KNOWLEDGE ENGINEERING
and
A PROPOSED CURRICULUM

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ABSTRACT

KNOWLEDGE ENGINEERING
and
A PROPOSED CURRICULUM

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The drastic developments in computer, information and communications technologies during the second half of the last century have resulted an explosion together with the name of 'internet'. It soon became clear, however, that the key to all these efforts and activities is the 'knowledge' itself. That is why 'software engineering' first, and later 'knowledge management' and 'knowledge science' disciplines drew attention during the last two or three decades. It soon became, however, clear that the key term should be the "knowledge engineering" to be able to build a bridge between various sciences and engineering disciplines such as computer science/engineering, software engineering, information science/engineering, knowledge science, knowledge management, business engineering, etc.

In the study, after a brief introduction, the terms data, information and knowledge have been elaborated. Later, the terms science/engineering, business/management, knowledge management were studied, the content of "knowledge engineering"

(KEng) as a new and different than expert systems development or knowledge based systems is defined next.

Some of the prominent university degree programs in the world relevant to the terms have been reviewed a synthesis, a new undergraduate program under the title of “knowledge engineering” is proposed at the end of the study. The four year curriculum and its course outlines are presented in the thesis. It is obvious that this proposal will be realized depending on the conditions of the individual university who decides to adopt it and will be revised accordingly.

Keywords: Course Outline, Curriculum, Knowledge, Knowledge Engineers, Knowledge Engineering, Knowledge Engineering Degree Program, Knowledge Science, Knowledge Management.

ÖZ

BİLGİ MÜHENDİSLİĞİ ve
ÖNERİLEN BİR MÜFREDAT PROGRAMI

Medeni, İhsan Tolga
Yükseklisans, Bilgisayar Mühendisliği Anabilim Dalı
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Eylül 2008, 69 sayfa
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Doksanların ikinci yarısından sonra bilgisayar, enformasyon (haber) ve iletişim teknolojilerinde yaşanan hızlı değişimler internet teriminin hayatımıza girmesiyle sonuçlanmıştır. Bu dönemi takip eden zamanda, tüm bu harcanan çabalar ve çalışmaların gerçekte aslında 'bilgi'nin kendisine yönelik olduğu ortaya çıkmıştır. Bu sebepten son iki, üç onyıllık süre zarfında öncelikli olarak 'yazılım mühendisliği' daha sonra da 'bilgi yönetimi' ve 'bilgi bilimi' dallarının önem kazanmasının en büyük nedenidir. Yine de, anahtar kelimenin aslında 'bilgi mühendisliği' olmasıyla, bilgisayar bilimi/mühendisliği, yazılım mühendisliği, enformasyon bilimi/mühendisliği , bilgi bilimi, bilgi yönetimi, iş mühendisliği vb gibi pekçok bilim ve mühendislik dallarının arasında köprü vazifesi görebilir.

Bu çalışmada, genel bir tanıtımdan sonra, veri, enformasyon (haber) ve bilgi tanımları irdelendikten, daha sonra, bilim/mühendislik, iş/yönetim ve bilgi yönetimi konuları incelendikten sonra, "bilgi mühendisliği"nin uzman sistemlerin geliştirilmesinde kullanıla gelen tanımından daha farklı ve daha geniş bir içerik ve kapsam tanımlanacaktır.

Dünyada öne çıkan bazı üniversitelerin konu ile ilgili lisans programları buradaki tanımlarla ilişkili olarak incelenmiş ve bunların sentezi olarak yeni bir lisans programı "bilgi mühendisliği" başlığı altında ortaya koyulmuştur. Tezde dört yıllık bir müfredat programına ve ders içeriklerine de yer verilmiştir. Şu açıktır ki, burada ortaya koyulan program, üniversitelerin kendi ihtiyaçlarına göre gözden geçirilip üzerinde değişiklik yapmaya yöneltilebilir.

Anahtar Kelimeler: Bilgi, Bilgi Bilimi, Bilgi Mühendisliği, Bilgi Mühendisliği Lisans Programı, Bilgi Yönetimi, Bilgi Mühendisleri, Ders Müfredatı, Ders Taslağı.

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LIST OF ABBREVIATIONS

A	:Art
Adm	:Administration
B	:Bachelor
Bus	:Business
Ce	:Commerce
Cer	:Certificate
Comm	:Communication
Comp	:Computer
KEng	:Knowledge Engineering
Man	:Management
KS	:Knowledge Science
D	:Doctorate
Dip	:Diploma
Eco	:Economics
Eng	:Engineering
Ex	:Executive
Gra	:Graduate
H	:Honor
ICT	:Information and Communication Technologies

Ind :Industrial

KM :Knowledge Management

Know :Knowledge

Lib :Library

LIS :Library and Information Science

M :Master

Mi :Minor

Ph :Philosophy

Sci :Science

Sch :School

Soft :Software

Sys :System

Tech :Technology

CHAPTER 1

INTRODUCTION

In this chapter, we provide an introduction to the study describing the context that motivates, clarifying the research problem, stating our goals and research questions, and detailing the methodology.

1.1. Statement of the Problem

The globalization and especially the developments in the internet applications have triggered unexpected and yet, significant changes in almost all dimensions of our lives, during the last few decades. In parallel with all these changes, the meaning and value of some terms such as data, information and knowledge have been refined and better understood for almost the first time in the human history.

The drastic developments in computer, information and communications technologies during the second half of the last century, especially during nineties, have been resulted an explosion with the name of 'internet'. It soon became clear, however, that the key to all these efforts and activities is the 'knowledge' itself.

When we look at the higher education environment relevant to information and knowledge, until 90s four important fields took our interest, management science, business science, computer engineering, and computer science. These fields were established for answering the needs of the globalization and technology, in the late 20^{th} century. In the globalization side, management science answered the need for organizational management requirements that shaped by the global market and business side tried to answer them from the point of management processes. On the other hand, the computer age defines the path of technological requirements. The name of the field that will educate the graduates had been a problem. Computer engineering and computer science fields are born together. With 90s, a new wave of changes affected these fields and new sub fields had been established. We can say that, these globalization and technology related fields combined together and, information, data, software, and knowledge oriented science and engineering disciplines were established.

Knowledge education itself can be found from undergraduate education to PhD education under different titles like computer, management, business, information, software and also knowledge. Because knowledge itself is a bridge between these titles, the education itself should establish connection between these entitled fields. From business and management side, the field knowledge management is trying to establish this connection; however, still there is a missing piece, engineering. We believe that a knowledge engineering undergraduate curriculum will establish this connection and by itself, it will become a starting point for establishment of knowledge engineering education all the way from undergraduate to PhD level.

1.2. Previous Work and Objective of the Study

Although there are some PhD level theses that have been finished in knowledge field, most of them are concentrated on the knowledge management discipline [40] and [45] [1]. Objective of the study is to develop a "Knowledge Engineering" curriculum while presenting the reasoning behind such an effort.

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[1] For this study we take Japanese Advanced Institute of Science and Technology (JAIST) for field research. As you will see, the thesis and papers mentioned mostly taken from JAIST.

1.3. Organization of the Study

In this thesis, we will give the history of knowledge in the ancient times, (in Chapter two). In the second section we continue with modern definitions of data, information and knowledge from the different perspectives and from the knowledge as we defined tacit and explicit knowledge and knowledge spiral. We will connect knowledge spiral with the knowledge pyramid and show the connection with management pyramid.

In Chapter three, we will state the encyclopedic definitions of science, engineering, business and management and the positions of these definitions in relation to each other, and show the connections of real world requirements.

In Chapter four, we will define the knowledge field and knowledge management with including the old definition of knowledge engineering and with the new definition of knowledge engineering.

In Chapter five, before talking about the research steps, we will give some example researches and the programs LIS (Library and Information Science) programs and connection with KM (Knowledge Management) programs in Turkey, after then we presented the titles of programs which we used to build our sample universities and program list.

In Chapter six, we will talk about the results of the degree programs research which we will use to build up our curriculum.

In Chapter seven, we will show the guidelines and accreditation criteria that applicable when we consider in our research and our host university, Çankaya University.

In Chapter eight, we will finally present our Knowledge Engineering (KEng) Curriculum.

In Chapter nine, we will end the thesis with the Summary and Conclusions part with including the summary of this study and important conclusions that we find from this study and finally we will give the future possible work related with this study.

CHAPTER 2

DATA, INFORMATION, KNOWLEDGE

The definition of data, information and knowledge has been evolving. In this chapter, we will start with the brief history of knowledge from the ancient times. Later we will take a quick look in the definitions of data, information and knowledge which lead us to understand the concepts of ontology. Definitions of data, information and knowledge under the ontology will give us brief definitions of these terms to be able to lead to a new content and understanding for "knowledge engineering".

2.1. Brief History

From the ancient times, knowledge has been an unreachable destination. Everyone try to reach the sky of knowledge to accomplish their desires, to answer the simple questions of reality why I am here?, what the meaning of life is? or to gain the secret formula of immortality. The legend of Babylon Tower is an example of the greatest desire to reach the impossible knowledge, the knowledge of the gods. As once said, the gods understood the desire of the humans; this endeavor made them angry and they decided to collapse the tower and as a punishment, they separated humans, who were speaking the same language, as different tribes with different languages and even let them use tools that do not match each other at all.

Sumerians and Hittites were of the sons of those tribes but they are two of the important civilization of the ancient world. They lived in a region which we call as Anatolia, and as a product of their civilization and their language they had written their knowledge into tablets, long before we know the meaning of data, information and knowledge. Also Hittites used their written language for peace agreement between Egypt and Hittites (Kades Peace Treaty) [28] which became the first in human history.

Before modern times, for Sumerians, the knowledge was also an important part of the culture. BC 2000s for religion, military, agricultural and magical knowledge [17] and [16]. Sumerians used tablets as a technology to keep explicit knowledge for later use. The education of tablet writers was nearly equivalent and important as our university educations. The graduates were worked in the important government positions. To show the respect of knowledge and wisdom, old mezapo worship the god of wisdom, Enki, Figure 2.1.

Figure 2.1 The Wisdom God of Enki

Like " ba-ma" [30], used by the far-east countries to define internal and external knowledge, BC 2000 "me" was used to define the most powerful external knowledge, the Gods wisdom and knowledge. The cultures and languages developed from the old languages. Like Hittite languages shared the roots of old Sumerian written language, the Anglo-Saxon language family shared the same roots of Hittite language [10]. The similarities helped to understand the meaning of tablets and the explicit knowledge inside of them.

After Sumerians and Hittites, lots of great empires had been seen, in the world history but only their written miracles remained after (the Gokturk's tablets, the obelisk of Egypt and the documents of Roman Empire). But all these languages are different from each other. To find a common language environment we needed to wait until the 20th century.

With the invention of the first computer, world again found a common language to share the culture with 0 s and 1s. With the personal computer and especially internet revolution, another common language brings humans again together. And as a result of this common platform, data, information and knowledge that produced by the different countries have been brought together. But understanding what data, information and knowledge is and which type of these entities can be helpful for humans, schools, companies and governments have become still the main concern for individuals and organizations.

There are lots of different studies related with a number of different disciplines under the interest area of science/engineering and business/management. But under this competitive environment managing the ocean of data, information and knowledge is another problem. There are some examples and different points of view for this purpose in all around the world. The knowledge related disciplines are the answer.

2.2. Brief History of Data, Information and Knowledge in Modern Times

In late 80s Aktaş [8] had defined the data, information and knowledge under the topic of meaning as seen in Figure 2.2. In this definition data has the lowest level of meaning; they are raw facts and opinions. Information is above the data with higher level of meaning, and it is useful for present decision situation. In this trio, knowledge has the highest level of meaning, because it represents information that can be potentially useful in future decision situations.

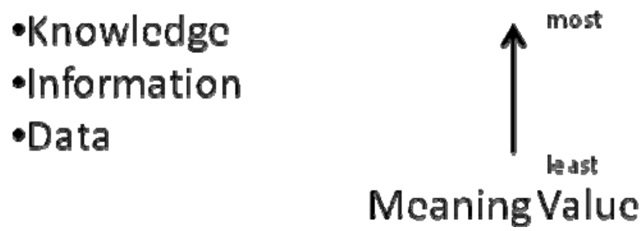

Figure 2.2 Meaning Values of Messages

These definitions are important milestones for knowledge science and knowledge engineering. Before the knowledge, people have been aware of data and information. The use of knowledge was a sense and requirement to give a humanitarian part to data and information.

In 90s the evolution of knowledge continues with Nonaka, [34]. He points out M. Polanyi's [37] distinction between tacit and explicit knowledge. Tacit knowledge is personal, context-specific and hard to formalize and communicate, explicit knowledge is codified and on the other hand refers to knowledge that is transmittable in formal, systematic language. Nonaka explains the conversion of tacit and explicit knowledge as shown in Fig. 2.3.

In this figure there are four terms, socialization, externalization, internalization and combination related to knowledge.

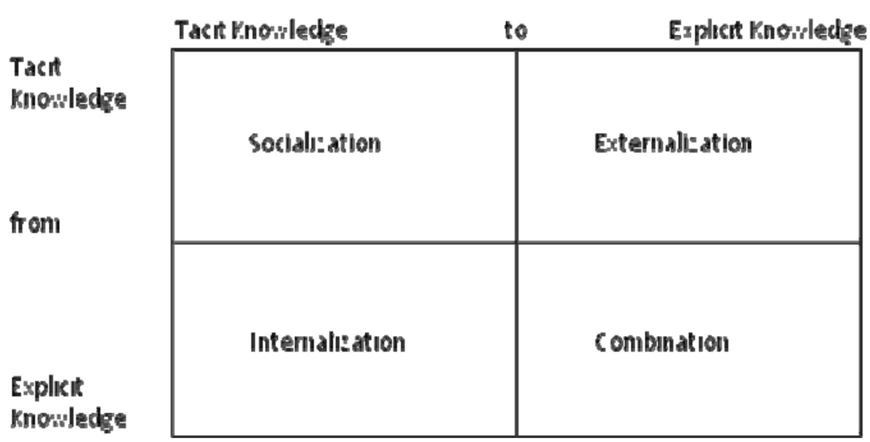

Figure 2.3 Meaning Levels of Message

Socialization can be simply defined as tacit to tacit transformation. It is a process of sharing experiences and thereby creating tacit knowledge such as shared mental model and technical skills. Shared models are defined as "knowledge structures held by members of a team that enable them to form accurate explanations and expectations for the task, and in turn, to coordinate their actions and adapt their extensive review of the literature team members" [15]. Here the common goals can be established by team work of unique tasks of members. Externalization finds its definition between tacit to explicit transformation. It is a process of articulating tacit knowledge into explicit concepts. Here combination is a process of systemizing concepts into a knowledge system. Since combination stays in explicit to explicit conversation, it involves combining different bodies of explicit knowledge. Internalization is a process of embodying knowledge into tacit knowledge. It is closely related to "learning by doing".

These conversions are continuous processes. The model in Fig. 2.3 is not enough to explain the continuity. In order to show this conversion continuity Nonaka used knowledge spiral model as in Fig 2.4 [34].

Three years later, Davenport and Prusak [21] had redefined the data, information and knowledge trio as follows:

Data

Data is a set of discrete, objective facts about events. In an organizational context, data is most usefully described as structured records of transactions. When a customer goes to a gas station and fills the tank of his car, that transaction can be partly described by data: when he made the purchase; how many gallons he bought; how much he paid. The data tells nothing about why he went to that service station and not another one, and can't predict how likely he is to come back. These facts say nothing about whether the service station is well or badly run, whether it is falling or thriving. P. Drucker [22] once said that information is "data endowed with relevance or purpose", which of course suggest that data by itself has little relevance or purpose.

