legs of the modern engineering career and concentrate more on science for the sake of science and mathematics for the sake of knowing mathematics. Consequently, engineers seek solutions to their problems by using the end products of the scientific achievements and mathematical end products in terms of formulations, equations or algorithms without linguistic basis, where philosophy can provide a creative thinking domain. They know superficially that mathematics means logical principles and science finds its basis in the philosophy.

Mitcham (1994) gives the general characteristics of engineering through a more linguistical side as follows.

"*what engineering is might be better determined by how the word "engineering" and its cognates and associated terms (such as invention, innovation, design, technology, science, etc.) are used, especially in relation to each other. From a linguistic philosophical perspective, it would be appropriate to begin not so much with our experiences of engineering, but with the words we use to talk about such experiences*"

On the other hand, Davis (2005) is against the idea of philosophical definitions of engineering and a linguistic approach. He suggests engineering definition as,

"*all attempts at philosophical definition will: a) be circular (that is, use "engineering" or a synonym or equally troublesome term); b) be open to serious counter-examples (whatever because they exclude from engineering activities clearly belonging or because they include activities clearly not belonging; c) be too abstract to be informative; or d) suffer a combination of these errors*"

After such criticisms he suggests engineering definition from the historical point of view as follows.

"*engineering, like other professions, is self-defining (in something other than the classical sense of definition). There is a core, more or less fixed by history at any given time, which determines what is engineering and what is not. This historical core, a set of living practitioners who – by discipline, occupation, and profession – undoubtedly are engineers, constitute the professions*"

Philosophy of engineering

Although science and comparatively to a lesser extent technology intermingle with philosophy, present day engineering has very limited overlap with philosophy (see Figure 1). Engineering benefits from the outcomes of the scientific works, which help to develop technological innovations and scientific inventions, whereas philosophy means marginal and almost non-existing contributions to engineering creative works.

Interactive discourses between various aspects

Philosophy of science has an active role in the scientific studies since the science became rather independently spelled out from the philosophy during the renaissance period. During the last decade through patent institutions, philosophy of technology started to ripen and there are many articles in the literature about such aspects (Scharff and Dusek, 2003; Meijers, 2009). However, philosophy of engineering is a very recent debate in the world, since the last several years (De Poel and Goldberg, 2010). Hence, philosophy of science is an overlooked or delayed aspect of systematic engineering creative thinking. This does not mean that engineers never benefit from the philosophical principles, of course they did, but this remained on an individual basis and it could not be systematized during the engineering education. For instance, ethical behaviors and career rules are based on philosophical basis, but real mass of engineering background on tangible aspects are far away from systematic philosophical principles. Even the entrance of

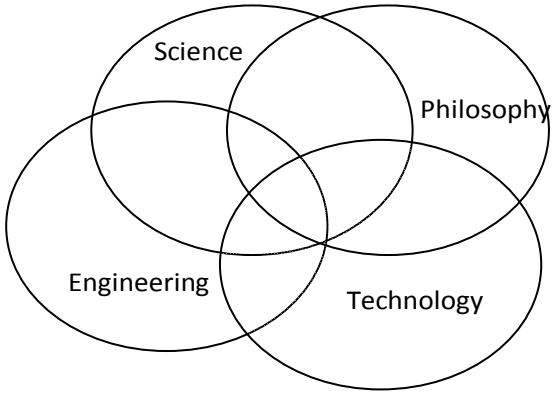

Figure 1. Interactive discourses between various aspects

ethics into the engineering domain is a work achieved during the last few decades (Davis, 2005). One can easily say that philosophy of engineering is almost non-existent in engineering curricula. Another vague entrance of philosophical thinking into engineering domain may be that generally, engineering and technology are thought as distinct disciplines, but there are occasional interferences between the two, which transfers some philosophical aspects into engineering thinking, because some engineers take active involvement in technological developments such as the first atom bomb production. Some may propose that there is no need for separate philosophy principles in engineering, because they are included in the philosophy of technology. This is not acceptable completely due to the benefit of engineers from the end products of science rather than technology in their mental formation outputs such as design, solutions to many problems and in report writing. Most of the engineering students in the world cannot write proper reports or articles due to their inefficient philosophical backgrounds.

