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Virtual library and continual learning for engineers

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ABSTRACT: The need for learning does not end after graduation from engineering school or the start of employment. It is actually the beginning of an engineer’s life-long education. Engineers are generally known for their good systematic problem solving skills acquired from years of solid education in universities and professional schools. However, with globalization and the rapid obsolescence of technology engineers now have to increasingly acquire new skills and knowledge to anticipate and face today’s as well as tomorrow’s unpredictable challenges. Engineers, like other professionals today, need to develop life-long and independent learning habits in order to keep pace with the fast moving environment. With the increasing power of Information and Communication Technology (ICT) and the proliferation of online content on the Web, information has now become more accessible to engineers as compared to the past. This paper will discuss how engineers can make use of the plethora of online resources in their continuous independent learning journey and will highlight how libraries can be a strong partner in their lifelong learning activities.

1. INTRODUCTION

Since the beginning of civilization, engineering has played a major part in building the world’s infrastructure (e.g. shelters, roads and water supply) and the creation of a myriad of devices that have increased our material comfort. The work of the engineer is never finished. Each day provides new challenges for engineers and they must, with their knowledge, insight, and creativity, continuously come up with innovative solutions to solve these problems. Like many professions that depend chiefly on cumulated knowledge, engineers need to engage in continual learning to stay relevant. This paper discusses briefly the need for continual learning for engineers and then suggests ways in which libraries play useful supporting roles.

According to The Concise Oxford Dictionary, continual means “always going on” and continual learning would therefore mean learning that never stops. For engineers it would mean a constant need to upgrade their skills and to embrace new knowledge and technology to meet challenges. The completion of engineering education at the university and the start of employment does not mean the end of an engineer’s education. On the contrary, it is only the beginning, the start of a life-long learning education.
2. NEED FOR CONTINUAL LEARNING

The idea of continual learning should not be alien to the engineering profession. As noted by Kirschenman and Brenner (2007), “engineering is a profession of practice”. Engineers solve practical problems in the real world. If the real world is changing rapidly, engineers must understand these changes before they can find solutions to problems that these changes pose. In a world of rapid technological change, continual learning is necessary in order for engineers to understand and respond to changes. For example, in the case of an electronic design engineer who graduated 30 years ago, he would have acquired new knowledge and skills continuously as the focus of design efforts changed from vacuum tubes to transistors to integrated circuits to very large scale integration (VLSI) of circuits in order to stay relevant and employable.

The difference between the design engineer 30 years ago and one who just graduated today is that the latter faces much more pressure to change than the former. There are 3 major types of change for today’s engineer – faster obsolescence of technology, the effects of globalization and the impact of the fast pace of life on personal and social behavior. All these come about from the exponential rate of growth and accumulation of knowledge.

Facing technological obsolescence

Technological obsolescence is a consequence of the rapid growth of knowledge and information. It is said that information grows exponentially and, depending on the disciplinary field, doubles every 15 years (Price, 1986). Though certain types of knowledge remains universal and true over time (like the physical properties of materials), other types are superseded and made obsolete, particularly in many areas of science and technology.

The growth of the consumer society has created greater demand for new and better products over shorter periods of time. Wants rather than needs drive the market place and product life cycles get shorter. Quite apart from planned obsolescence, where products are purposely designed to last only a few years in order to create demand for new lines of products later to add to the revenue stream, technological obsolescence also occurs as more technical R&D efforts produce rapid innovations that are incorporated in new products to supersede old ones. As a result, engineers have to keep pace with new knowledge and development in designing new products that will last a shorter duration over time.

Effect of Globalization

Globalization affects every aspect of our lives deeply. For enterprises, the world provides the market place and, at the same time, a greater number of competitors as well. The 2007 President of IEEE-USA, John Meredith noted that “globalisation has put engineers on the front line of an unrelenting drive by companies to shorten the development cycle and cut production costs. This means engineers must seek new tools and methods to improve their efficiency and speed in delivering new product designs to the market place” Meredith (2007).

In the report, The Engineer of 2020: Visions of Engineering in the New Century, the National Academy of Engineering has highlighted that “In the next 20 years, engineers and engineering
students will be required to use new tools and ever-increasing knowledge in expanding engineering disciplines (National Academy of Engineering, 2005).

**Social changes**

Globalization and the wide spread availability of information on the Internet (sometimes referred to as the democratization of knowledge) has led to a more well informed world citizenry which is changing the way engineers interact with society. People everywhere in the world feel the societal effect of technological changes, particularly when it is negative, for example in the Oil Spill in the Gulf of Mexico and global warming concerns. As leaders of technology, engineers cannot divorce their work from societal issues and must be an active part of citizenry.

Today, as never before, engineers must broaden their understanding of social responsibility in order to use their power wisely. “The blending of engineering and citizen is nothing new. What is new is that engineers are being asked to extend their sphere of responsibility into new areas like: the environment, the proper use of intellectual property, security and privacy issues. At the same time society is asking engineers to accept more responsibility for the impacts of new products and services they design. The world is not blaming engineers for climate change, loss of data privacy and so on, but society is making overwhelmingly clear that since engineers had a role in creating these challenges, engineers must accept their role in addressing them as well”. (Douglas, et al, 2010).