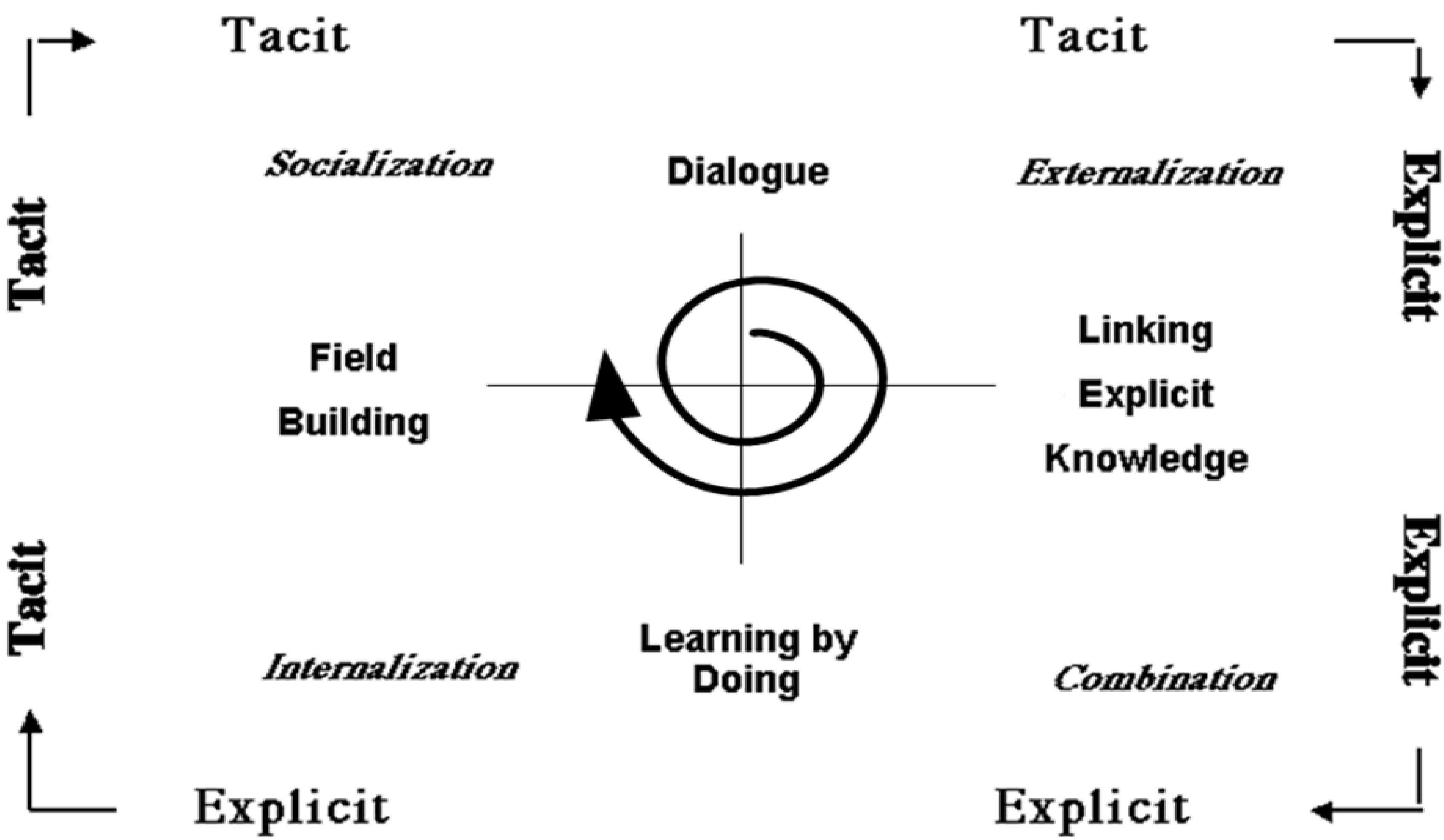

Figure 2.4 Knowledge Spiral Model

Information

It is like a message, usually in the form of a document or an audible or visible communication. As with any message, it has a sender and a receiver. Information is meant to change the way the receiver perceives something, to have an impact on his judgment and behavior. It must inform; it's data that makes a difference. The word "inform" originally meant "to give shape to" and information is meant to shape the person who gets it, to make some difference in his outlook or insight.

Strictly speaking, then it follows that the receiver, not the sender, decides whether the message he gets is really information-that is, if it truly informs him.

Unlike data, information has meaning - the "relevance and purpose" of Drucker's definition above. Not only does it potentially shape the receiver, it has a shape: it is organized for some purpose. Data becomes information when its creator adds meaning. We transform data into information by adding value in various ways. 6 Cs may be stated as [21]:

- **Contextualized:** we know for what purpose the data was gathered;
- **Categorized:** we know the units of analysis or key components of the data;
- **Calculated:** the data may have been analyzed mathematically or statistically;
- **Corrected:** errors have been removed from the data;
- **Condensed:** the data may have been summarized in more concise form.

Knowledge

"Knowledge is a fluid mix of framed experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organization, it often becomes embedded not only in documents or repositories but also in organizational routines, processes, practices and norms [21].

Knowledge derives from information as information derives from data. If information is to become knowledge, humans must do virtually all the work. This transformation happens to be through the following four C's [21]:

- **Comparison:** how does information about this situation compare to other situations we have known;
- **Consequence:** what implications does the information have for decisions and actions;
- **Connections:** how does this bit of knowledge relate to others?
- **Conversations:** what do other people think about this information.

Like Aktaş has sensed the knowledge years ago [8], Davenport and Prusak sensed the importance of experience as follows [21]:

Experience

Knowledge develops over time, through experience that includes what we absorb from course books, and mentors as well as informal learning. Experience refers to what we have done and what has happened to us in the past. "Experience" and "expert" are related words, both derived from Latin verb meaning "to put the test". Experts- people with deep knowledge of a subject- have been tested and trained by experience.

Putting knowledge and experience together knowledge worker may be defined as follows [20]:

"Knowledge workers have high degrees of expertise, education, or experience, and the primary purpose of their jobs involves the creation, distribution, or application of knowledge."
During the last decade another term, 'wisdom' is being elaborated in addition to the earlier trio of data-information-knowledge [46].

In Figure 2.5, wisdom is gained by using data, information and knowledge. We are gaining experience with using data, information and knowledge after a point without thinking what is data information and knowledge we use and create data information and knowledge continuously. This becomes our wisdom. Like knowledge spiral, this spiral shows a continuous conversion [46].

The pyramid in Fig. 2.5 shows similarities with the management pyramid. We can see the use of wisdom for the highest level of management pyramid, CEO; the use of knowledge for the board of directors, the use of information for the middle management and the use of data for transaction management as in Fig 2.6.

In Fig 2.6 Umemato [46] defines the wisdom, knowledge, information and data as knowledge management episteme:

- **Data:** A series of codes in the form of signals eg Letters and/or Numbers;
- **Information:** Pieces of meaning derived from data analysis;
- **Knowledge:** A value, action oriented system (or network) of information;
- **Wisdom:** Knowledge that has been time-tested and proven as truthful or useful.

Although one may also consider wisdom, in the rest of the study we deal with only data – information – knowledge trio

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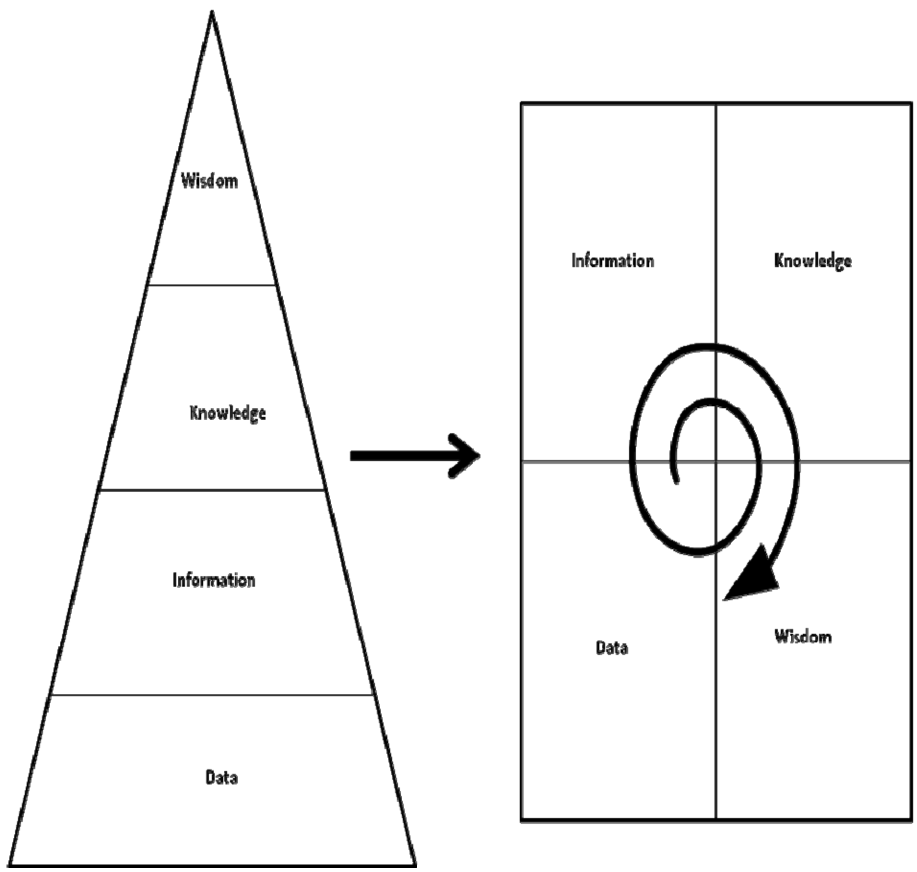

Figure 2.5 Pyramid vs Spiral for Data-Wisdom

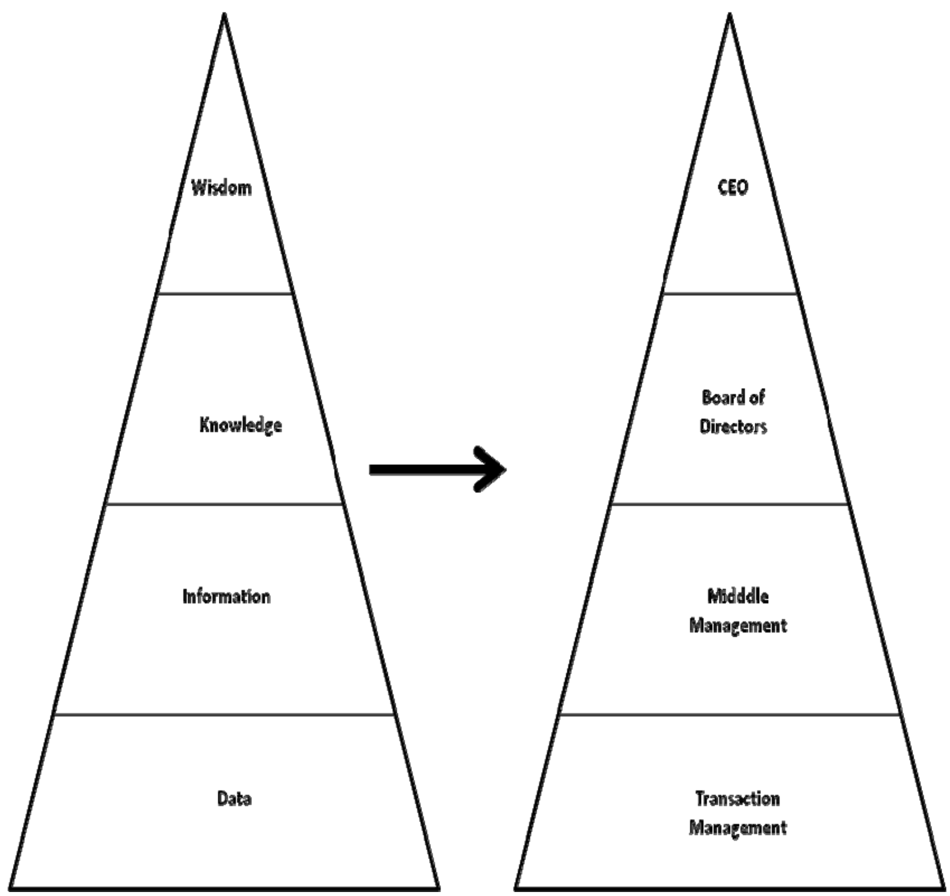

Figure 2.6 Knowledge Pyramid to Management Pyramid

CHAPTER 3

SCIENCE / ENGINEERING AND BUSINESS / MANAGEMENT

In the previous chapter we dealt with data – information – knowledge trio. Before we discuss the knowledge engineering in further details in the next chapter, it will be proper to start with elaboration of the science/engineering first and later the business/management.

3.1. Science/Engineering

Science may be defined as any system of knowledge that is concerned with the physical world and its phenomena and that entails unbiased observations and systematic experimentation. In general, a science involves a pursuit of knowledge covering general truths or the operations of fundamental laws [Britannica, 2004].

Engineering is the application of science to the optimum conversion of the resources of nature to the uses of humankind. The field has been defined by the Engineers Council for Professional Development, in the United States, as the "creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property" [Britannica, 2004]. The term engineering is sometimes more loosely defined, especially in Great Britain, as the manufacture or assembly of engines, machine tools, and machine parts.

The words engine and ingenious are derived from the same Latin root, ingenerare, which means “to create” [49].The early English verb engine meant “to contrive.” Thus the engines of war were devices such as catapults, floating bridges, and assault towers; their designer was the “engine-er,” or military engineer. The counterpart of the military engineer was the civil engineer, who applied essentially the same knowledge and skills to designing buildings, streets, water supplies, sewage systems, and other ‘civil’ projects.

Associated with engineering is a great body of special knowledge; preparation for professional practice involves extensive training in the application of that knowledge. Standards of engineering practice are maintained through the efforts of professional societies, usually organized on a national or regional basis, with each member acknowledging a responsibility to the public over and above responsibilities to his employer or tooter members of his society [49].

The person whose concentration is science is called as scientist, and the persons whose activities related with engineering activities called as engineers. They have their own activities that separate each other. These activities are on Britannica edition as follows:

- The function of the scientist is to **know**, while that of the engineer is to **do**. The scientist adds to the store of verified, systematized knowledge of the physical world; the engineer brings this knowledge to bear on practical problems. Engineering is based principally on physics, chemistry, and mathematics and their extensions into materials science, solid and fluid mechanics, thermodynamics, transfer and rate processes, and systems analysis.
- Unlike the scientist, the engineer is not free to select the problem that interests him; he must solve problems as they arise; his solution must satisfy conflicting requirements. Usually efficiency costs money; safety adds to complexity; improved performance increases weight. The engineering solution is the optimum solution, the end result that, taking many factors into account, is most desirable. It may be the most reliable

within a given weight limit, the simplest that will satisfy certain safety requirements, or the most efficient for a given cost. In many engineering problems the social costs are also significant.

- Engineers employ two types of natural resources—materials and energy. Materials are useful because of their properties: their strength, ease of fabrication, lightness, or durability; their ability to insulate or conduct; their chemical, electrical, or acoustical properties. Important sources of energy include fossil fuels (coal,petroleum, gas), wind, sunlight, falling water, and nuclear fission. Since most resources are limited, the engineer must concern himself with the continual development of new resources as well as the efficient utilization of existing ones. In one sense, one may also define knowledge as a special type of energy.

We can infer that most of the real life problems are solved with using the application of science. Because science is looking a problem in a perfect and control environment, the implementation of science in the real world may not be possible. The engineering is the intersection of real life problems with using optimized scientific methods to use constrained resources of the real life. We can summarize the positions of science and engineering in Fig. 3.1;

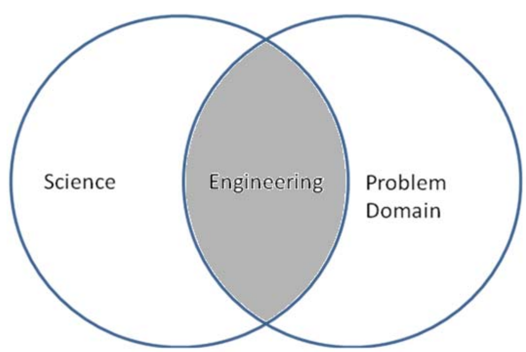

Figure 3.1 Science, Engineering and Problem Domain

3.2. Business/Management

Business and management concepts are very close and related, but they are not the same. In our research, most of the management programs were under the business related areas. For this reason in this part we start with a short definition of business and later continue with management concept.

