ENGINEERING KNOWLEDGE STOCK FOR GREEN OPERATIONS

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Abstract

The business of nature operates in a 'green' way, independent of the operations of businesses conducted in civilized society by humans. The depth and breadth of knowledge stock required to understand and use the mechanism of natural operations far exceeds the boundaries of the technical knowledge provided to an engineering graduate in majority of the engineering schools. The design of 'green' products and conduct of 'green' operations can be facilitated at a large scale in a short time by producing knowledge workers with the depth and breadth of knowledge that includes the study and application of mechanism of nature in designing products and processes of production.

Addition and expansion of engineering and technology knowledge stock and its compartmentalization on the basis of division of work have contributed to the branching of engineering knowledge stock into different engineering streams. The development of relatively independent streams of engineering have led, to a large extent, to the depth of knowledge stock in specialized engineering branches that in turn contributes to the tendency on the part of engineering professionals and academicians to limit the breadth of the engineering knowledge stock to be transferred to engineering students in engineering schools. The result is the production of engineering professionals with in-depth knowledge in their area of specialization but relatively limited breadth of the knowledge stock diversity required to understand nature and its mechanism as a whole.

The knowledge stock covering the mechanism of nature has also been expanded to the extent where some of the businesses have already started to make use of it in the conduct of their business operations. The process of green business operations can be speeded to a large extent by re-engineering the knowledge base of engineering graduates in such a way that they may be able to use their depth and breadth of professional knowledge to design products and processing systems for producing goods and services at less cost with more value and with minimum negative effect to the natural environment.

Keywords: Knowledge Worker (KW), Manual Worker (MW), Knowledge stock, Green operations, Productivity

1. Introduction

Remirez & Nebhard (2004) [6] made an exhaustive review of literature in their paper related to Knowledge Worker (KW) and Manual Worker (MW), their contribution to productivity in organizations along with the problems of measuring productivity of a knowledge worker (KW). In their work they differentiated a KW from a MW on the basis of work content, level of education, and type of output. A KW, it is explained, deals more with the information and knowledge side of the work content, and have higher level of education and training. The output of KW is categorized in the form of ideas, concepts, transformation of one form of knowledge into other, designs of new products, operations, techniques, methods, procedures, and processes. Output of KW is more on the service side of the spectrum as compared to the MW. Most of the management, engineering and technology professionals fall into the category of a KW.

As per Remirez & Nebhard (2004) [6] observations, number of knowledge workers (KWs) in organizations is increasing and the productivity of organizations is relatively getting more dependent on KWs relative to the MWs. In the second half of the last century more efforts were directed to improve KWs productivity whereas the first half of the last century mostly observed to be devoted to increase the productivity of MWs.

Remirez & Nebhard (2004) [6] in their paper emphasized the importance of increasing the productivity of a knowledge worker. In this regard they quoted Peter Drucker (1999) as:

"….the challenge today is not to increase manual worker's productivity but to measure and increase KW's productivity…..".

The benefits of division of labor, and specialization, led organization to promote narrow work specializations for raising productivity of manual workers (MWs). On the other hand, knowledge workers (KWs) were and are trained to take care of relatively broad work content spanning over the work content of many MWs. Engineering & technology area trained professionals, termed as knowledge workers (KWs), interact pretty closely with manual workers who are mostly involved in the transformation of raw materials and other resources into goods and services.

Important responsibilities of an engineering professional (KW) in an organization is to design new products (Goods & services), systems of production operations, picking and choosing material resources to be used for making products and systems of production, designing the system of transportation and warehousing. Most often, they join industry at a lower level of organizations and after gaining a few years of work experience get promoted to higher managerial levels. At that stage they get more involved in the policy and planning processes. Their choice of input materials and resource/s to be used is mostly determined at the planning and design stage of products and systems of production. The decisions taken at the planning stage generally have long term implications for producers, consumers, and the natural environment in general.

By looking at the quantum and nature of materials and resources consumed in the industrial sector of the big economies of the world and their impact on the global environment, Lester Brown (2005) [2], observed, "….global civilization today is on the economic path that is environmentally unsustainable, a path that is leading us toward economic decline and eventual collapse". Brown observed that Chinese economy is already consuming most basic resources more in quantity than United States of America and Indian economy is on the similar path of economic growth. Brown (2005) [2] stressed that the time has come to develop new economy and new world and he proposed for restructuring of the global economy with a view to sustain civilization, eradicate poverty, and restoration of natural systems.