After all that has been explained above, one can understand that philosophy of engineering is a virgin topic at the verge of development and there is no commonly agreed set of fundamentals, principles and rules for the definition of this field. Hence, it is within the context of this paper to propose such set of items, which can be elaborated in the future.

Figure 1 shows that engineering is a mixture of different disciplines and the best engineering training should adapt the relationship in different proportions between engineering, science, philosophy and technology (Şen, 2011). Engineering depends on aforementioned disciplines but some of them are also engineering dependent such as technology and some confirmations of science through experimentations. The most important aspect of engineering is design, which differentiates engineering from science and technology. It is well recognized by many that science is concerned with discovery, technology with invention whereas engineering is more craft work concerned with making, producing and generating alternative solutions for a given problem. Critical scientific knowledge including theories falls within the domain of science, which is in a continuous development throughout centuries. Patterns and blueprints are invention imprints in technological development. However, engineering tasks are concerned with material products and designs.

It does not mean that scientists and engineers alike try to improve human security and comfort, but perhaps more dangerously destruction of society through inventions of harmful weapons, tools and materials. Herein, philosophical topics as ethics and aesthetics come into view as interrogatives. Even noise pollution from any engineering production can be considered as an ethical inconvenience for the society. If philosophical principles are not cared for in engineering, then engineers may try to save the day only through their stagnant knowledge in their minds as memorizations. Hence, they may not heed for criticism, questioning, interrogation and hence they may apply their prescription on the memorization base without much benefit. Any applied formulation, procedure or software is not criticized prior to application as for their suitability for the current problem. If the fundamentals of knowledge are not taken on philosophical and logical foundations, then the engineer may not even know how to achieve the work dynamically, which leaves domain only for dogmatic prescriptions.

Since, philosophy is a way of rational explanation of natural objects and positive phenomena, an engineer apart from the understanding of a scientist, must draw a share from this definition. Even though engineers are not scientists, they may come close to scientific findings by acquainting themselves with the philosophy of engineering. It is possible that an engineer can reach depths of scientific knowledge provided that he/she is interested in interrogation, criticism and interpretation of the end products from different philosophical and logical angles. Of course, an engineer should do all these for a successful application of the knowledge in a dynamic manner. One may have engineering background, but

after graduation many years later, he/she may understand that engineering education as it is currently without philosophy of engineering and logical rules cannot entitle an engineer to be a scientist. In various discussions with many scientists, who did not have proper engineering background, in different countries, one may enter into scientific discussions about what is the science? What are its principles? What are the features of scientists? We came to the point that "engineers are not scientists". When others realized that he/she has engineering background, then they mentioned about exceptions. Such an exceptional stature is gained by trying to acquaint oneself with philosophy of science and logical rule generation verbally. Extra interests give one ambition to continue to work on even after graduation and at the end, one also may came to the conclusion that engineers cannot be scientists until they have acquaintance with philosophy, in general, and philosophy of science and philosophy of engineering in particular. Philosophy of science covers many aspects. Linguistic information, on the bases of philosophy and logic, can provide mathematical and engineering formulations or equations, but the reverse is not true necessarily and it is a dead end. Philosophy is not the property of any career; it has inter-career and service characteristics without distinction. In the classical education systems, philosophies of engineering principles are overlooked and engineering is defined only on the bases of economy, simplicity, speediness and practicality. Crisp engineering solutions may overlook environmental conditions and at the end harmful productions can take place without improvement after destruction. Presently, greenhouse effect, global warming and climate change are among such phenomena.