Business

We would like to share a business definition from [31] as "activity and enterprise that provides goods and services that an economic system needs". In our global environment, the business processes are done over free-market, profit oriented systems, and most of the time businesses are profit oriented businesses. Also the management of the companies and environment is concentrated on money oriented businesses.

Management

Management comprises directing and controlling a group of one or more people or entities for the purpose of coordinating and harmonizing them towards accomplishing a goal. Management often encompasses the deployment and manipulation of human resources, financial resources, technological resources, and natural resources. Management can also refer to the person or people who perform the act(s) of management.

The verb **manage** comes from the Italian maneggiare (to handle — especially a horse), which in turn derives from the Latin manus (hand). The French word mesnagement (later ménagement) influenced the development in meaning of the English word management in the 17th and 18th centuries [49].

Our main purpose is to understand management concept, so it is better to look at the basic functions of management. Four basic functions of management are classified as planning, organizing, leading/motivating and controlling of management [31]:

- **Planning:** deciding what needs to happen in the future (today, next week, next month, next year, over the next five years, etc.) and generating plans for action;

- **Organizing:** making optimum use of the resources required to enable the successful carrying out of plans;
- **Leading/Motivating:** exhibiting skills in these areas for getting others to play an effective part in achieving plans;

Controlling/monitoring: checking progress against plans, which may need modification based on feedback.

3.3. Science/Engineering and Business/ Management

In every science discipline, to create a link between the real world problems and scientific problems, there is an application disciple, as we defined earlier, this is engineering. From the management science point of view, for the business environment there some engineering disciplines to support like management engineering, industrial engineering, most of them related to the sector the business is in.

Management science itself has its own knowledge spiral and the education of management science covers some topics from different engineering discipline. Also like management science the engineering and business environment have their own spiral. These spirals interact with each other as shown in Fig. 3.2. In our research we faced with the fact that in the business and management educations, there were some courses given by some engineering departments, like computer engineering and industrial engineering. And also it has its own spiral for data, information and knowledge. But most of this part is the know-how, the technical implementations [41].

In the business environment, the momentum of this science discipline finds a body. Daily life activities, risk and problems that a business can face gives case studies to study by the management science.

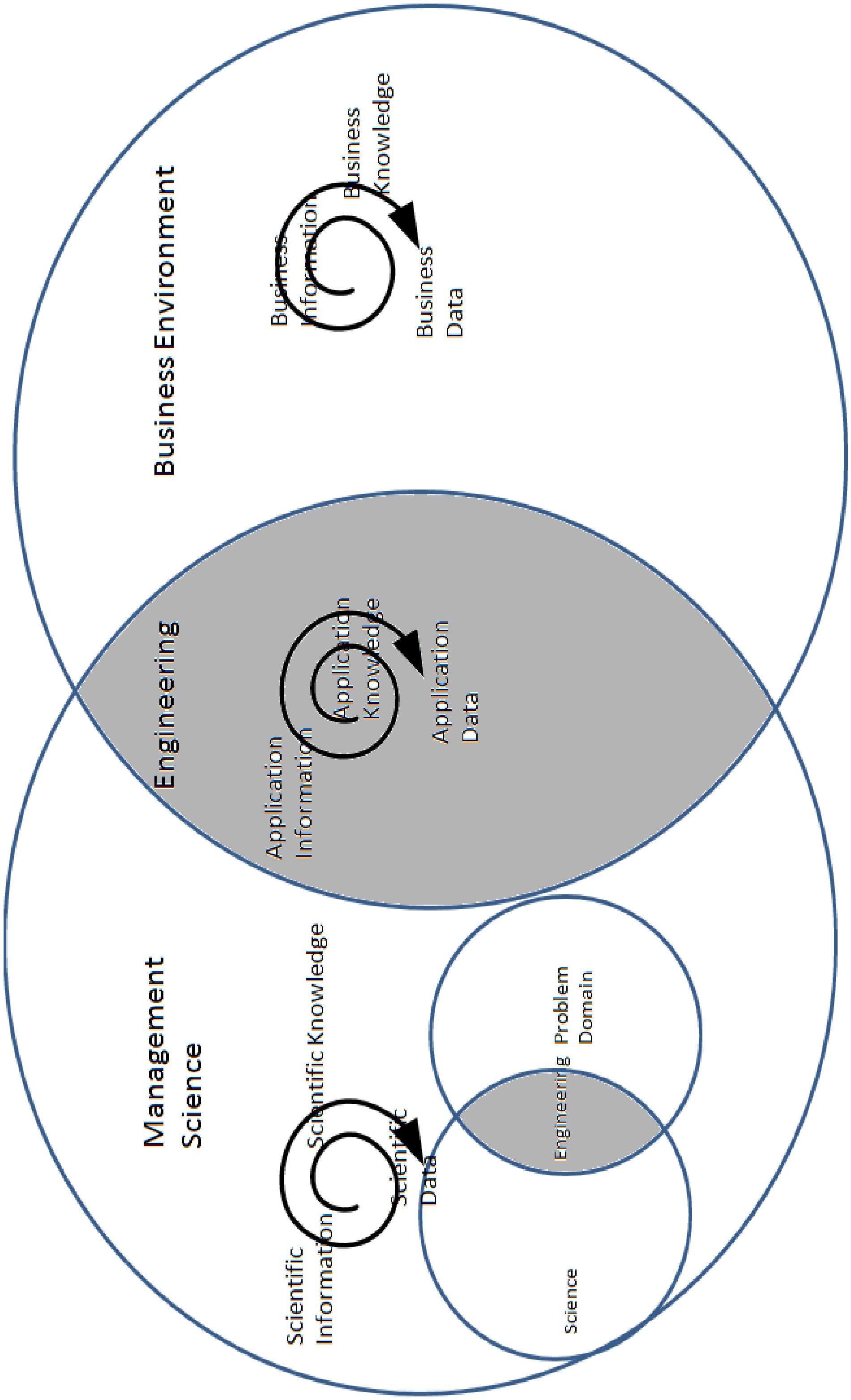

Figure 3.2 Management Science, Engineering and Business Environment

The engineering creates a connection between the theoretical background (management) with the real world (business environment). This connection can be explained by the same spiral model as in Fig 3.3.

This model also shows us, “continues conversion of data – information – knowledge” from science – engineering – business environment or from business environment – engineering - In the following chapter we will continue with the definitions of knowledge management and knowledge engineering. Data, information or knowledge can be born in management science or in business environment. But engineering, with staying in the middle helps the connection and creation of scientific trio or business trio. Also engineering creates the trio for itself.

In the following chapter we will continue with the definitions of knowledge management and knowledge engineering.

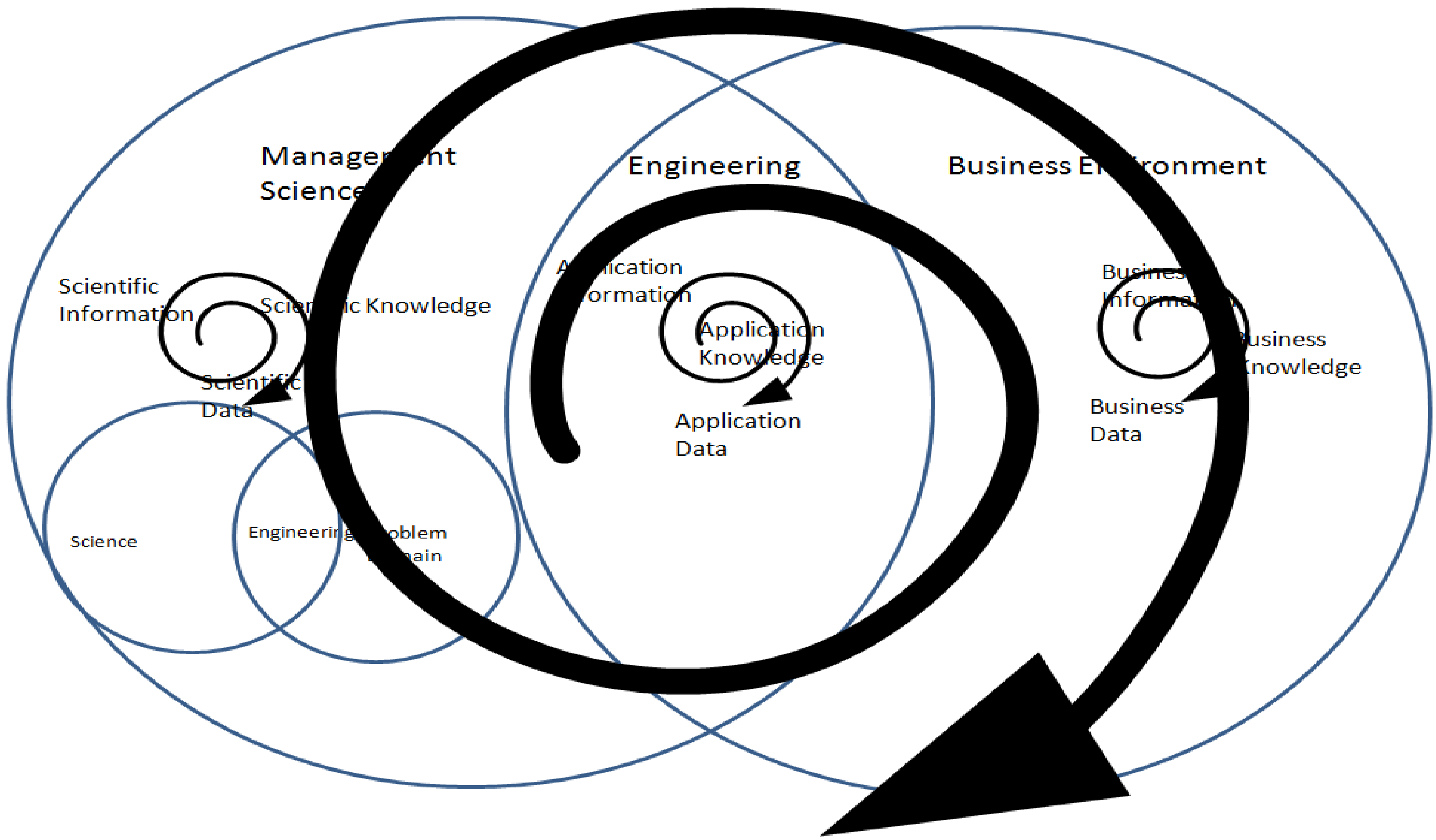

Figure 3.3 The Great Spiral of Management, Engineering and Business

CHAPTER 4

KNOWLEDGE FIELD, KNOWLEDGE MANAGEMENT AND KNOWLEDGE ENGINEERING

In this chapter we will start with a general view of knowledge science. Before entering the new the definition Knowledge Engineering (KEng), we will visit the definition which is used under in the Knowledge Management (KM), then we talk about KM and at the end, we will define our knowledge engineering point of view and its basic structure.

4.1. Knowledge Science

Peter Drucker [22] is the one of the greatest supporter of human oriented management concept. He said, to achieve success, companies should focus on humans. But in reality the essential part is not just human, the core of human beings; their intellectual assets that is knowledge. The idea of the intellectual assets [43] brought a new way of thinking in management science, that pointed us the assets of organizations should not been just the equipments and buildings to produce services and products but the employees and employers of the companies' intellectual capital. We can define the intellectual capital of workers as their tacit knowledge. On the other side, the organizational knowledge mostly defined as the explicit knowledge. But at that time, the general focus is to find the specific parts of the puzzle and every piece of tacit knowledge. Like P. M. Senge [42] mentioned in the 5^{th} Discipline, to understand the organization itself and to see the puzzle itself, we need the look at the general picture. We can say that, this general picture is the organizational tacit and explicit knowledge. Thus one recalls her R. L. Ackoff who is one of the key philosophers in Operations Research area. He published a number of interesting books and articles since 1950s. In a publication he discussed the scientific method

[6]. In another publication he argued that purposeful social systems are capable of recreating their future; they do so by redesigning themselves [7].

The idea that knowledge field started to become popular after 90s after Ziya Aktas took a little look at the trio few years ago [8]. Ikujiro Nonaka talked about knowledge creation [34], and Thomas Davenport on Managing knowledge [21]. But at that time, the concentration moved from the humans and concentrated on the technological aspects like repositories, implementation of information systems, document management systems, and groupware systems.

In 2000's the direction of the wind changed and KM has become popular for human and social aspects of the knowledge science. Knowledge management has become a locomotive of the knowledge field during the last decade. The table of academic activities of the knowledge management shows the status in 2006 is given as Table 4.1 [40].

But again the human and social part of the knowledge has given inside of KM. In 2005 Davenport [20] defined the knowledge workers aspect. KM alone is important for social and human aspects and which technologies are required on the social dimension. But we should look at the social outcomes of learning from a discipline. The results from [35] show the need for a new structural change in education. Everything become an e-aspects problems, from e-mail to web browsers (may be defined as e-browsers) and from e-business to e-government. Combination of business/management and science/engineering is required.

Table 4.1 Academic Activities in the Field of KM in 2006

International academic conferences held in 2006: • 15th Conference on Information and Knowledge Management (CIKM '06), United States • 7th European Conference on Knowledge Management (ECKM 2006), Hungary • 6th International Conference on Knowledge Management (I-KNOW '06), Austria • 6th International Conference on Practical Aspect of Knowledge Management (PAKM 2006), Austria • 3rd International Conference on Knowledge Management (ICKM 20(6), United Kingdom • 3rd Asia-Pacific International Conference on Knowledge Management (KMAP 2006), Hong Kong.
Academic journal: • Knowledge and Process Management (since 1994) • Journal of Knowledge Management (since 1997) • Journal of Information and Knowledge Management (since 2002) • Knowledge Management Research and Practice (since 2003) • International Journal of Knowledge Management (since 2005) • International Journal of Knowledge and Learning (since 2005) • Knowledge Management for Development Journal (since 2005) • International Journal or Applied Knowledge Management (since 2006) • Journal of Universal Knowledge Management (since 2006) • International Journal or Knowledge Management Studies (since 2006) • lnterdisciplinary Journal of Information, Knowledge & Management (since 2006)

Table 4.1 (Cont'd)

Handbooks, collections and encyclopedia: • Easterby-Smith, M., & Lyles, M. A. (Eds.) (2003). *The Blackwell Handbook of organizational learning and knowledge management*. Maid n, MA: Blackwell Publishing. • Holsapple, C. W. (Ed.) (2003). *Handbook on knowledge management. Vols. 1 and 2*. Berlin: Springer. • Nonaka. I. (Ed.) (2005). *Knowledge management: Critical perspectives on business and management, Vol. I to III*. London: Routledge. • Schwartz, D. G. (Ed.) (2006). *Encyclopedia of knowledge management.* Hershcy, PA: Idea Group Reference.
Textbooks : • Jashapara, A. (2004).*Knowledge Management: An integrated approach*. Harlow,England: Pearson Education. • Becerra-Fernandez, I.,Gonzalez. A., & Sabherwal, R. (2004). *Knowledge management : Challenges, Solutions and Technologies*. Upper Saddle River. NJ: Pear on Education. • Awad. E. M.. & Ghaziri, H. M. (2004). *Knowledge Management*. Upper Saddle River, NJ: Pearson Education. • Dalkir, K. (2005). *Knowledge management in theory and practice*. Burlington, MA: Elsevier Butterworth-Heinemann. • Hiplos. D. (200S). *Knowledge management in organizations: A critical introduction*. Oxford: Oxford University Press.

As noted by Saito [40], KM has an important role to create a path for knowledge science. Once how reverse engineering was used to transform building oriented organizations to human oriented organizations, change management has been used to transform human oriented organizations to knowledge oriented ones.