It is big challenge for engineering professionals (KWs) to help restructure the global economy by changing the design of the production machine at grass root level. It is easier said than done as it may need the basic change in the mind set of a knowledge worker by making changes in their training and knowledge base along with the changes in policy and planning in the use of resources for economic development.

The breadth of the knowledge base along with the depth of knowledge provided to a professionals help them to see the problem in a system as a whole and it helps to find a better solution for a problem to be solved. The engineering professionals by virtue of their backgrounds and placements at operational levels in the beginning of their professional careers seem to be better placed to make use of the breadth and depth of knowledge to do a better job of designing products, designing processes and systems of production and distribution, designing the communication and management systems for organizations, and above all managing the affairs of an organization more productively and environment friendly manner.

In this paper an effort is made to understand the concept of knowledge along with the concept of green operations to set the stage to look into the engineering knowledge stock provided to engineering graduates in engineering schools for green operations in various kinds of production systems.

Motivation

Illiteracy is generally considered as one of the important reasons of poverty and poverty is considered as one of the important reasons of population explosion. The increase in world population is considered as the main cause of increase in demand & consumption of food and fossil fuel. The increase in demand & consumption of food requires more water for irrigation purposes to produce more food. For producing more food, natural flow of river waters are diverted by making dams and long canals for irrigation purposes to far off lands across river basins. The shortage of water supply from natural rivers led to the increase in the pumping of water from ground and thus causing the water tables go down day by day in many fertile parts of the world. The increase in the use of fossil fuel based water pump engines and increase in the transportation of goods and human populations back and forth has increased the consumption of fossil fuel that is leading to the increase in the green house gases in our global system and environment degradation.

The problem starts with illiteracy and it means the design and delivery of prevailing educational system being followed is expensive and the service is not reaching where it is required the most. The growth in population requires more food and it means to divert more resources for more food production. It implies the prevailing design of production and transportation system used for production of food, shelter and clothing in the world is using more water and other fossil based energy resources.

Engineering and technology professionals, whatever branch of engineering and technology they are in, have a big responsibility to radically change the design of products and of production systems to provide education & health services, food, shelter and clothing to the world community by using less and less natural resources. In this context it becomes important to have a look at the concept of 'knowledge' and 'green' operations to set the stage for evaluation of the engineering knowledge base for making positive changes in global environment.

In section 2 of the paper, the green product is defined and explained and in section 3, the importance of green operations is highlighted in the context of environment. In section 4, knowledge is defined and explained and in the section 5, an effort is made to show that how compartmentalization of knowledge has led to the depth of knowledge at the cost of breadth of knowledge. The breadth and depth of knowledge is required to be transferred to the young engineering professionals for designing green products and green operations.

2. Green Products

There is wide variety of literature available on green products. Some authors describe green products as the products that are certified and labeled as 'green' by certifying organizations. Others argue that certified 'green' products might be environmentally friendly in relative terms only in comparison to their alternatives available in the market. However, some of these environment friendly products might have been produced using operational practices and production systems that are not environment friendly. A product may be certified 'green' but the production and distribution operations involved might not be green.

Green products do not destroy the dynamic relationship between a natural system and a society in which these are produced and consumed. On the basis of the survey of literature related to green products; the way these are produced, marketed and distributed, used and re-used, and consumed and finally sent back to the environment, Jannine Gauthier (2005) [5], categorized green products in to five categories of different shades of a spectrum starting with deep green, dark green, medium green, light green, and finally ending with pale green. Deep green being certified organic / fair trade / re-useable / recyclable, locally produced or manufactured, locally sold, by locally owned and operated businesses. Pale green, on the other side of green spectrum, is certified green, organic, fair trade, recycled or re-used and sold at corporate owned businesses.

The proposed definition of green products by Gautier (2005) [5], not only provide general criteria to identify green products but also provide some indications as to how these are to be produced and distributed to a consumer and how it needs to be disposed of back to the natural environment (Total supply chain from end to end) . Gauitier (2005) [5], gone far beyond to include the circulation of the revenue generated by including the local distributors who buy locally and sell locally as compared to the corporate distributors who might buy and sell products locally but take the surplus to some other places as per the decisions taken by higher management levels of a corporation.