Science and engineering can be distinguished because the former aims to build theories that are true, while the latter tries to make things work. Although the science is based on models or theories, engineering deals with artefacts or processes. It is possible to understand the world through science and the change of the world is the main concern of engineering. On the other hand, the philosophy of engineering paves the antecedent conditions of both science and engineering. The main purpose of philosophy is to pursuit a question in order to find a genuine knowledge about the world. It is the task of a philosopher to search for such knowledge and then about its confidence and reliability. Hence, genuity and truthness are the aims of philosophy and science, respectively. Additionally, science tries to find the truth leading to knowledge, whereas the philosophy has interest in understanding such a truth genuity. It is the philosophers' duty to turn a critical eye toward science, to assess whether it really achieves knowledge, by what means, and whether we can ever be sure that the most successful scientific theories represent genuine knowledge about the world.

In order to respond to such accusations and attack on engineering activities, engineers need to care for the philosophical foundations at an extent to defend themselves on ethical and aesthetical bases prior to any other philosophical issue. Hence, on ethical and aesthetical bases philosophy becomes a crucial issue for engineers. However, the main topic of this paper is not such a crucial affair only, but more significantly the importance of the philosophical issues within the engineering aspects of basic understanding concerning the scientific facades of training so as to bypass memorization and rather dogmatic training in establishing the fundamental engineering knowledge. Presently the philosophical fundamentals are mostly unrecognized in engineering universities, institutes and colleges. Philosophy is important, because engineers faced with actual problems cannot solve them simply with engineering methods alone. They begin to realize their inability in the philosophical thinking when confronted with problems that do not have spoon feeding solutions according to what they have acquired during traditional and philosophy immune trainings. Most often engineers start to ask themselves questions about in what way and how they should solve the problem that cannot be solved by technical knowledge and expertise alone.

Different subdivisions in the philosophy can be brought together by considering the following points and their mixtures to a certain extent (Mitcham, 1994). He mentioned about the following steps as for the importance of engineering philosophy.

1) Conceptual analysis: It is necessary for clarification and correction of terms in theoretical and practical uses, which involves basically logic,

2) Reflective examination: It provides practice and thought, so as to deepen insight and understanding of, extend, or criticize both dimensions of experience. This includes the core areas of philosophy known as ethics, epistemology, and metaphysics, often with an emphasis on their rational methodologies,

3) Thinking about aspects of experience: These are more global than customarily dealt with by any one discipline. Such thinking may also involve inter-, multi-, trans-, and anti-disciplinary consideration of what is right and good (ethics), knowledge (epistemology), and the structure of reality (metaphysics),

4) The practice of a distinctive way of life and thought: It can be taken to be good in itself, with its own unique knowledge of reality. Philosophy in this sense may also be regionalized into the general guiding practices or principles of an individual or group, as when one refers to someone's personal philosophy or the philosophy of a firm.

Apart from classical ethical and aesthetical aspects of philosophy in engineering some other issues are also related to engineering, but they are not very obvious or not used frequently by engineers. Since philosophy is verbal in its character, it is necessary to consider epistemological aspects of each terminology and

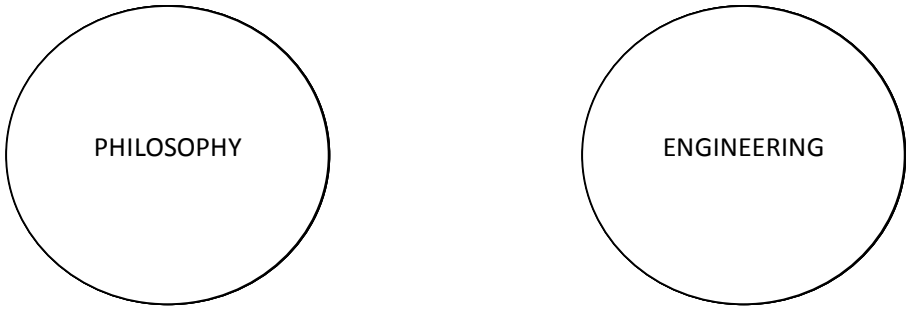

Figure 2. Philosophy-engineering separations

question in their logical contents in order to make successful decisions. Epistemology is a sub-branch of philosophy and engineering is also related to philosophy through this branch.