What we are saying is, why we need to re-discover everything from the beginning again, we can find what we need from this ocean with a good administration and engineering. There are some programs available. What we need is like management, business, information, software and computer sciences, engineering and we have also some titles that need to require a new definition like knowledge engineering.

Knowledge science can be seen as the combination of management, computer and library and information sciences. The education of knowledge is classified as under the graduate education programs. There is still a lack of undergraduate programs to take into consideration of data, information and knowledge disciplines. Knowledge engineering was included as a tool in knowledge management discipline [21]. But actually KM is a supportive part in for Knowledge engineering.

4.2. Knowledge Engineering Relevant to Knowledge Based Systems

Since 1980's the term Knowledge Engineering (KE) has been mostly used under expert systems or knowledge based systems. The area of expert systems is giving an expert solution way into the related domain [24]. Knowledge engineering of that time has been defined as the effort of gaining the knowledge and experiences of the expert in the specific domain. Knowledge engineering was also defined as building a knowledge-base activity [Russel and Norvig, 1995]. Knowledge engineers defined as someone who investigates a particular domain, determine what concepts are important in that domain, and creates a formal representation of the objects and relations in the domain. These points of views are just limited with the expert systems need. But when we have a closer look we see that, there is a specific chapter for expert system project management and life cycle. Most of the time, these activities are on the shoulders of knowledge engineers, and the definition is already not enough to meet these requirements [24].

Davenport and Prusak [21], defined expert system as the part of Knowledge Management (KM) systems that we shall discuss next. They pointed the knowledge engineers as good candidate for being knowledge managers. Still at these days, the early definitions of Knowledge Engineering are not enough to cover all area of KM applications.

An interesting contribution is given recently by Leach and Keeling [27].

4.3. Knowledge Management

Knowledge Management may be defined as follows [46]:

- KM has emerged as information technology has developed into knowledge technology;
- KM includes also data management and information management. Data management: e.g., Data Mining, Data warehouse; Information management: e.g., Message broadcasting;

The reason to use KM instead of Data Management and/or Information is stated as "Because knowledge is the most usable and representative of episteme of data-information-knowledge trio" [46].

KM, embodies organizational processes that seek synergic combination of data and information- processing capacity of information technologies, and creative and innovative capacity of human beings [11]. This definition is deciphering the knowledge management hype [32].

Knowledge Management can also be defined as performing the activities involved in discovering, capturing, sharing and applying knowledge so as to enhance, in cost-effective fashion, the impact of knowledge on the unit's goal achievement [13].

Once can combine these definitions as follows: knowledge management is the activities for capturing, sharing, discovering, and applying to create synergy between individuals and organizational transaction through data, information, knowledge to cost effective management of the knowledge.

According to Becerra-Fernandez et al [2004] there are four KM processes that KM relies on:

- Knowledge Discovery
- Knowledge Capture

- Knowledge Sharing
- Knowledge Application

Knowledge discovery may be defined as the development of new tacit or explicit knowledge from data and information or from the synthesis of prior knowledge. Knowledge capture is defined as the process of retrieving either explicit or tacit knowledge that resides within people, artifacts and organizational entities. In knowledge sharing, individuals are communicated with each other through explicit and tacit knowledge. Knowledge application, depending on available knowledge, contributes directly to organizational performance when it is used to make decision and perform tasks.

These four levels of KM processes rely on the four important factors of organizations:

- People
- Processes
- Products
- Overall organizational performance

So far, we defined knowledge management above, but we also need to define what knowledge management is not about. Tiwana [47] did this job for us as follows:

- *KM is not knowledge engineering.* KM is a business problem and falls in the domain of information systems and management, not in computer science. KM needs to meld information systems and people in ways that information management never has.
- *KM is about process, not just digital network.* Management of knowledge has to encompass and improve business processes. Technology is only an enabler that can rarely produce the same results in two different organizations.

- *KM is not about building a smarter intranet.* A KM system can use your company's intranet as its front end, but one should never be mistaken for the other.
- *KM is not about a one-time investment.* KM, like any other future-oriented investment, requires consistent attention and continued evaluation, even after it begins to deliver results.
- *KM is not about enterprise-wide "infobahns"*. Though enterprise integration helps, the primary focus of KM is on helping the right people apply the right knowledge at the right time.

From management science point of view, management is required for planning, organizing, leading and controlling the KM activities, but for application and putting them in real life applications with considering constraints, engineering is required. In the following section, we will define knowledge engineering in a way that modern age requires.

4.4. Knowledge Engineering

In early nineties some references appeared to advocate Knowledge Engineering e.g Olugbemiro et al. [36].

Aktaş and Çetin [9], had pointed the need for a new discipline that will cover some relevant definitions of engineering disciplines together with KM and business and management related activities. Their vision is summarized as the Figure 4.1.

As shown on the figure, the old and classical definition of Knowledge Engineering (KE) is in the Expert Systems-AI of this structure but as you can see this definition also covers the expert systems definition. One way to define this level as Expert System Engineering. The old definition can easily support the requirements. Computer Engineering, software engineering are related but software engineering born from computer engineering. Expert systems engineering has risen from the shoulders of software engineering and computer engineering.

The other elements defined in [9] are as follows:

- *Requirements Engineering* deals with exploring the exact needs of systems and various stakeholders, where functional and non-functional (quality related) issues should be extracted, elicited, and associated correctly for a better knowledge management .

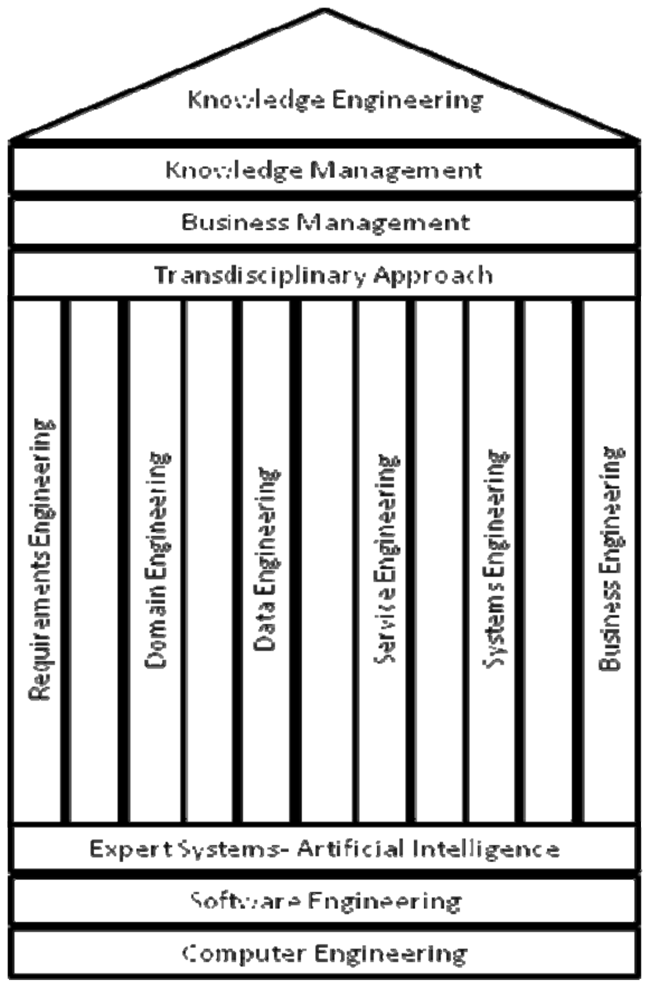

Figure 4.1 The Foundations and Six Pillars of Knowledge Engineering

- *Domain Engineering*, as an emerging discipline, manages the reusability of knowledge through commonality and variability models in software product design. Using systematic techniques such as Feature-Oriented Domain Analysis (FODA) and Feature-Oriented Reuse Method (FPRM), Domain Engineering aims to help industrialize the software production process.

- *Data Engineering* approaches to classification of raw data in a way that proper level of knowledge can be extracted and structured by suitable mining techniques, which is essential to transform the data into knowledge within an extremely growing size of information in the World Wide Web era.
- *Service Engineering* is required to structure the huge amount of data systematically in a crossbusiness environment for a loosely-coupled management of knowledge, where new trends such as "Web 2.0" and "Software as a Service (SaaS)" concepts are pushing enterprises every day to understand the need for epistemology in their daily businesses.
- *Systems Engineering* is an interdisciplinary way to manage the "enterprise knowledge" by means of integration of disciplines within a business or across businesses. It integrates other disciplines and specialty groups into a team effort, forming a structured information management process that proceeds from concept to production and later to operation and disposal.
- *Business Engineering* leverages the rest of five pillars to use knowledge for creating more business opportunities through Business Process Management possibly with the segregation of business rules, processes, services, persistence, and presentation models.

The figure also tells to use a transdisciplinary approach to bring together six seemingly different engineering applications so that Business Management and Knowledge Management will lead us to the Knowledge Engineering (KEng) with a new content and meaning. An alternative definition for KEng may be given as Fig. 4.2:

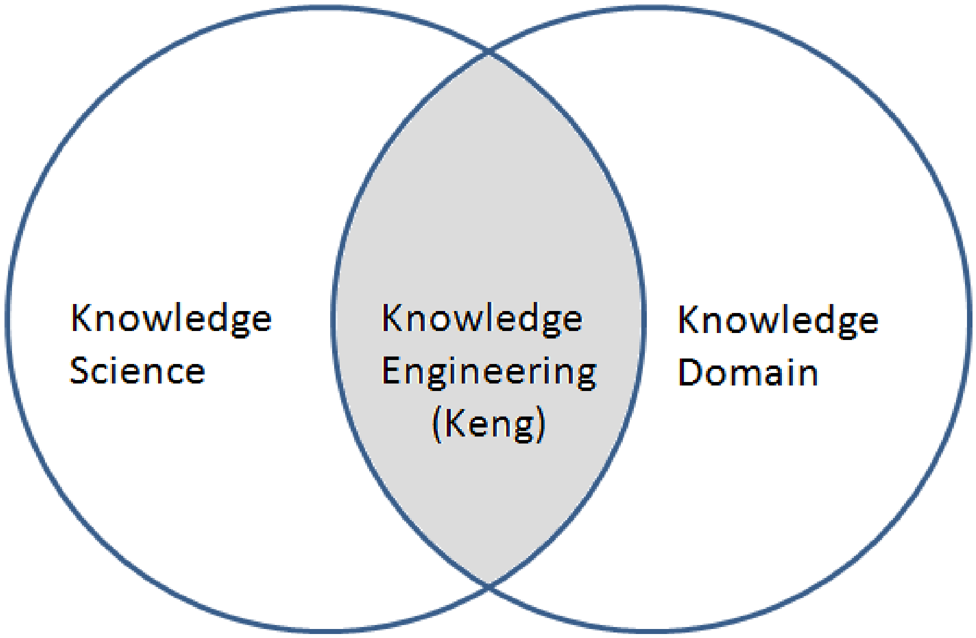

Figure 4.2 Knowledge Science, Engineering and Problem Domain in Real Life

Similar to the model that we used earlier we can define knowledge engineering as given in Figure 4.3.

As we stated earlier, our purpose is to create an undergraduate discipline to prepare future knowledge engineers KEng (under the title of knowledge workers). Like shown in the Figure 4.3, this education is a structure and that will be included different disciplines. In the following chapter we will look at these disciplines closer for a synthesis for KEng.

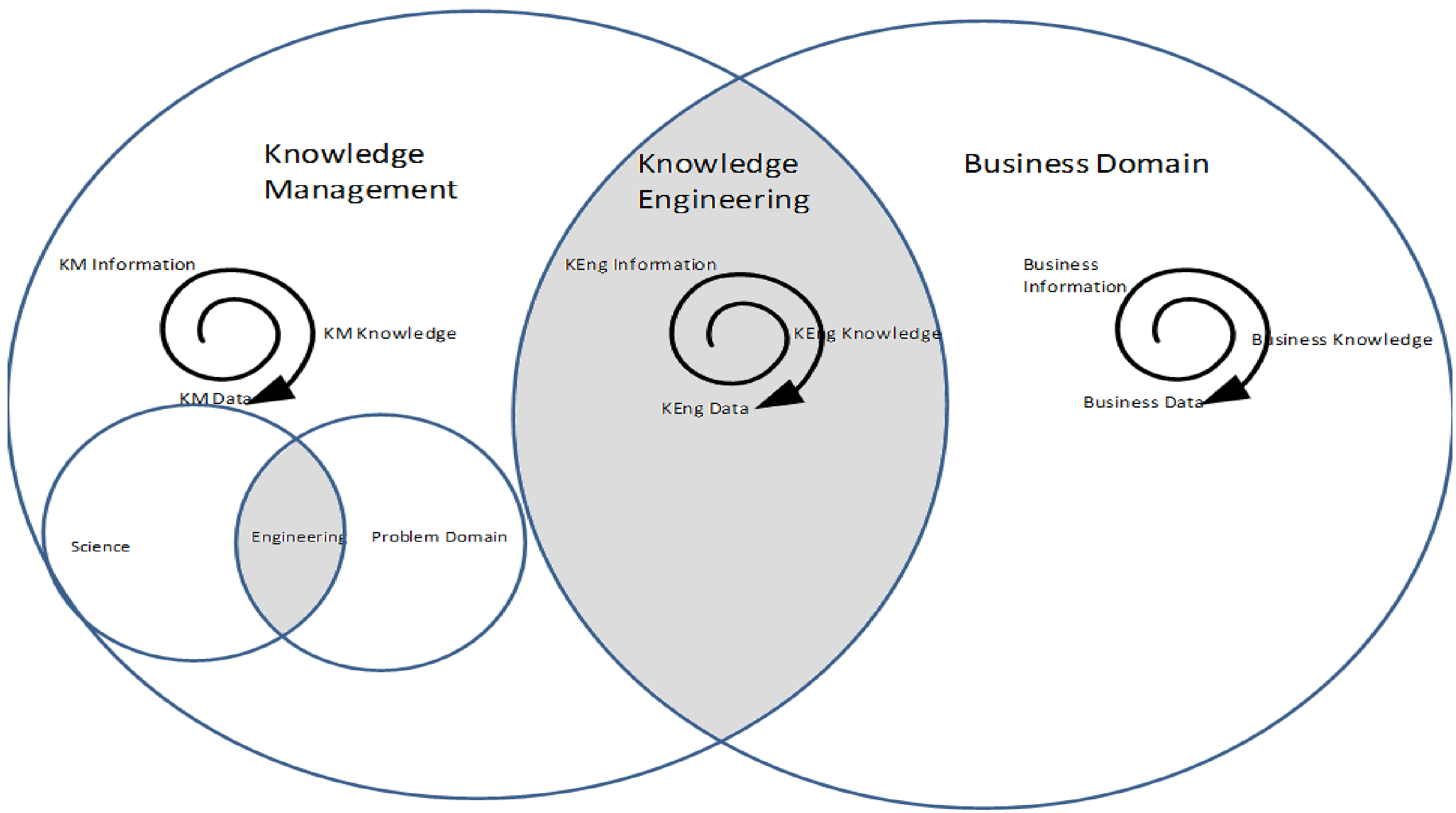

Figure 4.3 Knowledge Science, Knowledge Engineering and Business Domain

CHAPTER 5

A REVIEW OF CURRENT ACADEMIC PROGRAMS RELATED WITH KNOWLEDGE ENGINEERING (KEng)

In this chapter we present some current studies and academic programs directly in the field of knowledge and closer to Knowledge Engineering (KEng).

5.1. General

Some of the material in this chapter is borrowed from JAIST (Japan Advanced Institute of Science and Technology) due to a visit of the author.

5.2. Thesis/Examples

When we look at the current research being conducted at JAIST related with Knowledge Education we note two Ph.D theses Saito [40] concentrated on educating knowledge managers from Knowledge Management point of view, and Sutton [45] concentrated on Knowledge Management side from Library and Information studies.