Therefore engineers must not only keep up-to-date with their areas of professional expertise but must also be well versed in social and cultural issues to set engineering solutions in their societal context. Continual learning is therefore necessary for engineers to achieve a well rounded approach to solving real world problems holistically.

We live in a fast paced world created by faster information flow and the incessant demand for more advanced gadgets to improve our material comfort. Compared to our parents, it would seem as though we are living more “lives” than they have. Engineers, like many other professionals today are likely to have more than one job or career in their life time. In their report on continuing education of engineers more than 25 years ago, the U.S. National Research Council noted that “the focus and direction of an engineer’s career may change from time to time and education is needed to prepare for each direction” (National Research Council, 1985).

**3. LEARNING ACTIVITIES**

How can engineers continue to learn after completing their formal education? The traditional way of learning is in a classroom with students and a teacher. Though this is an effective way to engage in continual education, there are also many limitations in terms of physical constraints, immediacy, mismatch of needs and course availability, cost and dependence on trainers and course providers. Usually this approach is tied to credentialing, i.e. the trainee obtains a formal recognition that certifies his/her participation in the activity.
Independent learning

Another flexible approach is independent learning where a person creates his or her own agenda, approaches and methods of achieving the desired learning outcome. Though it requires much more effort, the learning outcome in independent learning is likely to be more successful as the process is constructed to meet the exact needs of the learner.

Learning could, of course, occur in the workplace where the process of solving novel problems often leads to an increase in knowledge not previously acquired in formal learning environments.

Whatever the learning method, the key to continual learning is the awareness of need and the application of conscious effort to increase our present store of knowledge. As noted by Bary and Rees (2006), “self-directed learning refers to any learning process, whatever its degree of formalization, that is sought, planned and conducted by the trainee in an autonomous way”.

Learning resources

Independent learning can only be carried out when rich and relevant information resources are available for the continual learner to draw on. In the past, this role has largely been performed by libraries.

Well known science fiction author, Isaac Asimov underlined the importance of libraries in continual education when he wrote “I received the fundamentals of my education in school, but that was not enough. My real education, the superstructure, the details, the true architecture, I got out of the public library” (Asimov, 1994).

Today, with 15.59 billion pages on the web (as estimated by WorldWideWebSize.com on 19 Sep 2010), the ordinary person has tremendous information at his disposal at the touch of a button. The Internet is no doubt an important resource in helping us with continual learning but it has its limitations. For deep learning and access to organized and scholarly resources, libraries remain important to life-long learners as we will discuss in this paper. Engineers engaging in continual learning should use all available resources and understand their strengths and limitations.

4. TYPES OF INFORMATION NEEDS

There are many tools and services available on the Internet that are useful to the engineer. This paper will however focus on libraries as an important resource for continual learning. Before this discussion, it would be useful to consider the various information needs that engineers may encounter in their continual learning journey.

a) Exploratory or discovery searches

As the name suggests, this type of information need occurs when a person encounters some idea or phenomena that arouses his interest but with which he is not familiar. Further preliminary investigation is needed to determine whether it is worth his while to continue the pursuit of detailed information on the topic. A person usually needs easy to
understand accounts and overviews of the topic which are generally found in the secondary literature. An exploratory search usually ends when a person has satisfied his original curiosity but often enough, such searches could also lead to new areas of interest and ideas through unexpected encounters and serendipity. Though searching on the Internet and using sites such as Wikipedia is a fast and easy way to engage in exploratory and discovery searches, library sources in print or electronic form will often provide more succinct, authoritative accounts and possibly greater serendipitous opportunities.

b) Current awareness

Current awareness is a method of keeping oneself up to date in one’s area of expertise or interest on a continual basis. As Confucius said, “To do a job well, you must first sharpen your tool”. Current awareness is the continuous sharpening of the engineer’s mental tools. It assumes that one already has a high level of knowledge and skills in an area of expertise which one needs to constantly be on top of. Current awareness can also refer to keeping up to date with business and societal issues that have a bearing on either one’s work or one’s interests.

c) In-depth research

Information seeking for in-depth research often leads to the development of new knowledge and skills. Such activities often involve intensive and extensive use of information resources which require good research skills and sustained effort. Unlike exploratory searching, in-depth research requires access to reliable and authoritative information sources. Engineers cannot afford to have outdated and inaccurate information form the basis of their decision making and professional solutions. Information sources in the professional and scientific literature are the evidential base of professional practice.

In depth research often requires bench work or field investigations. However prior to such activities, it is critical that past cumulated information on the topic be systematically collected, reviewed and studied so as not to re-invent the wheel. Much time could also be saved in bench work and field investigations if one can use prior knowledge that has been previously obtained and published by others. Information seeking for in-depth research is therefore an important activity for engineers, either to ascertain the prior existence of relevant articles or build on the work of others.

d) Inter-disciplinary information needs

Many current branches of knowledge such as mechatronics, bioinformatics and nanotechnology have their roots in more than one traditional discipline. As research activities mushroom, particularly in Asia, new research areas are likely to cut across different interdisciplinary areas. Karl Popper aptly wrote that “we are not students of some subject matter, but students of problems. And problems may cut right across the borders of any subject matter or discipline” (Popper, 1963). For engineers engaging in new interdisciplinary research, a lack of formal training in one of the component disciplines has to be remedied with other forms of learning. The acquisition of knowledge in a new discipline is largely about immersing oneself in a different body of literature,
which comprises primary and secondary works such as books, journals and other publications. This must form the main diet of continual learning in order to understand the discipline thoroughly.