Verbal information and knowledge are capable to produce symbolic expressions that fall within the domain of mathematics. On philosophy side, they should pay attention to the reality of engineering practices and make analytical and especially empirical grounds. Immediate result expectations by engineers do not give way to enter philosophical issues, and therefore, most often without any questioning, interpretation or criticism engineering education empowers engineer candidates in such a manner that they seek ready crisp answers by using one of the methodologies through symbols in any equation. This is tantamount to saying that crisp thinking and expectations in engineering prevent entrance of philosophical aspects into engineering activities. Any engineer should consider that exact solutions are not possible and hence the results must be questioned from different facets. For instance, the “safety factor” concept kills the possibility of philosophical issues to enter into engineering studies and it is rather an “ignorance factor”; ignorance in the sense that all the blame is thrown over this factor without further ponder and solution in the domain of uncertainty. One can state that the more crisp the engineering works, the less philosophical are activities from the start to the end product in engineering.

If one thinks philosophy and engineering as sets of knowledge then without philosophy of engineering the picture between the two appears as in Figure 2. Is it possible to regard such a situation as dynamic, productive and creative knowledge mechanism? The appreciation of the point is left to the reader.

Philosophy-engineering separations

In the current engineering education systems, philosophy and engineering have separate sub-divisions, which cannot have common points with the sub-divisions of other domain, but in reality one cannot escape from such inference. Logic, epistemology, ontology, art, aesthetics and ethics are sub-divisions of philosophy. On the other hand, civil, electric, mechanics, mining, electronic, nuclear, industry, etc. are sub-divisions of engineering. Today, even one can mention about the philosophy of politics, but what about the philosophy of engineering? Are the sub-divisions in engineering arranged according to philosophical principles or according to mechanical principles with crisp and impermeable boundaries? Are there not philosophical and logical relations between each engineering domain? The reader can appreciate at least that ethics, aesthetics, art and knowledge have relationships with any engineering specialty. Hence, it is impossible that an engineer can be without philosophy. Otherwise, it is not possible to have generative, productive, rational engineering outputs without philosophical ingredients in thoughts. Without the philosophy of engineering and logical rule base in generative engineering career, it is not possible to have engineering outperformances in a society.

In the past, bridges, aqueducts, mosques, cathedrals have been built; say before 500 years without numerical solutions. However, is it possible that present day engineering structures can survive many centuries without philosophy of engineering aesthetics, durability, and economic consequences in the long-run? Fantastic examples of such structures can be found today in many places and also in Istanbul, Turkey, as St. Sophia Museum from the fourth century after Christ, and Blue Most from the 15th century as well as Roman aqueducts in the center of Istanbul in addition to city walls from Byzantine period. In 1998 there was a severe flood that occurred on the European side of Istanbul in one of the valleys. After the flood occurrence one could realize that bridges by Mimar (Architect) Sinan (1490-1588) from 16th century were intact, whereas recently made bridges were all demolished or played the role of small dams due to high water flow, and therefore, surrounding areas were subjected to inundation. One can reason as follows. Old engineers and architects did not have scientific tools such as theories, equations, formulations, crisp algorithms, computers and software but they depended on their philosophical thoughts, imaginations, verbal information, logical rule bases, and consequently, they based designs on these knowledge sets leading to rational solutions. However, present day engineers, without resorting to engineering philosophy concepts, found numerical results from well-established equations (are they really so?) or

ready software and applied them perhaps without linguistic judgments and critical reasoning.

Today one may witness many environmental problems, which may be there, due to the absence of the philosophical (ethical, aesthetical, logical, etc.) principles and ready application of crisp formulations without interpretations and possible consequent assessments of the aftermath phenomenon. One must not forget that any engineering formulation is with assumptions, simplifications and idealizations, all of which may not be suitable for the present problem at hand. Hence, any engineer, with philosophy of engineering and logical principles can suggest alternative formulations to present cases for solution. Not static knowledge only, but dynamic philosophy of engineering principles makes an engineer alive, active and successful in his/her career.