In this work, Saito [40] proposes a model of individual knowledge management compentence to support the education of knowledge managers. The prelimary model was theoretically developed after an extensive review of literature in the KM field and on the concept of competence. The model explains KM competence as specific combinations of presumed KM-related activities and the individual capabilities required to perform them. It also noted that, those activities and capabilities are strongly dependent on particular perspectives on knowledge and management.

In the study four basic perspectives were considered as, information, human, computing and strategy. In information perspective, knowledge is mostly seen as codified/codifiable content and transferable expertise/experience, and KM usually means to facilitate access to information, expertise and so-called best practices. In the human perspective, knowledge is largely interpreted as social practice and collective sense making, and KM usually means to cultivate contexts and facilitate connections that improve practice and sense making. In the computing perspective, knowledge is typically regarded as objective and suited to computational approaches and KM normally means to develop systems/methods that compute knowledge and to build computational models for decision making. Strategy perspective knowledge is interpreted at the organizational level as capability or asset, and KM typically means to prioritize knowledge valuable to the organization and to design and implement strategies and processes to acquire, create, use and protect it.

The study describes four typical profiles being developed in current KM education: the information manager, the learning facilitator, the knowledge systems developer and the KM manager.

The findings of the study are summarized as Fig. 5.1.

In Sutton [45] thesis the basic purpose was an investigation of KM program design and development. This investigation focused on two cases of graduate KM programs. Choo's Learning Cycle [18] is the conceptual framework for the study. And two methods were used for data collection:document analysis and structured interviews.

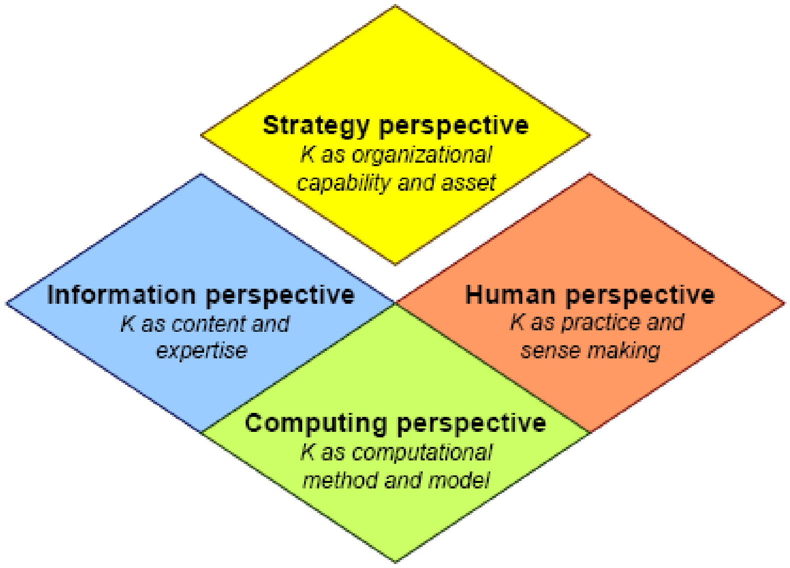

Figure 5.1 Major Epistemological Perspectives on KM

The major conclusions of the study were:

1. The program were triggered by the need for generating new revenue streams at the educational institutions;
2. Deep knowledge about KM was not necessary in order to design and develop an educational program;
3. The two institutions established KM programs because of passionate leaders and teams [14]; group and personel agility and self-learning [44]; innovative and creative curricula;
4. Librarians and information professionals played a pivotal role in conceiving, designing, and developing the programs; and
5. KM did not exhibit the characteristics of a mature field with the experences represented by these two cases.

5.3. Articles

There are also some articles related with knowledge education. Some of them are described below:

In a research, the concentration is related with library and information science (LIS). KM integrates theories and practices from many disciplinary areas and includes a diverse course contents in its education programme. In this study, the paper analyzes the interdisciplinary views of KM, and examines the extent and scope of KM graduate programmes with special reference to LIS schools [38].

In a, paper existing KM degree programs, analyse their content, and categorize the topics covered into four perspectives: business, knowledge, technology and organization. By adding profeciency levels, the paper suggest a content profile of KM programs and concepts. With combining the four perspectives and their topics they are combined into a framework that guides the development of new program in at least two different ways: by indicating topics to be covered, and by allowing the flexible development of many different formats, from the course level, to KM minor and major degrees [41].

At Çankaya University the paper by Aktaş and Çetin [9] may be cited directly related to Knowledge Engineering (KEng). This paper points out the needs for the redefinition of knowledge engineering and steps that require to follow for building up KEng as an new engineering field. KEng has a transdiciplinary position in their approach which is also adopted in this study.

5.4. The Practical Applications of Knowledge Programs in Turkey

In Turkey, most of the Knowledge related programs are formed based on library management programmes. Until 2000's most of the programs have changed their names to Knowledge related ones. In Table 5.1, a summary of current programs, is given. Actually Knowledge and Document Management departments that give Information and Library Management education are in Ankara University, Hacettepe University and Istanbul University. On the other hand, Ataturk University and Marmara University program are concentrated on achieve management side of library education.

Table 5.1 Universities and LIS to KM

University	Faculty	Name Of The Program
Ankara University	Faculty of Literature	Department of Information and Records Management (Bilgi ve Belge Yönetimi)
Hacettepe University	Faculty of Literature	Department of Information Management (Bilgi ve Belge Yönetimi)
Marmara University	Faculty of Science and Literature	Bilgi ve Belge Yönetimi
Baskent University	Faculty of Communications	Department of Knowledge Management (Bilgi ve Belge Yönetimi)
İstanbul University	Faculty of Literature	Department of Information and Records Management (Bilgi ve Belge Yönetimi)
Atatürk University	Faculty of Science and Literature	Library (Kütüphanecilik)

On the other hand there some other formations. In Istanbul University, under Information and Record managements a new department was founded under very recently the name of Knowledge Management and Technologies.

5.5. Selected Programs

In this section, we give course outlines related with selected programs. The summary is given as Table 5.2. which is created with using the matrix which is given in APPENDIX A (in the following chapter we will look at relevant university degree matrix).

As you can see, in this table, we could not take any knowledge related undergraduate program, because of lack of entering knowledge education into the ARWU.

In the next chapter, we will talk about relevant university degree programs.

Table 5.2 Summary of Table of Courses

Degree Programs	**Sample Universities**
Management Science	MIT
Management Engineering	University of Melbourne
Business Science	9 Eylül Üniversitesi
Business Engineering	none taken
Information Management	National Taiwan University
Information Science	Boğaziçi University
Information Engineering	Yonsei University
Information and Communication Engineering	none taken
Information Technology	Swiss Fed Inst Tech – Zurich
Information Systems	University of Sydney
Computer Science	McGrill University
Computer Engineering	Cairo University
Computer Science and Engineering	Sabanci University
Computer Technology	none taken
Software Engineering	University of Western Australia
Knowledge Science	none taken
Knowledge Management	none taken
Knowledge Engineering	none taken
Knowledge Technologies	none taken

CHAPTER 6

RELEVANT UNIVERSITY DEGREE PROGRAMS

In the previous chapters some of the basic concepts of science and engineering programs related to computer, data, information, knowledge, business and management were already given. Globally there are a number of degree programs in these fields at BS, MS, MA or MBA and PhD levels.

The objective of the work in this chapter is to have a closer look at some of these programs.

6.1. Countries and Universities

It is not an exaggeration to say that there are thousands of universities, hundreds of thousands of degree programs and different curriculum. As expected we need to draw our borders to continue our research. For this reason we intended to include some of the top world universities. Academic Ranking World Universities (ARWU) list was our choice. Every year this list is updated according to academic performance at the universities. We used ARWU-2006 list, which was published on August 15, 2007 [50] for our research. At that time when we started our research (June 2007) this list was the most updated one. We chose the countries and the number of universities according to their region and their position on their region and the number of universities that they enter the ARWU list. The countries and number of universities were shown in Table 6.1.

Table 6.1 International Universities Included in the Study

Region	**Country**	**Number of Universities**
Africa	Egypt	1
	South Africa	1
Asia-Pacific	Australia	5
	China	3
	India	2
	Japan	5
	New Zealand	2
	South Korea	3
Europe	Denmark	3
	Germany	5
	France	1
	Netherland	1
	Russia	2
	Sweden	1
	Switzerland	1
	United Kingdom	5
North/Latin America	Argentina	1
	Brazil	1
	Canada	5
	Chile	1
	Mexico	1
	USA	5
Total		**55**

One should note that in 2006, no Turkish University was in this list. We, however decided to include 9 universities in three Turkish cities, Ankara, Istanbul and Izmir, in Turkey to study the relevant degree programs as in Table 6.2.

In each of these cities, at least one foundation and one state university has been selected. We included also Çankaya University as our host university. Thus, with the inclusion of these 9 universities, total number of universities to be studied reached number 64.

Table 6.2 Selected Turkish Universities

City	University
Ankara	Middle East Technical University
	Bilkent University
	Çankaya Universitiy
İstanbul	İstanbul Teknik University
	Boğaziçi Universtiy
	Koç University
	Sabancı University
İzmir	İzmir Ekonomi University
	Dokuz Eylül University

6.2. Grouping the Programs

Some of the recent research work by Saito [40], Sutton [45], Saito et al. [41] and Roknuzzaman and Umemoto [38] were relevant to programs in knowledge science, knowledge management, and information and library management. On these studies, most of the programs are named using the term *information*. This may be expected natural when we looked the level of development of the country. Most of the countries are still in the level of data level (most of the programs are named titled under computer, business and management), the level of knowledge is very low. Most of the knowledge countries prefers to use the name of knowledge in their programs (like Taiwan, Japan), the other countries prefer information (e.g. Australia). There are also information level countries which pointed their program names under information (like Germany). When we looked at this picture, information is formed in the middle with different names. This is summarized in Table 6.3 as Episteme levels of Knowledge Engineering.

Table 6.3 Episteme Levels of Knowledge Engineering

Episteme Level		Knowledge Engineering				
		Science	Engineering	Management	Technology	System
Knowledge Level		Knowledge Science	Knowledge Engineering	Knowledge Management	Knowledge Technology	
Information Level		Information Science	Information Engineering	Information Management	Information Technology	Information System
			Information and Communication Engineering			
Data Level	Computer	Computer Science	Computer Engineering		Computer Technology	
			Software Engineering			
		Computer and Science Engineering				
	Management	Management Science	Management Engineering			
	Business	Business Science	Business Engineering			

In our matrix, we included these programs. On the intersection of name of the programs and the countries we putted the name and the level of degree of programs like undergraduate, master and doctorate, i.e, Ph.D.

6.3. Results

As noted earlier, when we started the university degree program matrix, there were 64 universities with different languages and contents. During the research we used **translate.google.com** and **translate.yahoo.com** for English translations. Most of the time these services worked fine, but because of some URL errors, content errors and translation errors we removed some universities and countries. So that, we ended up with 54 universities.

Thus, there are total 222 programs in these universities. The name of the programs are given on Table 6.5: Table 6.6 includes the full list of universities divided by the region. We can summarize the number of degree programs in the Table 6.7

Table 6.4 Number of Universities and Programs

Program Main Title	Program Title	Turkey	Africa	Asia-Pacific	Europe	North-Latin America	**Total**
	Total Number of Universities	9	2	19	13	11	54
Management	Management Science	4	1	7	6	6	24
	Management Engineering	1	0	3	2	2	8
Business	Business Science	4	0	15	5	8	32
	Business Engineering	1	0	0	1	0	2
Information	Information Management	1	0	3	2	1	7
	Information Science	2	0	8	1	5	16
	Information Engineering	0	0	4	2	0	6
	Information and Communication Engineering	0	0	4	2	0	6
	Information Technology	2	0	7	2	0	11
	Information Systems	0	1	9	3	3	16
Computer	Computer Science	2	0	13	8	10	33
	Computer Engineering	8	1	10	2	8	29
	Computer Science and Engineering	1	0	3	2	5	11
	Computer Technology	0	0	0	0	0	0
Software	Software Engineering	2	0	9	3	4	18
Knowledge	Knowledge Science	0	0	0	0	1	1
	Knowledge Engineering	0	0	1	0	0	1
	Knowledge Management	0	0	1	0	0	1
	Knowledge Technology	0	0	0	0	0	0
Total		**28**	**3**	**97**	**41**	**53**	**222**

Table 6.5 Title of the Degree Programs

Undergraduate	**Master**	**Doctoral**
• Engineering • Science • Business Administration • Information Management • Information Technologies • Programs with Business Experience • Programs with Dual Degrees	• MBA • eMBA • Executive MBA • Post MBA • MSc • MSsD • Graduate Diploma • Applied Science Master	• Minor Doctoral • Doctoral of Science • Doctoral of Arts • Doctoral of Philosophy

As an example when we look at the degree program on Table 6.7, under the name of software engineering there are 18 universities which are providing degree programs related with software engineering. In these 18 universities there are 14 undergraduate, 10 master and 1 doctorate programs.

We also see that these 222 universities have 145 undergraduate programs, 159 graduate programs and 69 doctorate programs.

But as you can see there are some programs, like computer technology and knowledge technology which are not included in ARWU 2006 list of universities. When we look at other universities that are not in these 54 universities it is easy to find related programs like knowledge related discipline. JAIST may be just an example. As noted earlier JAIST was founded based on Knowledge Science and Information Science and as an institute it has still working with private sector for the applications of knowledge science and information science.

The final matrix is given as APPENDIX A. Course outlines of the proposed curriculum is given as APPENDIX B.

Table 6.6 Name of the Universities in the Region

Program Main Title	Program Title	Turkey	Africa	Asia-Pasific	Europe	North-Latin America
Management	**Management Science**	Çankaya, Bilkent, Boğaziçi, Sabancı	Cape Town	Indian Inst. Of Science, Indian Ins. Of Tech., Tokyo, Kyoto, Osaka, Auckland	Goettingen, Swiss Fed Inst. Tech, Cambridge, Oxford, Coll London, Manchester	Buenos Aires, Toronto, British Colombia, Harvard, MIT, California Ins. Of Tech
	Management Engineering	Boğaziçi		Aukland, TsingHua, Melbourne	Oxford, Tech Univ Denmark,	Stanford, McMaster,
Business	**Business Science**	ODTU, Koç, İzmir Ekonomi, 9 Eylül		Australian National, Melbourne, Queensland, Sydney, Western Australia, National Taiwan, Hong Kong, Indian Inst of Tech, Tokyo, Osaka, Tohoku, Aukland, Otago, Seauhl National, Yonsei	Aarhus, Munich, Tech Univ Munich, Goettingen, Machester	Buenos Aires, British Columbia, McGıll, McMaster, Harvard, Stanford, Alberta, Berkeley
	Business Engineering	İstanbul Teknik			Machaster	
Information	**Information Management**	Sabancı		Western Australia, National Australia, Aukland	Aarhus, Coll London,	Berkeley
	Information Science	Odtu, Bogaziçi		National Taiwan, Tokyo, Kyoto, Osaka, Tohoku, Tokyo Inst, Otago, Yonsei	Tech. Univ. Munich,	Buenos Aires, Toronto, British Colombia, McMaster, Alberta,
	Information Engineering			Australian National, National Taiwan, Hong Kong, Yonsei,	Cambridge, Manchester,	
	Information and Communication Engineering			Australian National, Western Australia, Tokyo, Osaka	Tech Univ Denmark, Oxford	
	Information Technology	Sabancı, İzmir Ekonomi		Australian National, Melbourne, Queensland, Sdyney, Indian Inst of Tech, Aukland, Yonsei	Swiss Fed. Inst. Of Tech, Manchester	

Table 6.6 (Cont'd)