Green product and how these are manufactured and distributed provides information to a consumer for selecting a product for their consumption. It is good for a conscious consumer to know before making a purchasing decision. However, from an engineering perspective the definition of green does not provide precise guidelines for its production and distribution. It is the engineering professionals who design products and systems of production and the information about 'green' needs to be translated in terms of the terminology they understand and work with.

3. Green Operations

The literature reviewed related to energy use in the production of goods and services provide evidence that it takes more energy to produce and distribute a product than the energy stored in the product itself and most of the energy used in processing and distributing products is coming from resources that are not environment friendly. For example, the amount of energy required to produce a tin of frozen peas and then to send it to a consumer's kitchen takes five times more energy than the energy stored in a tin of peas itself. It also takes 1000 tons of water to produce a ton of grains (Earth Policy Institute, 2005)

The analysis of the design of a product helps an engineering professional to look into the materials, components or parts that make up a product. Since most of the energy is consumed in the production and distribution process, so it is more important for an engineering professional to look into the design of the system of operations in addition to the design of a product so that operational practices that are not environment friendly be replaced with environment friendly practices.

Professionals working at shop floor generally perceive an 'Operation' (Deo & Strong, 2003) [3], or an 'Activity' (Turney, 1991) [7], as a basic unit of work in a production system. As per Deo & Strong (2003) [3] and Turney (1991) [7a system is a combination of 'Activities' or 'Operations'. In this paper, an operational concept for a unit of work is used to define work in a system of production as this concept helps relatively better to identify the work content and resource content of each operation (Deo & Strong, 2003) [3].

In a production system raw material inputs fed to the system follow a certain sequence of operations before being turned out as outputs. Diagrammatic representation of a production system model as a system of operations given by Deo & Strong (2003) [3]. is shown in Figure 1.

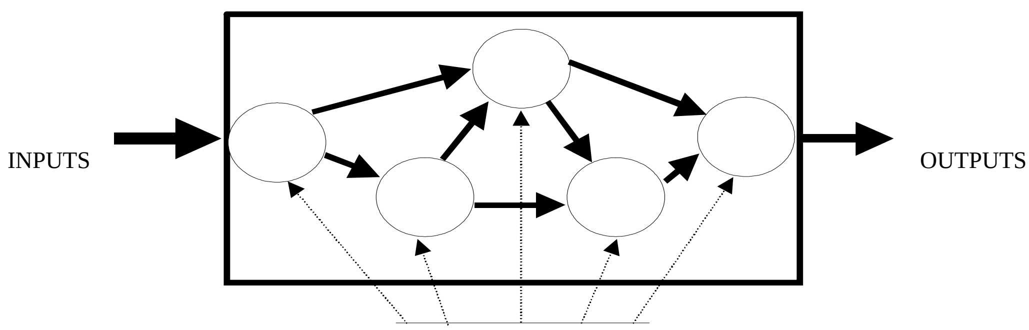
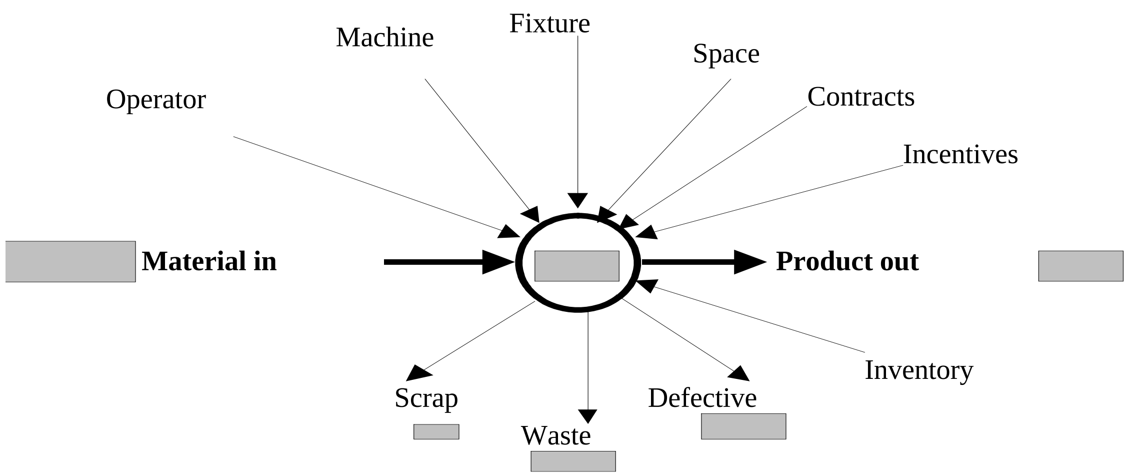