Engineering education and philosophy

In order to obtain better results from an engineering training, instead of repetition, memorization and crisp perception of knowledge, education system should reflect critical discussion, logical and rational thinking. Criticisms must not be limited; otherwise philosophical thinking may be driven away from the education giving way to memorization. Philosophical and logical bases, in arriving to known conclusions, throw away the limitation boundaries, which mean that any knowledge can be criticized continuously. Philosophy of engineering principles can lead engineers to innovative inventions, findings and even to innovative technologies. Invention is related to the accumulation of knowledge in the memory with criticism and rational mind activation near the boundary between known and unknown (uncertain) worlds. This indicates that for creative and innovative findings one should engage his/her mind not within the known domain, but comparatively more near the unknown domain. If the engineer remains within the known domain, then he/she can repeat the same information without any search for betterment or generation of new ideas and hence becomes an engineer without the philosophy of engineering. Interest, excitement and ambition for research are all fueled by philosophy of science and engineering in particular, and basic philosophy, in general.

If in universities and research institutions the right for explanation (authority) remains with the instructors, then such units can produce knowledge, science and technology. Dynamism can be achieved by giving at least equal chance to the attendants as students. In fact, in any education system clients are students, who request information in return of payment (either by government or private enterprise), and therefore, clients' requests must be satisfied with guidance of sellers (i.e. instructors).

Such a liberal education system cannot be established if philosophical principles are missing. Philosophy arena provides each shareholding the same opportunity for questioning and answering with criticisms. The most important duty of an instructor is to stimulate the students for criticism until they understand the explanations linguistically in a rational manner. In an engineering education system linguistic information can be converted later into symbolic and mathematical abstract expressions. Without linguistic bases abstract mathematical expressions are hung in the air only leading to blind applications and unique solutions. Answers to any question must not be individual (subjective) but a common mind (objective) production. For such an opportunity, it is necessary to descent down to the philosophical level and leaving academic titles aside, debates must take place on equal footing level, and the mutual benefits must be rational inferences from logical and engineering philosophical propositions. Putting academic titles aside does not mean that the two sides are on the same knowledge level, but it provides spiritual comfort in debates on both sides. On free thinking horizons, there will be a flow from potential knowledge level towards lower side, but this does not mean that potential side remains on this stage all the time; the balance may shift towards lower side and vice versa.

In many education systems and also in engineering, do training mechanisms that give rise to inscriptions of static knowledge gathering empower the attendants with independent, creative and innovative inventions? In order to provide a continuous and dynamic knowledge production, is it necessary to have only engineering aspects or, social, human philosophy or any other science? Are there linguistic information and knowledge generations based on philosophical fundamental and principles that lead to logical rules and finally produce dynamic ends? If any engineer sticks to the last part of the sentence, he/she must start to train himself/herself with philosophical and logical principles with linguistic information accumulation rather than symbolic or numerical solutions directly. It is obvious from the history of science that since the first human beings astronomy, meteorology, physics, chemistry and similar natural sciences have started within the philosophical thinking circles with accumulation of new knowledge throughout many years, where there were not mathematical, scientific and engineering principles. However, they achieved all such knowledge and their applications for the benefit of human beings by using their minds, memories, philosophical and logical principles in a dynamic and progressive manner. Is it possible that information and knowledge about the natural phenomena can have continuity and dynamism without the inert human abilities such as mind, memory, rational thinking, doubt and especially critical discussion? Continuous, innovative and dynamic knowledge generation cannot be achieved without philosophy and logic. Molded static engineering knowledge cannot provide such a dynamic development. Static, memorizeable and dogmatic

knowledge and information remain as wild giants, but engineering philosophical thinking can overtake these giants and direct them at the service of men. It is also necessary to keep balance between scientific wings of engineering with special art. Engineers must renew their knowledge after graduation through courses offered by engineering societies not only for new information on specific engineering topics, but also on their functions based on philosophy of engineering and logic rules. During such trainings not only affirmative and useful behaviors, but also bad and unwanted examples must be provided. In developed countries engineers cannot sign plans or any contract right away after graduation, but they need to pass through a professional examination worked out by experienced engineers after certain periods. Hence, a new graduate must wait for some time in order to gain experience and then he/she is entitled to apply for such a professional examination. Only after the proficiency examination, an engineer is entitled to sign under professional reports, plans and documents. After graduation prior to proficiency examination an engineer may experience ethical and aesthetical aspects of engineering in practical life and he/she should also try to have training from philosophy of engineering point of view. Any engineer should have the following points among his/her classical training aftermath concerning the career.