Program Main Title	Program Title	Turkey	Africa	Asia-Pasific	Europe	North-Latin America
	Information Systems		Cape Town	Australian National, Sydney, TsingHua, Hong Kong, Kyoto, Tohoku, Aukland, Seoul National, Yonsei	Tech Univ Munich, Goettingen, Manchester	Buenos Aires, Toronto, Columbia
Computer	**Computer Science**	İstanbul Teknik, Sabancı		Australian National, Melbourne, Queensland, Sydney, Western Australia, TsingHua, Hong Kong, Tokyo, Osaka, Tokyo Inst Tech, Aukland, Otaga, Yonsei	Copanhagen, Aarhus, Bonn, Swiss Fed Ins. Tech. Oxford, Imperal Coll London, Coll London, Machester	Toronto, British Colombia, McGrill, McMaster, Alberta,Harvard, Stanford,Berkeley, MIT, California Ins.of Tech.
	Computer Engineering	Çankaya, Odtu, Bilkent, İstanbul Teknik, Boğaziçi, Koç, İzmir Ekonomi, 9 Eylül	Cairo	Melbourne, Queensland, Sydney, Western Australia, Hong Kong, Indian Inst Scie.,Indian Inst. Tech., Kyoto, Auckland, Yonsei	Tech Univ Denmark, Machester	Buenos Aires, Toronto, British Colombia,Mc Grill, McMaster, Alberta, Stanford, Berkeley
	Computer Science and Engineering	Sabancı		Indian Inst Tech., Tokyo Inst. Tech., Seoul National	Tech Univ Denmark, Tech Univ Munich	Buenos Aires, British Colombia, McMaster, Berkeley, MIT
	Computer Technology					
Software	**Software Engineering**	Boğaziçi, İzmir Ekonomi		Australian National, Melbourne, Queensland, Sydney, Western Australia, TsingHua, Osaka, Aukland, Otago	Oxford, Coll London, Manchester	Toronto, British Colombia, McGrill, McMaster
Knowledge	**Knowledge Science**					Buenos Aires
	Knowledge Engineering			Otago		
	Knowledge Management			National Taiwan University		
	Knowledge Technology					

Table 6.7 The Name of Programs and Number of Undergraduate, Master, Doctorate Programs

Program Title	Number of Universities that Has Relevant Programs	Number of Undergraduate Programs	Number of Master Programs	Number of Doctoral Programs
Management Science	24	12	19	9
Management Engineering	8	4	6	2
Business Science	32	14	27	14
Business Engineering	2	1	2	0
Information Management	7	3	5	2
Information Science	16	11	8	4
Information Engineering	6	3	3	1
Information and Communication Engineering	6	2	5	3
Information Technology	11	8	7	2
Information Systems	16	14	9	0
Computer Science	33	28	27	17
Computer Engineering	29	24	19	9
Computer Science and Engineering	11	6	10	5
Computer Technology	0	0	0	0
Software Engineering	18	14	10	1
Knowledge Science	1	0	1	0
Knowledge Engineering	1	0	1	0
Knowledge Management	1	1	0	0
Knowledge Technology	0	0	0	0
	222	145	159	69

CHAPTER 7

APPROACHES FOR CURRICULUM DEVELOPMENT

Until now we have collected the material that we needed to build up our undergraduate degree program of KEng. During the last decade nongovernmental organizations such as ACM (Association for Computing Machinery) and IEEE Computer Society have been conducting some curriculum development work in the fields of Computer Engineering, Computer Science, Information Systems, Information Technology and Software Engineering under a general title of Computing Curricula [4]. A similar joint work is performed in 2004 for Software Engineering [5]. Referring to this report for curriculum guidelines, "Guidelines for SE Curriculum Design and Delivery" guidelines, one may adapt the guidelines given in the following section.

7.1. Guidelines for KEng Curriculum Design and Delivery

Guideline 1: Curriculum designers and instructions must have sufficient relevant knowledge and experience and understand the character of knowledge engineering, KEng.

Guideline 2: Curriculum designers and instructors must think in terms of outcomes.

Guideline 3: Curriculum designers must strike an appropriate balance between coverage of material, and flexibility to allow for innovation.

Guideline 4: Many KEng concepts, principles, and issues should be thought as recurring themes throughout the curriculum to help students develop a knowledge engineering mindset.

Guideline 5: Learning certain knowledge engineering topics requires maturity, so these topics should be taught towards the end of the curriculum, while other material should be thought earlier to facilitate gaining that maturity

Guideline 6: Students must learn some application domain (or domains) outside of Knowledge Engineering.

Guideline 7: Knowledge engineering must be taught in ways that recognize it is both software, information, management, business, computer, knowledge and an engineering discipline.

Guideline 8: Students should be trained in certain personal skills that transcend the subject matter.

Guideline 9: Students should be instilled with the ability and eagerness to learn.

Guideline 10: Knowledge engineering must be taught as a problem-solving discipline.

Guideline 11: The underlying and enduring principles of knowledge engineering should be emphasized, rather than details of the latest or specific tools.

Guideline 12: The curriculum must be taught so that students gain experience using appropriate and up-to-date tools, even though tool details are not the focus of the learning.

Guideline 13: Material taught in a knowledge engineering program should, where possible, be grounded in sound research and mathematical of scientific theory, or else widely accepted good practice.

Guideline 14: The curriculum should have a significant real-world basis. Incorporating real-world elements into the curriculum is necessary to enable effective learning of knowledge engineering skills and concepts. A program should be set up to incorporate at least some the following:

a) *Case Studies:* Exposure to real systems and project case studies, taught to critique these as well as reuse the best parts of them

b) *Project-based classes:* Some courses should be set up to mimic typical projects in industry. These should include group-work, presentations, formal reviews, quality assurance, etc. Group projects can be beneficial if such a course were to include a real-world customer or customers. Group projects can be interdisciplinary. Students should also be able to experience the different roles typical in a knowledge engineering team: project manager, tools engineer, requirements engineer, etc.

c) *Capstone Course or Project:* Students need a significant project, preferably spanning their entire last year, in order to practice the knowledge and skills they have learned. Unlike project-based classes, the capstone project is managed by the students and solves a problem of the student's choice. In some locales group capstone projects are the norm, whereas in others individual capstone projects are required.

d) *Practical exercises:* Students should be given practical exercises, so that they can develop skills in current practices and processes.

e) *Student work experience:* Where possible, students should have some form of industrial work experience as a part of their program. This could take the form of one or more internships, co-op work teams, or sandwich work terms (the terminology used here is clearly country dependent). It is desirable, although now always possible, to make work experience compulsory. If opportunities for work experience are difficult to provide, then simulation of work experience must be achieved in courses.

Despite the above, instructors should keep in mind that the level of real-world exposure their students can achieve as an undergraduate will be limited: students will generally come to appreciate the extreme complexity and the true consequences of poor work only by bitter experience as they work on various projects in their careers. Educators can only start the process of helping students develop a mature understanding of the real world; and educators must realize that will be a difficult challenge to enable students to appreciate everything they are taught.

Guideline15: Ethical, legal, and economic concerns, and the notion of what in means to be a professional, should be raised frequently.

7.2. Accreditation of Knowledge Engineering

Up to now we have seen different engineering programs. Most of these programs are also essential parts of our program. As we mentioned before, our primary purpose is to establish an engineering program for knowledge science and management. Knowledge engineering will be a field under the engineering education field. It will be, therefore, proper to look at some higher education standards for engineering fields including some accreditation standards.

7.3. Engineering Accreditation Standards

According to [29], the history of accreditation may be divided into three main phases:

a) Accreditation has been first a process driven by professional institutions to simply validate programmes before individual licensing (e.g. UK).

b) Accreditation has become in a second phase a tool under a shared responsibility of professional and academic circles (ABET, CTI) to ensure the respect of minimum standards (protective intervention).

c) Accreditation procedures have been developed in recent years in many countries as external support to public policies (or as an alternative to…), with a large contribution to the regulation of professional higher education programmes.

In the modern forms of accreditation procedures, they have found their positions in a part of public policy. A political decision is at the origin of the implementation of an accreditation process. Public authorities keep at least an eye on the system, most of the cases as an independent status.

Accreditation appears today much more than a yes-no validation of minimal standard, and become actual quality insurance system, and as an opportunity to give shape to a policy.

Accreditation is defined including with three perspectives [29

- *Technically*, accreditation is a process where a committee checks with the support of experts, if a programme is meeting a set of minimum standards.

- *Socially* (social dimension), accreditation is a process where a community recognizes a programme as full member.

- *Politically* (political dimension), accreditation is a process where respectable people say "you trust me" and say "this programme is worth of your confidence"…

When we look at the recognition of accreditations, most of them stays in national regions, and they cause lack of international mobility.
In the following sections we summarize some of the well known accreditation institutes such as Euro-Ace, ABET and MÜDEK.

i. *Euro-Ace* [www.euroace.org, 2008]

In Europe, accreditation is not seen as the common rule everywhere, because of variations in the content of education programs, and variations in educational systems. In Europe, the greatest requirement is the wish of European Commission to set up, an actual transnational system and an accreditation for covering bachelor and master level programs. The Euro-Ace project's efforts will be made on to get a mutual recognition, to have similar standards and methods, and to deliver a common label or title.

ii. *ABET* [www.abet.org, 2008]

ABET is the recognized accreditor for college and university programs in applied science, computing, engineering and technology in the USA. It has been working for 75 years.

iii. *MÜDEK* [www.mudek.org.tr, 2008]

It is established for accreditating undergraduate level engineering programs in Turkey in 2003. It is Turkish organization and it has been evolving according to domestic and international requirements. Recently there are some attents for coorperation with Euro-Ace.

In Europe, there are also some examples of national systems like;

a) In France, Commission des Titres d'Ingenirur(CTI) has granted 'habilitation' to appropriate engineering programmes.
b) In Italy, Conformity to the rules of the Ministry of Education means that the programme is automatically accredited.
c) Ireland and UK: Professional engineering institutions are licensed to carry out accreditation.

Referring to ABET criteria under *applied science programs, computing programs, engineering technology programs* [1],[2],[3]; Euro-Ace *Framework Standards for the accreditation of Engineering Standards the criteria of Euro-Ace* [23]; and MÜDEK *engineering accreditation criteria* [33] are tabulated and given as Table 7.1 for applying Knowledge Engineering program. This table should be considered as an initial attempt to be refined later.

In this table, the last column shows the applicable status of these criteria when Knowledge Engineering program successfully founded. Because, one of the must requirement is the giving graduates before accreditation process, our graduate program will not satisfy this requirement at least 4-5 years. Also there are some expected outcomes like the skills must have obtained after education programs. Normally we also need graduates to satisfy this requirement. But we look the expected program structure to think about these kinds of criteria. In table 7.1 "+" shows applicable criteria, and "x" shows un-applicable criteria right after the program starts.

In the following chapter, we will present the KEng curriculum which has been prepared according to guidelines and accreditation criteria as much as we can initially.

Table 7.1 Accreditation Standards and Applicability into KEng Program

Programme and Universities Can Apply for Accreditation		Applicable
1	From Engineering and Architecture Faculty	+
2	Undergraduate or graduate program	+
3	Contains the word of "engineering" in its title	+
4	At least gave one graduate before application	x
5	Support evaluation of every options related with program	x
Second Level Education		
6	Before accreditation of second level education programs, application of normal education must be done	x
7	Satisfactory results of criteria must be given for normal education programs before second level	x
Interpretation of Evaluation Criteria		
Basic Definitions		
8	Goals of education must be defined	+
9	Outputs of the program must give the definitions of career and occupational definitions after graduation	+
10	Measurement, is used for taken for correcting the program	x
Engineering Programs Requirements		
11	The program must be sufficient as an engineering program	+
12	Must be reflect the title of education	+
13	If one program is related with one or more programs, new program must be contain all other programs measurements	+
General Criteria		
Students		
14	Evaluation	+
15	Consultancy	x
16	Monitoring	x
17	Have a double major policy	x
18	Execution of double major policy	x
19	Have a changing the major policy	x
20	Execution of this policy	x
21	Acceptance of previous courses taken from another program	x
22	Transferring credits gained from another program	x
23	All student must satisfy program requirements	+
Goals of Education Program		
24	Follows published main goals and crieterias	+
25	Completed defined and seasonal evaluation procedures	+
26	Take into consideration the needs of stakeholders	+

Table 7.1 (Cont'd)

27	For preparing students to the goals of the program, well prepared curriculum and processes	+
28	Seasonal evaluation clues	+
29	Results of evolutions used in the increasing the efficiency of program	x
Program outputs and Evaluation		
30	Evaluation procedures according to results of documented outputs	x
31	Results used for evaluation of the program	x
	Showing graduated possessions of the following knowledge and abilities as follows (with the clues and results of procedures and the results of criteria)	
32	The skills of applications of mathematics, science and engineering knowledge	+
33	The skill of designing experiments and making	+
34	The skill of analyzing and commending the results of experiments	+
35	Skill of designing of a part or process of system according to requirement	+
36	The skill of working interdisciplinary	+
37	The skill of finding the engineering problems, defining them and solving them	+
38	Intelligence of occupational and ethical responsibilities	+
39	Effective communication skill	+
40	A wide range of education contains to understand the effect of engineering solutions	+
41	The skill of life long learning conceit and to continue to it	+
42	Knowledge of problems of the age	+
43	The skill of usage of techniques and tools required by the engineering applications	+
Occupational Education		
44	Experience of main design	+
45	One year long main science and mathematics	+
46	One and a half year long engineering subjects	+
47	Complement the technical content, general education parallel to organizational and program goals	+
Academic Personnel		
48	Perfect and adequate number for covering all areas of education	+
49	Interaction level between student and the staff	x
50	Students consulting	x
51	Activities of university services	+
52	Occupational development	+

Table 7.1 (Cont'd)

Infrastructure		
54	Classes	+
55	Laboratories	+
56	Tools and equipments	+
57	Computer and informatics infrastructure	+
Organizational Support and Money Funding		
58	Suited for educational quality and continuity	+
59	The ability of attract and keeping qualified educational personnel	+
60	Suited for maintenance, keep work and supporting to obtain infrastructure and equipment	+
General Program Criteria		
61	Curriculum subjects	+
62	Qualities of academic staff	+
Electric and Electrical, Information and Communication or Computer Engineering Related Programs		
63	Statistical knowledge	+
64	The knowledge of mathematics (derivative, integral calculations), basic sciences, computer and engineering sciences for complex software system's analyzes, design	+
Industrial Engineering and Related Engineering Programs		
65	The skill of design, development, application of human, equipment, knowledge, tool and energy integrated systems	+
66	Educate for calculation of analytical and experimental ways for system integration	+
67	The general knowledge of current subjects and occupational applications of academic staff	+
68	Academic staff must have sufficient authority and responsibility for defining the purpose of education, evaluation , application and carrying these purpose to the goal	+
Software and Related Engineering Programs		
69	Program structure contains computer science requirements	+
70	Program structure contains engineering requirements	+
	Graduate must have	
71	The skill of analyzing software systems	+
72	The skill of designing software systems	+
73	The skill of verification of software systems	+
74	The skill of evaluate software systems	+
75	The skill of achieve software systems	+
76	The skill of apply software systems	+
77	The skill of maintenance of software systems	+

Table 7.1 (Cont'd)

78	The skill of application of discrete mathematics, probability calculations, statistics, computer science and other supporting disciplines into the complex software systems	+
79	The skill of working one of the critical application areas	+

CHAPTER 8

A PROPOSED CURRICULUM FOR A "KNOWLEDGE ENGINEERING" UNDERGRADUATE DEGREE PROGRAM

One may defines the previous chapters as the needed building blocks for paving our way toward "Knowledge Engineering" degree program. As noted earlier, the term "Knowledge Engineering" has been used previously for expert systems or knowledge based systems. It is now concluded that it will be proper to redefine `Knowledge Engineering" with a new content and objective. This is the key function of this chapter.

8.1. General Course Structure

When we put together all the parts, we can group the educational requirements into two levels: the Generic Courses, and the Specialized Courses. The generic courses are the basic courses for an engineering curriculum including also business and management courses. The specialized courses for knowledge engineering are collected under three episteme such as data, information, and knowledge as in Table 8.1.