Figure 1. Production system as a set of operations

An operation in a system of production is defined as; a predefined set of tasks, performed in a predefined sequence on a specific material to transform it into the required form, shape or output, at a specified space, for a specified period of time, using a predefined set of resources. The set of resources used in operations are grouped into 8 categories. These are: Materials & supplies used, Operator/s, Machinery, Fixture/s, Space, Contract/s, Incentive/s, and tied capital resources in inventories. Diagrammatic representation of the resource use model for an operation given by Deo & Strong (2003) [3] is shown in Figure 2.

The definition of an operation tightly connects the work content of an operation in terms of tasks, their sequence, and time along with the resource content of an operation in terms of Materials & Supplies, Operator/s, Machinery, Fixture/s, Space, Contract/s, Incentive/s, and tied capital resources in inventories. The model of operation can be used to identify the work content and resource content of an operation. For example, the work content can be identified by the identification of the set of tasks performed in a particular sequence on the material at a particular space for a particular time period.

The resource content can be identified on the basis of the type of material & supplies and their quality and quantity required as inputs. The questions such as: Are materials to be used are re-usable, recyclable, and biodegradable? What kind of machinery to be used? What form of energy and resources required to run machinery? Are the materials and components of a machine and fixture are replaceable, recyclable, and re-usable? What kind of operator skills is required to run an operation? Is labor used in operation is a child labor, bonded / slave labor, or prison labor? Is the operator labor is compensated fairly? Are working conditions and benefits provided to operator / labor adequate? What kind of space is used for conducting an operation? Is it in big city or in the small city or in the country side? How the space is maintained for functionality? How the space is heated and lighted for comfortable operations? What is the type of layout used? Whether location of facilities is close to the market or close to the raw material supplies? What type of transportation system used for raw materials, supplies, and products for distribution to the consumer? What quantity of raw materials, supplies, finished product inventory held? What type of storage system used for storing stocks as inventory? What kind of incentives provided to the suppliers for providing the quality materials on time?



Resource Category use in an Operation

Figure 2. Operation showing set of resources

For analysis of the total system of production, operation as a unit of work model prompts an engineering professional to ask the set of questions at each and every operation, thus reducing the chance to leave any resource unaccounted in terms of its evaluation from an environment angle.

4. Knowledge

In the American Heritage Dictionary of the English Language (1975) [1], the term ‘Knowledge’ has been given various meanings, such as; Information, Learning, Erudition, Lore, Scholarship, Wisdom, and Enlightenment. Information is defined as a random collection of material rather than orderly synthesis; learning is explained as schooling and study; erudition as an idea of profound knowledge often in a specialized area; lore as the knowledge gained from traditions / culture, an individual being part of; scholarship is defined as a distinctive mark of some one who mastered some area of learning that reflected in the quality of work performed especially with respect to the scope, thoroughness, and care; wisdom is defined as sound judgment and the ability to apply what has been acquired mentally to the conduct of one's affairs; and enlightenment as the state of possessing the knowledge and truth.

The meanings of term 'Knowledge' can be categorized in three categories. The first category of meanings can be categorized on the basis of the level of effort made to achieve it, and depth of knowledge achieved. 'Information' falls into relatively lower level of effort and lower level of gain in the depth of knowledge. However, it may not be the outcome at all times, because sometime the information might lead to some more breadth & depth in knowledge. 'Learning' with high level of effort through systematic process specifically designed to provide some specific type of education and training in schools / colleges, and other educational institutions. Erudition also falls in the same category gaining very higher level of depth of knowledge but relatively in a narrow specialized area.

The second category of knowledge represented by the 'Lore' is the stock of knowledge got accumulated in a community or society's culture over a period of time. An individual who spends a reasonable good span of time in a society or a community absorbs it automatically by virtue of being part of it, through day to day interaction with various components of a social system. It may also be assigned to the 'tacit" category of knowledge.