1) Fundamentals of physics and mathematics,
2) Social, economic and cultural activities and development of engineering history,
3) Design of engineering projects and after their assessment for the application engineer should provide abilities and different opinions,
4) Benefit from experienced and expert engineers' knowledge, information, view and questionings.

The first three can be obtained during the university education and the last one through, so to say, "Life University." In general, neither university nor post-graduate education provides formal philosophy of engineering (Şen, 2011).

Perhaps one of the main reasons of this is that at each stage there are not rational criticisms. However, providence of such knowledge at the second stage may provide engineering benefits, not only during the graduate study duration, but also after graduation during the career life, leading to more productive consequences. Otherwise, physics, mathematics and social topics cannot be stimulating without philosophy of engineering. Integration and dynamic nature of the philosophy may give the same properties to engineering so as to reach the best desired target. Social and humanitarian topics help engineers to integrate with the society and linguistic information attaches them together. Philosophy of engineering helps to reach to a single best and optimum solution among many alternatives in the most rational manner. Without philosophical principles, decisions cannot be sound and likewise engineering formulations, algorithms and equations cannot be documented in the form of computer programming (software), which needs philosophy and logic.

In the past, engineers were almost addicted to repetitions and memorizations, but today they are under the pressure of modern thinkless and mindless usage of software, which kills the creative ability and fruitful interpretation without philosophical and logical bases. It is better to have simple solutions with philosophy of engineering principles rather than complicated solutions with software. All software and mathematical formulations have basic linguistic foundations. If an engineer does not have preliminary foundations of philosophy of engineering then he/she cannot question software or mathematical formulations. Apart from philosophy of engineering, the formulations and software are accepted without any criticism and they are used as black-box models that do not yield any information about the generation process of outputs under the effect of a set of inputs. Without philosophy of engineering any approach remains at technician level, however, even a technician with the principles of philosophy may be more fruitful in knowledge generation than an engineer.

It is necessary that engineering education must pass through the questioning and philosophy of engineering criteria. An engineer can provide service to any society through various engineering activities, structural designs and management procedures, but such services may be dangerous during medium or long-terms. For instance, for the benefit of a company or local administration, withdrawal of groundwater by very strong pumps does not abide by engineering aesthetics and ethics. Today detailed stages of an engineering education system should have the following steps.

1) To teach fundamental engineering, mathematical and scientific methodologies and to arrive at rational inferences,
2) In cases of necessity, as for preparation of experiment and apparatus designs numerical and especially verbal information play dominant role,
3) To have ability, methodology and software for processing of numerical and verbal information,
4) Try to reach the target for the required needs through useful and systematic designs,
5) Definition of engineering problems, their solutions, formulations and application facilities,
6) To have principles to abide by career and ethical subjects and feel responsibility for this purpose,
7) To exhibit not only local solutions to engineering problems but also at areal, regional and global scales and then their integration for wholeness,
8) To be conscious that engineering problems cannot be solved only according to university education training, but also experience gained after graduation with criticism and interpretations,
9) To complete devoid points in the preliminary information by considering modern approaches and

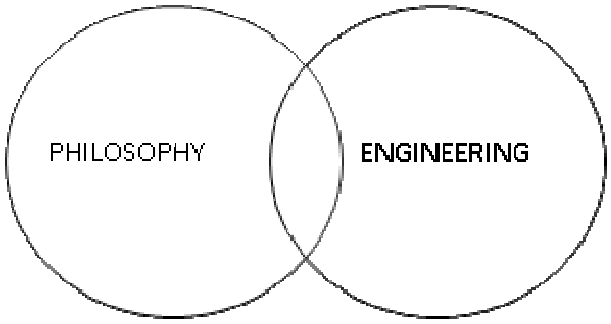

Figure 3. Engineeringphilosophy interference

ethodologies,
10) Try to share engineering knowledge in complementary manner in an inter-career team and to reach to integrated solutions,
11) To know the use of practical techniques and modern methods with instrumentation and engineering applications,
12) At least one commonly used foreign language is necessary to follow technological and scientific developments all over the world.