As it is seen in the Table 8.1 specialized courses start with the data level. This level is based on how to create and control data. Data can be from computer system or management systems. For this reason, the lectures which are based on data management and creation are grouped under computer science and engineering, business and management. The lectures that are grouped under Computer Science and Engineering are Introduction to Programming, Programming Languages, Data Structure and File Management, Computer Organization and Operating Systems, Database Programming, Management Information Systems, Database Management Systems, Data Communications. For the business and management part, the courses are Business Communication, Organizational Theory, Introduction to Business, Engineering Management, Human Resource Management, Operations Research and Accounting.

Table 8.1 Grouping Courses According to Course Level

Courses	**Lectures**		
Generic Courses			Calculus, Statistics, Algorithms, Engineering Mathematics, Linear Algebra
Specialized Courses	Data	Computer Science and Engineering	Introduction to Programming, Programming Languages, Data Structure and File Management, Computer Organization and Operating Systems, Database Programming, Management Information Systems, Database Management Systems, Data Communications
		Business and Management	Business Communication, Organizational Theory, Introduction to Business, Engineering Management, Human Resource Management, Operations Research, Accounting
	Information	Computer Science and Engineering	Computer Networks, Data Security, Web Programming, Information System Analysis and Design, UML
		Business and Management	Production and Operations Management in IT Firms, Finance
	Knowledge	Computer Science and Engineering	Decision Support Systems, AI, Expert Systems, Data Mining
		Business and Management	Forecasting in Business, Knowledge Management

Davenport and Prusak [20] defined information as data that makes difference with its added meaning. The information level is based on how to add meaning the data which is produced in the data level. Same as data level, the transformation of data can be in computer science and engineering and business and management levels. In computer science and engineering level, the lectures are Computer Networks, Data Security, Web Programming, Information System Analysis and Design, UML and for the business and management level the lectures are Production Operations Management in IT Firms, Finance.

When we look at the spiral model proposed by Nonaka and Takeuchi [34] and Umemoto [46] the highest level of the meaning is the wisdom, but wisdom cannot be obtained without experience. For our discipline this is only be gained after graduation. For the knowledge engineering discipline the highest level should be knowledge. As Aktas [8] mentioned, knowledge has the highest meaning in the trio. Adding meaning to the computer science and engineering and business and management information is the main concern of this level. For computer science and engineering Decision Support Systems, AI, Expert Systems, Data Mining and for business and management Forecasting in Business, Knowledge Management should be the relevant courses for knowledge creation and use.

8.2. Proposed Curriculum

In the curriculum, proposal given as Table 8.2 we did not include the Turkish or History of Republic lectures in this curriculum, hoping that curriculum may be applied not only in Turkey but also in other universities abroad. Similar special courses may be added and/or deleted considering the university and country conditions.

In Table 8.2 first year can be seen as the generic courses level. Second year is equivalent to the data level and third year is also information level. The knowledge level is completed with the fourth year. The elective courses are started with the second semester of the third year. We named the courses in short version of

Knowledge Engineering as KEng. The lectures that does not belong to the department is named with their original versions.

Course outlines of these courses are given as APPENDIX B.

Summer Practice and Senior Projects are also to be included in the final curriculum.

As it is shown in Table 8.2 there are at least three elective courses in the curriculum. Some of the candidate topics for these courses may be cited as Total Quality Management (TQM), Reliability Engineering, and Requirements Engineering etc.

Table 8.2 Proposed Curriculum

First Year	**First Semester**	Calculus	English I	Algorithms & Programming	Linear Algebra	Introduction to Business
	Second Semester	Engineering Mathematics	English II	Statistics	Accounting	Engineering Management
Second Year	**First Semester**	Data Structures and File Management	Organizational Theory	Mathematical Logic	Operations Research (OR)	Business Communication
	Second Semester	Finance	Human Resource Management	Management Information Systems	Engineering Economics	Database Management Systems
Third Year	**First Semester**	Data Communications	Productions and Operations Management in IT Firms	KE Modelling : UP and UML	Data Security	Computer Organization and Operating Systems
	Second Semester	AI and Expert Systems	Computer Networks	Information Systems Analysis and Design	Web Programming	Elective
Fourth Year	**First Semester**	Software Engineering	Forecasting in Business	Knowledge Management	Knowledge Ethics	Elective
	Second Semester	Decision Support Systems	Software Architecture	Knowledge Engineering	Data Mining	Elective

CHAPTER 9

SUMMARY AND CONCLUSIONS

9.1. Summary

In this thesis our main purpose is to build a curriculum that can be used for knowledge engineering undergraduate education. In building the structure of the education we followed the following steps:

In Chapter one, we gave a brief description of the problem, why we need an engineering discipline to educate knowledge workers? We briefly explained.

In Chapter two, we started the history of knowledge in the ancient times. In section two of the definition we continue with modern definitions of data, information and knowledge from the different perspectives. The knowledge was later defined as tacit and explicit knowledge. We related knowledge spiral with the knowledge pyramid and show the connection with management pyramid.

In Chapter three, we gave the encyclopedic definitions of science, engineering, business and management showed the connections of real world requirements.

In Chapter four, we defined the knowledge field and defined knowledge management with including the old definition of knowledge engineering and with the new definition, our definition of knowledge engineering. We build our model above the pre-model which was given in chapter three.

In Chapter five, before talking about the research steps, we gave some example researches and the programs relevant to information and knowledge in Turkey. After that we presented the titles of programs which we used to build our sample universities and program list.

In Chapter six, we gave the results of the degree programs research which we used to build up our curriculum.

In Chapter seven, we showed the guidelines and accreditation criteria that applicable when we consider in our research and our host university, Çankaya University.

In Chapter eight, we presented our Knowledge Engineering (KEng), Curriculum.

9.2. Conclusions

During the study we met some unexpected results. They are summarized below:

- Most of the management and business related programs are concentrated on management disciplines. So most of the content of the courses of business departments are closely related and nearly the same as management departments. Probably for this reason, a new discipline may be taken into account, such as “commerce”. The commerce is not included in this study, but for later studies this could be a good starting point.
- Under Data title there are not many programs (and most of the available ones are specifications of master or PhD programs, in computer engineering or software engineering). But for our purpose Data should cover some management, business and computer related lectures.
- The information titled programs are on a level to cover the requirements of knowledge programs. During this study it is noted that, there is not any program to create an intersection of two sets, namely knowledge science and business requirements.

The crucial point for this study is to initiate an undergraduate degree program in “Knowledge Engineering” in one of our universities, say Çankaya University.
Considering the educational structure of Çankaya University, it will be feasible to start a “Knowledge Engineering” (Bilgi Mühendisliği) program for the following reasons:

a) Almost all of the courses will be given by the faculty members of Computer Engineering, Industrial Engineering and Business Management Departments of the University. These departments are the strongest academically in the University and additional load will not harm them.
b) With a minimal additional faculty members, say for departments chairman and so on, the Department can get functional after the approval.
c) The needed classroom and lab facilities are available and there will be no need for a new investment.
d) Starting with (50) students, 10 of which will have a scholarship may, be good start.
e) The graduates of the department may apply to the professional organizations (odalar) same as Computer Engineering.
f) Considering some interdisciplinary/transdisciplinary programs such as mekatronik etc. YÖK approval should be no problem.

It is obvious that this proposal will be realized depending on the conditions of the individual university who decides to adopt it and will be revised accordingly.

9.3. Extension of the Study

It is expected that the proposed curriculum for undergraduate degree program, may be a first step for specialized higher level degree programs such as MS and Ph.D. in Knowledge Engineering in later years.

It will also be needed and useful to follow performance of the proposed degree program after it is initiated.

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APPENDIX A

UNIVERSITY MATRIX

	1	2	3	4	5	6	7	8	9	10	11	12	13
Region	**Turkey**									**Africa**			
Country	**Ankara(3)**			**İstanbul(4)**				**İzmir(2)**		**Egypt(1)**	**South Africa (1)**	**Australia(5)**	
University	Cankaya University	Middle East Technical University	Bilkent University	İstanbul Teknik Üniversitesi	Boğaziçi Üniversitesi	Koç Üniversitesi	Sabancı Üniversitesi	İzmir Ekonomi Üniversitesi	Dokuz Eylül Üniversitesi	Cairo Univ	Univ Cape Town	Australian Natl Univ	Univ Melbourne
Programs													
Management Science	BS, MSc, MBA		BS, MBA, MSc, PhD		BS, M In Man(MA), MBA, Ex MBA, PhD		BS, M, PhD				ManStudies BS, MBA, ExMBA		
Management Engineering					Enginnering and Technolgy Man M								Bof Eng Man(in Com, Soft),GraDip, M in EngMan
Business Science		BS,MBA,ExMBA,Phd				BusAdm, MBA, ExMBA		Bus Adm BS, M, Phd	Bus Adm BS, M			M of Bus, M of Bus Adm	MofBus and IT
Business Engineering				BS, MBA									
Information Management							ITM M						
Information Science		MS,Phd			BS and M i MIS, MA in Bus Inf Sys								
Information Engineering												M of Inf Eng	
Information and Communication Engineering												M of Inf and Comm Tech	
Information Technology							M	M				Bac. Of IT, M of IT	B of IT, M
Information Systems											BS, PostG	M of IS	
Computer Science				Msc, PhD			M					B Of Com Sci, M of Comp, M of Comp with H(course list of IT and Eng M Programs included)	B of Com Sci, M, Phd
Computer Engineering	BS, MSc	BS,MS,Phd	BS, MSc, PhD	BS, Msc, PhD	BS, MSc, PhD	BS ComEng, MSc, Phd		BS	BS, Msc, Phd	BS, MSc, Phd			B of Com Eng
Computer Science and Engineering							BS, M, PhD						
Computer Technology													
Software Engineering					Ms			BS				BofSoftEng, M of SoftEng	B of Soft Eng, M
Knowledge Science													
Knowledge Management													
Knowledge Engineering													
Knowledge Technologies													

	14	15	16	17	18	19	20	21	22	23	24	25	26	27
Region	**Asia-Pasific**													
Country	**Australia(5)**			**China(3)**			**India(2)**		**Japan(5)**					**New Zealand(2)**
University	Univ Queensland	Univ Sydney	Univ Western Australia	Natl Taiwan Univ	TsingHua Univ	Univ Hong Kong	Indian Inst Sci	Indian Inst Tech - Kharagpur	Tokyo Univ	Kyoto Univ	Osaka Univ	Tohoku Univ	Tokyo Inst Tech	Univ Auckland
Programs														
Management Science							MBA	M Tech of Ind Eng and Man, Post G in Man	Man(G)	Man (G Level)	Man Sci(BS),M of Man Sci, Phd	ManSci and Tech(G)		M of Man
Management Engineering					Man Sci and Eng(M, PhD, post-Ph.D)									M of Eng Man
Business Science	GC, Coursework, M, G Dip in BusAdm	M of Bus	D of, Ex M of, G C, G Dip, G Dip (Creative Industries), M, M(Adv), M(Interl), M(Coursework) in Bus Adm	Bus Adm (BS, grad, phd)		Bus Adm, B M, phd; B of Bus Adm Inf Sys		M of Bus Man, Post G in Bus Man	Bus Adm (BS)		M and PhD of Man Sci and Bus Adm	Bus Adm (BS), MBA' Phd		MBA,
Business Engineering														
Information Management			M of, G Dip in Inf Man	Inf Man(BS, M, PhD)										B of Bus Inf Man
Information Science				Lib and Inf Sci (BS, MA, Phd)					Inf Sci(BS)	Inf and Mathematic Sci (BS)	Com and Man Inf(BS)	Inf Sci(G)	BS, Inf Sci	
Information Engineering				Com and Inf Eng (BS,MS, Phd)		BS Inf Eng								
Information and Communication Engineering			G Cerftificata, G Dip, M of, D of Inf and Comms Tech						Inf and Comm Eng (BS, G)		BS Inf and Comm Eng, G Inf and Comm Tech			
Information Technology	B. Of IT, G C, M, G Dip	B of Inf Tech						MS IT, Post G Dip in IT,M Tech M of Com and IT						Ttech Inf Tech(Btech, PhD)
Information Systems		B Bus Inf Sys, M of Inf Sys, G Dip in Bus			Man Inf Sys(BS)	BS Inf Sys and Com Sci, Inf Sys and Soft Eng		,		DepAment of Inf(G)		Inf and Intelligient Sys(BS)		Inf Sys(B)
Computer Science	B of Com Sci, B of Com Sci Dual Degrees, G C, Mi G Dip, D of Sci	B of Com Sci	B of Com Sci, G Dip, M		Com Sci and Tech(BS, G, PhD)	BS Com Sci			Com Sci (G)		BS Com Sci		BS Com Sci	Bsc, MSc Com Sci
Computer Engineering	B of Com Sys Eng,	B of Com Eng	B of Eng			BS Com Eng.; MS in Com Eng	ME	M of Tech Com Eng		Comm and Com Eng(G)				Com Sys Eng(BS; M of Eng, G Dip, Phd)
Computer Science and Engineering								Com Sci and Eng B. Of, M, Phd					Com Sci and Eng (G)	
Computer Technology														
Software Engineering	B, G C, M, M Dip	B of Soft Eng	B of Soft Eng		Sch of Soft(G, BS)						BS Soft Eng			Soft Eng(BS
Knowledge Science														
Knowledge Management				Know Man C Program (under Inf and Lib Man)										
Knowledge Engineering														
Knowledge Technologies														

	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Region				**Europe**										
Country	**New Zealand(2)**	**South-Korea(2)**		**Denmark(3)**			**Germany (4)**				**Switzearland(1)**	**UK(5)**		
University	Univ Otago	Seoul Natl Univ	Yonsei Univ	Univ Copenhagen	Aarhus Univ	Tech Univ Denmark	Univ Munich	Tech Univ Munich	Univ Goettingen	Univ Bonn	Swiss Fed Inst Tech - Zurich	Univ Cambridge	Univ Oxford	Imperial Coll London
Programs														
Management Science									M of Bus Sci		M and MAS of Man, Tech, and Eco,	BS,	BS in Eco and Man, MBA	
Management Engineering						B, MsC							BS Eng Eco and Man	
Business Science	M of Bus, Phd, MBA	BS Bus Adm	G and BS in Bus		BS Bus Adm		B of and MSc in Bus Adm	MBA and Tech Man	B of Bus Adm					
Business Engineering														
Information Management					M of Inf Man									
Information Science	BS, M, Phd		Lib and Inf Sci(BS)					Inf M/Dip B, M of Applied Inf						
Information Engineering			Inf and Ind Eng(BS)									Inf Eng		
Information and Communication Engineering						Msc(also applied MSc), Phd							Dphil in Inf, Comm and the Social Scis	
Information Technology			Inf and Statistisc(BS)								B, M of Electrical Eng and Inf Technolgy			
Information Systems		Man Inf Sys (BS, M)	Man Inf Sys (BS)					Inf Sys (B, M)	B and M					
Computer Science	BS, PGDIPSci, PGDIPAs, MSc, MA, PhD		G and BS in Com Eng	BSc, MSc, Phd Com Sci	BSc, MSc, Phd Com Sci					BSc, M in Com Sci	B, M of Com Sci, MAS, Phd		Com Sci, Mathcs and Com Sci, MSc Com Sci	BS Comp, MS Comp Sci, MS Adv Computing
Computer Engineering			BS in Com and Telecom. Eng			Msc in Com Sys Eng								
Computer Science and Engineering		BS and G ComSci and Eng				MSc in Com Sci and Eng		M of Comp Sci and Eng						
Computer Technology														
Software Engineering	B in IS and CS												PA time Soft Eng M	
Knowledge Science														
Knowledge Management														
Knowledge Engineering	M of Soft and Know Eng													
Knowledge Technologies														