The third category can be based on the exhibition or reflection of the quality of behavior by the owner of the knowledge person. 'Scholarship' seems to indicate the clarity of thought process that can be used for sharing and transferring the specific knowledge and its depth to others or making the knowledge mobile. 'Wisdom' is the operational side of the knowledge in the sense that a knowledgeable individual puts his/her knowledge to practical work for creating a new product, idea, service, innovation, or, in other words, for something useful or productive. The wisdom appears to have the breadth component of knowledge along with the depth component for the application of the knowledge depth to create something new and useful. 'Enlightenment' seems to indicate the knowledge of the 'Whole' or 'Total' that guide the thought process and actions of an enlightened person. An enlightened person seems to be able to see the outcome of actions in advance because of the understanding of the functioning of the 'Whole' or 'Total'. However, it appears to be difficult to put a boundary around the depth and breadth of knowledge of an 'Enlightened' individual. along with the capability of making knowledge mobile through scholarship, wisdom, courage and individual's capability to tell the truth and to persuade others to see it for the benefit of themselves, others and for the 'Nature and Natural environment.

5. Expansion and Compartmentalization of Engineering Knowledge Base

The definitions of green products, green operations, and knowledge discussed in section 2, 3, and 4 indicate that engineering students needs to know and understand the total system as it operates in natural setting. However, on the other hand, expansion of engineering knowledge led to its natural branching into mechanical, military, civil, industrial, and electrical engineering. Other branches such as metal and metallurgical, mining, agriculture, environmental, computer and software engineering etc. also emerged over a period of time. The specialization of engineering branches may be the outcome of the division of work for better productivity. It is almost similar to the concept of job specialization as a result of division of labor, a management concept evolved and implemented as per the scientific management thought promoted by F.W.Taylor and his contemporary thinkers. Division of labor or work makes good sense to raise levels of productivity of both manual and knowledge workers. However, over a period of time, it appeared the expansion of engineering knowledge and its branching not only led to the depth of the field but also led to the tendency on the part of academicians and practitioners to compartmentalize the engineering knowledge-base for its transfer to the new generation of engineers. For example, Diemer (1910) [4] observed in his works that some of the engineering professionals used to oppose discussions on management and cost related issues at various meetings of engineering societies and in engineering publications. Their argument was that engineers should discuss technical matters dealing directly with pure mechanics, nothing else. In their view, professionals from other areas, such as accounting, bookkeeping, statistics etc. should be discussing the issues related to their own areas of expertise.

It appears that the process of not dealing with issues at broad level led to the reduction in the number of professionals who were interested to study other management & environment issues in the engineering disciplines. The process may have led to the study of other newly emerging human and organizational concepts to be formed as part of other emerging discipline rather than the part of engineering discipline. The literature on this side of the issue needs more exploration.

The compartmentalization of the knowledge base for engineering professionals appears to have deepened the technical base of the knowledge but limited the breadth of knowledge base largely to sister branches. The knowledge base that expanded on the side of environment, nature, and humanities such as Ecology, Human factors, Psychology, Sociology, Economics, Finance and Accounting etc. seems to have reduced almost to the minimum.

The breadth of the knowledge base related to nature, environment & humanities side help capture useful information from various sources including the knowledge stock that already exist in societies in the form of lore. The formal learning, erudition and scholarship attained in our engineering schools help identify the engineering problems, and business opportunities that can be harnessed to create wealth in society. The application of engineering knowledge to understand the concrete realities of nature and society and its impact not only on business but also on natural environment in future (Wisdom) help design and produce products and production machines that work in harmony with nature. However, it needs to be observed and analyzed that how far breadth of knowledge is provided to engineering graduates along with the depth of the engineering knowledge in engineering schools.

6. Conclusions

These days, the criticism coming from various directions as a result of disturbances in our natural environment indirectly signal that the design of products and the production & transportation machines being used to produce goods and services, are the causes of various environmental problems being faced today or going to be faced in future. Be it global warming; Katrina; pollution of rivers; lakes and ocean fronts; drying of natural aquifers by pumping more water for irrigation, and its use in industrial processing systems; smog caused by the transportation vehicles in big cities of the world. So it raises the question: Are we providing the right mix of knowledge, in terms of depth and breadth, to engineering graduates in engineering schools for developing green products and green production machines and system? Or do we need to re-engineer the engineering knowledge stock for producing green products and green processes?

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