If there is a question as to where is the philosophy in the aforementioned steps, since engineering is transfer of scientific and technological thinking production into practical applications, at each step philosophical principles should help to develop active and alert thinking channels. By making use of few or all of these steps, an engineering production can be brought into existence, and hence their functions are completed, but philosophical thinking is never complete and it is continuous towards more fruitful and better consequences.

After all what has been explained above, it is obvious that engineering cannot be separated from the philosophy completely. For such a situation, engineering and philosophy domains must have common area as in Figure 3. The more is the common area the more will be the critical development, and hence there will exist an engineering horizon open to innovative and dynamic activities in knowledge generation. Engineering-philosophy interference

The most important and required points in an engineering education can be summarized as follows.
1) Determination of engineering problems, synthesis and increasing solution capability,
2) Increase of engineering solutions that will respond to needs by planning, design and verification,
3) Development of common work abilities with different engineering disciplines,
4) Team works especially with those from the same engineering discipline but with different ideas,
5) Encouragement of student contributions to various activities in engineering education system in various faculties and departments,
6) Provide an academic atmosphere that is suitable to students' social activities,
7) Spread of engineering career understandings and ethical values during engineering education,
8) It is important to give some principles to students for critical discussion in all works during the education period,
9) Development of engineering skills in presentations, software writings and report writings,
10) To provide fundamentals for engineering problem solutions by daily methodologies and approximations,
11) Provide information increment abilities for life-long engineering works even after the education period,
12) Information share with other individuals for the solution of various problems,
13) Increase of engineering views and abilities for engineering applications through modern methodologies and techniques,
14) In different design projects at decision making stage to improve personal connective usage,
15) Keep high level and ambitions in preparation for engineering career after graduation.

CONCLUSIONS

The main concern in this paper is on the ignorance of science philosophy in engineering education systems, which lead to classical training in education with only analytical thinking capability improvements in problem solving in deductive manner based on rather memorization without critical reasoning. In the past, often philosophical and engineering aspects are treated as mutually and holistically distinct phenomena. However, in recent years, philosophy of engineering started to come into view for better engineering education, because philosophy empowers the engineer to reason and criticize in addition to select the most convenient solution after generation of alternatives. All over the world, engineering philosophy aspects are now being considered as a significant element in the engineering curricula. Without philosophical thinking engineers are not empowered with capabilities of creative technological and scientific

innovations or modification of the existing procedures for the evolution of engineering career. Classical engineering training leads to memorization, crisp and dogmatic grasps of symbolic expressions in the forms of equations, formulations and algorithms, which require analytical solution leaving aside the synthesis part of creative thinking process.

Engineers must be ready to deal with philosophical linguistic explanation of design, model, formulation, and problem solution not numerically at first stages, but verbally (linguistically) through logical rules leading to rational products. Philosophers should recognize existence of engineering works, their empirical solutions and decision making at the end of reasoning system. Rather than philosophers, engineers themselves should try and provide philosophical grounds in problem solving prior to symbolic logic that may lead to complicated equations, the meaning which may not be clear for engineers, who come across with such complicated formulations. It is stressed by in this paper that if the background and foundations of any engineering problem are known linguistically (philosophy and subsequent logic) then their conversion to mathematical expressions is only a matter of translation from the language (Turkish, English, Chinese, Arabic, French, etc.) to mathematical symbols. Of course, the reverse should also be applicable in that any formulation in front of an engineer with the meaning of each symbol should be convertable to translate into linguistic compositions, where philosophy (at least science philosophy) and logic prevail.

In order to melt the rigid boundaries between the engineering and philosophical aspects, there is a need for philosophy of engineering. In fact, philosophical principles are already well established throughout the history since old Greeks before Christ almost 2300 years ago, and they are there for engineering exploitation and further exploration.

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