	42	43	44	45	46	47	48	49	50	51	52	53	54
Region			**North-Latin America**										
Country	**UK(5)**		**Argantina(1)**	**Canada(5)**					**USA(5)**				
University	Univ Coll London	Univ Manchester	Univ Buenos Aires	Univ Toronto	Univ British Columbia	McGill Univ	McMaster Univ	Univ Alberta	Harvard Univ	Stanford Univ	Univ California - Berkeley	Massachusetts Inst Tech (MIT)	California Inst Tech
Programs													
Management Science	Phd in Man Sci and Inn	Comp for Bus App(und),BS Man, BS Man(Des Sci), BS Man and Inf Sys	MA in Policies and Man of Sci and Tech	Man and Ce(BS), B of Bus Adm, MBA, Man and Prof Acc (M), Man(Phd)	Man				PhD in Sci Tech Man			BS in Man Sci, Phd (related with Inf Tech, Sys Des and Man(M of Eng and Man)	BS in Bus Eco and Man
Management Engineering							Eng and Man			Man Sci Eng (BS, MsC, Phd, and Phd Mi			
Business Science		MBA	BS and M Bus Adm		Bus and Com Sci, General Bus Man(B of Ce),Bus Adm (MScD, PhD)	MBA, Phd(InfSys Spe) Post MBA	MBA, Phd	MBA, Phd, in BA	MBA, Ph.D in Man	MBA, Phd	BS,MBA,PhD		
Business Engineering		M Bus Adm for Eng Bus Man MBA											
Information Management	BSci in Inf Man										M of Inf Man and Sys , Phd		
Information Science			BS in Lib Scis and Documentation(Inf Scis)	InfStudyMIS , PhD	Archival Studies and Lib Inf Studies (MASLIS)		Bus Inf	M of Lib and Inf Studies					
Information Engineering		MSc Inf Sys Eng											
Information and Communication Engineering													
Information Technology		BS Inf Tech Man, Inf Tech Man Ind Exp											
Information Systems		BS Man Inf Sys, M Inf Sys	BS Sys of Inf in Org, Sys Ana	Bsc Inf Sys	B of Ce MIS								
Computer Science	BS Bsc, Meng, MsC, Phd	BS Com Sci with Man, Com Sci with Man and Ind, Com Sci, M Adv Com Sci and IT Man (MSc), Adv Com Sci (MSc)		BsC, Msc, Phd Com Sci	BA of Com Sci, B of Com Integrated, Com Sci, BAS Com Sci, Com Sci (MSc), Phd	BS , M, phd in Com Sci	B.Sc, MSC and Phd in Com Sci	BSc, MSc, PhD in Com Sci	BS, G	BS, MS, Phd	MS in Com Sci, PhD	Electrical Eng and Com Sci, M of Eng, Phd, D of Sci	B and G in Com Sci
Computer Engineering		BS Com Sys Eng (Bsc, Beng, Meng)	BS in Computing Scis	Msc, Phd in Electrical and Com Eng	B of Com Eng	BS, M phd Com Eng	B Eng, B Eng Mgt, Com Eng	BS in Com Eng, Phd, MSc in Electrical and Com Eng, Meng		Com Sys Eng (BS)	Electrical and Com Eng (BS),		
Computer Science and Engineering			BS in Comp Scis Eng		Electiral and Com (MASc) (Phd)		M Eng and M Sc,Phd in Comp Eng and Sci				Com Sci and Eng (CSE) (BS)	BS Com Sci and Eng, MS and phd, D of Sci	
Computer Technology													
Software Engineering	Msc Soft Sys Eng	BS Soft Eng (Meng, BSc), M Soft Eng MSC)		BSC Soft Eng	Soft Sys (MSS)	BS Soft Eng(from eng and Com Sci)	B, Meng, MASC, Phd Soft Eng						
Knowledge Science			MA in Data Mining and Know Discovery										
Knowledge Management													
Knowledge Engineering													
Knowledge Technologies													

APPENDIX B

PROPOSED CURRICULUM- COURSE OUTLINES

FIRST YEAR *First Semester*

MATH Calculus(4 0 4)

Calculus of one variable: Real and complex numbers, vectors, functions, limits, sequences, series, power series, differentiation and integration in one variable, introduction to ordinary differential equations

ENG English 1 (3 0 3)

First semester, It supports management and business side of knowledge engineering English

KEng Algorithms & Programming (2 2 3)

Programming in C++ language. Structured problem solving and top-down analysis and design of solution algorithms. Control structures, data types, input output format, program structure, functions, recursion, files, pointers and dynamic data structures.

MATH Linear Algebra (3 0 3)

This course introduces the fundamental concepts of linear algebra such as matrix, linear equation, vector space, coordinate transformation, eigen vector and eigen value

KEng Introduction to Business (3 0 3)

Foundations of business and private enterprise system; forms of business ownership; basic business functions: marketing, accounting, finance, production, and human resources; management and organization; business and environment.

FIRST YEAR ***Second Semester***

MATH Engineering Mathematics (3 0 3)

Integration topics include techniques of integration; applications of integration to areas and arc length; improper integrals. Differential equations topics include first-order ODEs (separable, linear via integrating factor, homogeneous) and applications; second-order ODEs (reducible to first order, linearly independent solutions); second-order linear ODEs (particular solutions, complementary functions) and applications. Sequences and series topics include convergence and divergence of sequences and series; tests for convergence; Taylor's theorem and series representation of elementary functions; generation of series solutions of first order ODEs, including non-linear types not solvable by elementary methods

ENG English II (3 0 3)

First semester, It supports science and engineering side of knowledge engineering English

MATH Statistics (4 0 4)

The relationship between statistics and business in the means of social sciences, data presentation and analysis, basic probability, variables and dispersion, sampling and dispersion are the topics that will be covered in the lesson.

KEng Accounting (4 0 4)

The concepts and principles of financial accounting, issues of financial and management accounting, accounting cycle, transactions, principles of bookkeeping, balance sheet, income statement, trial balances, adjustments, financial flow, inventory, income measurement, financial data for business decision making. Cost accounting system for manufacturing, standard cost accounting and variances for managerial decisions; control and evaluation of economic activity, cost revenue analysis.

KEng Engineering Management (3 0 3)

Introduction to management of engineering and technology. Principles and applications to effectively manage technical projects, people, budgets and schedules. Organizing and motivating people, and controlling activities. Managing research, development, design, and production activities. Directing projects and improving quality.

SECOND YEAR *First Semester*

KEng Data Structures and File Management (2 2 3)

Sequential files, external sorting, large memory sort. Introduction to DBMSs, relational databases, query languages, SQL. Index organization, inverted file systems, volatile files, fast-response systems.

KEng Organizational Theory (3 0 3)

The concept of organization; formal and informal organizations; organizational dynamics, effectiveness, efficiency and economy-based design and development of an organization; management of change and improvement.

KEng Mathematical Logic (3 0 3)

Logical applications with mathematic, the main purpose to give students algorithmic logic in software design

KEng Operations Research (3 0 3)

Network analysis, CPM and PERT, non-linear program, Kuhn-Tucker conditions, inventory management and control, dynamic programming, waiting lines, Markov processes, transition probabilities and matrices, absorbing chains, heuristics, simulation, future developments, and business applications.

KEng Business Communication (3 0 3)

Understanding the purposes and processes of communication in business; study of cases and examples; project to improve students skills in a collaborative communication; emphasis on written and oral communication for effectiveness; professional report writing and presentation.

SECOND YEAR *Second Semester*

KEng Finance (4 0 4)

Financial analysis, planning and control; ratio analysis, profit planning and financial forecasting; capital budgeting decision; short-term and long-term financing, working capital management; financial policies regarding the acquisition of funds and their allocation to competing assets within the firm. Present value, risk analysis, cost of funds, capital structure, option valuation; factoring, futures, options, mergers and acquisitions.

KEng Human Resource Management (3 0 3)

The management of human resources in complex organizations, personnel recruitment and selection; on-the-job training and development of human resources to increase employees effectiveness and efficiency; performance evaluation, promotion; motivation and communication; employee morale and productivity; labour management relations; incentives and security; grievances and corrective disciplinary measures.

KEng Management Information Systems (3 0 3)

Value of information as an organizational resource; systems development, methodologies, systems analysis, design, implementation, documentation and evaluation; modification, improvement, phototyping; data communication and data base management.

KEng Engineering Economics (4 0 4)

Engineering decision making within the framework of macro and microeconomics, supply and demand, budgetary and monetary policy. Financial evaluation and analysis, and accounting principles, ledgers, profit and loss statements, balance sheets applied to engineering systems. Financial evaluation of Research and Development and technological innovation. Introduction to law, contact, tort, project delivery systems and engineering contracts, liability and intellectual property corporations law, environmental law. An introduction to systems management, systems analysis, mathematical and linear programming.

KEng Database Management Systems (3 2 4)
Review of relational databases, relational data model, data base design, normalization integrity constraints, dependency entity relationships, query processing and optimization, transaction processing, recovery and security, SQL query language.

THIRD YEAR *First Semester*

KEng Data Communications (2 2 3)
Building a network : LAN, WAN, bridges, routers, gateways, Ethernet; TCP/IP, IP addressing; digital date transmission; error detection and correction.

KEng Productions and Operations Management in IT Firms (3 0 3)
Fundamental decisions and trade-offs in the control of a IT business in operations in obtaining materials, technology and human resources and converting them to product(s) in a facility; production systems, improvement of processes; analysis, analytical tools, design, planning and control of product and services systems, facility layout and location problems; inventory control, quality control and management; time and motion, methods analysis; work measurement and compensation.

KEng UP and Project Management (2 2 4)
Review of Object oriented concepts. The rational Unified process. Fundamentals o UML. Use case diagrams. Class diagrams and associations, Object diagrams. Behavioral diagrams, Sequence diagrams, collaboration diagrams, activity diagrams, state diagrams. Implementation Diagrams, component diagrams, deployment diagrams. A general review of CPM and PERT models to cover cases with certainty and uncertainty of activity durations; project crashing and PERT/Cost analysis;

GANT charts and resource balancing decisions; control, revision and verification of projects; computer applications with Unified Process

KEng Data Security (2 2 3)

Specification of Security Objectives, Security Policies, Threats, Risks, and Impacts. Essentials of Data Security and Cryptography: Encryption Techniques, Encryption Standards, Confidentiality using Symmetric Encryption, Public Key Cryptography, Message Authentication and Hash Functions, Digital Signatures and Authentication Protocols. System Security: Intrusion Detection, Malicious Software, Boundary Protection and Firewalls.

KEng Computer Organization and Operating Systems (2 2 3)

Multi tasking real-time operating systems, batch systems, multiprogramming systems, time sharing systems, interactive systems, operating system services, file system, CPU scheduling, memory management, deadlocks, buffering and spooling concurrent process and concurrent programming languages.

THIRD YEAR *Second Semester*

KEng Artificial Intelligence and Expert Systems (3 2 4)

Problem solving with computers, knowledge representation, control strategies, searching strategies, predicate calculus and rule-base deduction, goal directed planning applications, programming languages for AI, robotics systems.

KEng Computer Networks (3 0 3)

Introduction to the importance of computer networks, to discuss hardware, software and architecture issues for computer networks, to discuss a number of essential layers that constitute a protocol stack, to discuss a number of applications over computer networks, to introduce methodology for computer network planning and management, to train executive professionals who need to know computer networks

KEng Information Systems Analysis and Design (3 0 3)

Fundamentals of information systems. Managing information system resources. Analysis of organizational problems and role of the information systems in an organization. Application of database and interface design principles to the implementation of information systems. Centralization and decentralization of the information system facilities. Solving organizational decision-making problems. Use of decision-support problem-solving tools. Business information systems.

KEng Web Programming (2 2 3)

The Internet and the World Wide Web. Overview of the .NET development platform. Overview of PHP. Object-oriented concepts in C#. Databases and data access. Introduction to ASP.NET and web forms. Advanced web forms. XML/Web services. .NET security. CLR. Design considerations.

Elective- I

KEng FOURTH YEAR *First Semester*

KENG Software Engineering (3 0 3)

Software Engineering Methods aims to examine some of the more specific processes required for the production of high quality software, for example, methods for testing software, ensuring reliability or performance in software. At the conclusion of this subject students are expected to understand the principles of software testing, to know how to apply software testing techniques to the development of quality software, to understand the principles of software reliability and methods for assessing software reliability; to understand and apply a range of engineering methods.

KEng Forecasting in Business (3 0 3)

Qualitative and quantitative forecasting methods, forecasting errors; smoothing methods: simple, Holt and Winters exponential smoothing; economic indicators: leading, coinciding, lagging; forecasting with time series and regression models; decomposition of trend, seasonal, cyclical and irregular elements of time series;

ARIMA forecasting models; econometric forecasting, simulation and business policy analysis.

KEng Knowledge Management (3 0 3)

Meaning of data, information and knowledge, differences between information and knowledge systems. Knowledge modeling and knowledge mapping techniques.

KEng Knowledge Ethics (3 0 3)

The dark side of knowledge, the intelligence agencies and the results of manipulation of knowledge. How to use knowledge without committing unethical actions.

Elective-II

FOURH YEAR *Second Semester*

KEng Decision Support Systems (3 0 3)

Rational decision making and appropriate data support, components of Decision Support Systems (DSS): data, information, databases, DBMS, knowledgebase, datawarehouses, Rulebase/ModelBase. Expert systems mechanism and certainty factors, system dynamics and simulation, group DSS, executive information systems, user-interface components. Designing, implementation and evaluation of DSS.

KEng Software Architecture (3 0 3)

The different software architectures, modular architectures to featured oriented architectures.

KEng Knowledge Engineering (3 0 3)

This course aims to give students to be knowledge workers for applications of information and knowledge systems.

KEng Data Mining (3 0 3)

This course gives the methods and algorithms to find data and reach information in different levels of complex databases.

Elective-III

ELECTIVES

KEng SOA and Web Services (2 2 3)

SOA has become the main application structures for larger than middle organizations. The structure of object-oriented, component oriented and process oriented structures done by web services programming. This course aims to give students different point of view of SOA technologies and web services programming techniques without depending any technology.

KEng Fuzzy Logic (3 0 3)

Fuzzy sets theory and application ways of fuzzy logic in different concepts and disciplines.

KEng Software Quality Assurance (3 0 3)

Software quality. Quality planning. Risk analysis and resolution. Software testing, Test techniques, Test Strategies, Software metrics, CMM, CMMI, ISO standards.

KEng IT Auditing (3 0 3)

The auditing techniques for IT firms

KEng Optimization Methods in Management Science (3 0 3)

Introduces students to the theory, algorithms, and applications of optimization. The optimization methodologies include linear programming, network optimization, integer programming, and decision trees. Applications to logistics, manufacturing, transportation, marketing, project management, and finance.

KEng Information Security Management System (3 0 3)

The standards for information security. Gives general concepts of standards and certificates levels to the students.

KEng Managerial and Cost Accounting (2 2 3)

Accounting for tangible and intangible assets, accounting for natural resources, depreciation theory, depreciation methods and depreciation applications in Turkey, current and long-term liabilities, payroll accounting and its applications in Turkey, partnerships and corporations, cash flow statement and analyzing financial statements

KEng E-Business (3 0 3)

The main characteristics of a formalized system of making available to management timely, accurate, and relevant information to support decision makers; the accounting, marketing and inventory control systems are viewed as a total system of information to be integrated and coordinated to minimize overlaps, duplicate reports and separate systems for data gathering and computer applications.

KEng Web Mining and Retrieval (3 0 3)

This course aims at introducing state-of-the-art technology of Web mining and retrieval. The Web is becoming the largest data repository in the world. Web mining is a study on how to discover knowledge from diverse data resources in the Web and benefit Web information systems. On the other hand, Information retrieval (IR) is a research area with a goal of exploration of information storage, classification, extraction, indexing and browsing techniques for the retrieval of non-structural databases such as textual documents. Not only IR technology has changed considerably in the last years with the expansion of the Web, it but also can benefit the development of a number of Web mining research areas

KEng Software Project Management (3 0 3)

The success of a software (or software-intensive) project involves numerous interdependent factors and resources, including technology, domain knowledge, personnel, finance, time, etc., and requires sophisticated managerial skills for utilizing and balancing these resources/factors. This course aims to help the students understand the intricacies and learn the required skills of software project management in a systematic manner.