The above description of the major types of information needs of engineers helps us to clarify and identify appropriate information sources for different purposes. For exploratory and discovery purposes, easy and quick access to less demanding and informal sources such as those found freely on the Internet may be adequate, even though more organized tertiary sources such as bibliographies may be more efficient and effective to use. On the other hand, to meet the needs of in-depth research, a greater reliance on more formal sources and scholarly materials is necessary. Any of these formal information resources are provided by libraries which have evolved from largely print-based collections to the current hybrid model of a mix of formats, increasingly dominated by electronic resources.

5. LIBRARY AS A KEY RESOURCE FOR CONTINUAL LEARNING

Engineering is largely a knowledge based profession. The engineering knowledge base is the accumulation of scientific and technological knowledge gathered from research and practice. As Martin Ward, an information specialist, noted: “The engineering knowledge base is set within the general knowledge base of society. It is subject to time, it is close to action, and it is inseparable from being. It also reflects the convergence of three major concepts: knowledge, communication and learning.” (MacLeod, 2005)

For thousands of years, libraries have been the main vehicle in preserving the body of knowledge of societies accumulated in all types of information materials. They have been organized as national, public, academic, research, special and school libraries to serve different sectors of society. Engineering literature can be found mainly in academic and research libraries, sometimes in special libraries and to a lesser extent public libraries. Libraries provide access to information for people to transform that knowledge into their individual construct.

“Though libraries cannot provide knowledge, they are also much more than providers of information. Libraries provide information within an appropriate context to help transform information into knowledge in an individual’s mind. A library, as a whole, is a knowledge base and not just a mere collection of information resources or materials” (Choy, 2007).

Engineers engaging in continual learning will find libraries to be excellent partners in their journeys. Understanding the roles and functions of libraries will help engineers to make the best use of libraries and to place appropriate demands on services. Very often, a mere awareness of what libraries can do is sufficient to open up useful doors to learning for a life time.

What roles do libraries play in helping engineers in their continual learning and education?
6. PROVIDING ACCESS TO QUALITY INFORMATION

Libraries undertake a fundamental role in sharing quality information resources obtained by pooling together financial resources that individuals are unable to afford on their own. A sizeable and useful collection of print, audio visual and electronic material is expensive to build up and maintain. Despite many free resources available on the Internet today, a large part of formal information resources is controlled commercially. The Library collection also plays an important role in filtering the world’s available information into a manageable subset that caters specifically to its clientele or user groups. In a world inundated with information of all kinds, this selection role can help users to manage their information diet more effectively.

Information resources

Information needed to support in-depth research needs are mainly found in scholarly resources such as journals, proceedings, technical reports, books and other publications. These are the formal outputs of research, real world practice and thinking by scholars as well as practitioners. These documents are generated in different parts of the information cycle in every discipline. Awareness of the characteristics of these documents will help a person find the appropriate and relevant sources for different needs in their learning journey.

Primary and secondary information resources

For example, in science and technology, conference papers collected in proceedings are usually preliminary findings that are shared and discussed among people in an expert group. Some of these, together with other original contributions are published in professional or scholarly journals which are vetted by peers to meet high standards of scholarship, integrity and reliability. These are usually primary materials which are meant for consumption by experts in the field.

Depending on the subject, book length documents with original findings can also be considered as primary materials. However, most books are secondary materials which consolidate previous knowledge from the journal and other current literature. Books are therefore very useful in giving a complete picture of a topic in one place. Some journals such as trade journals are also considered as secondary materials as they fill an important need for practitioners by providing digested information and news on specific fields.

Another common document type in science and technology is the technical report. These are usually the result of sponsored research and development activities, meant for a very specific audience and often not published in the mainstream.

As engineering is a practice oriented profession, many document types are rooted in real world practice. For example, standards and specifications are critical to implementing technical work while patents provide legal protection for innovation in the market place.

Tertiary information resources

The large amount of documents cumulated over time has also created a need for another class of documents called tertiary information sources. Information in tertiary sources are compiled,
edited and organized for quick access and use. They save the reader having to plough through tons of primary and secondary literature to find gems and routine facts to solve their practical information needs. Examples of these are directories, encyclopedias, yearbooks, dictionaries, handbooks, manuals and glossaries.

Directories are used for locating people, products, companies, statistics, and specifications and other types of technical information. Encyclopedias and dictionaries provide both general and specific descriptions of concepts, events and terminology. Handbooks and manuals provide detailed information on specific topics to guide the engineer in using techniques, methodologies, tools, or equipment or provide general and technical background information. They usually provide the reader with diagrams, statistics, charts, tables and references to additional reading and cover almost all aspects of engineering and technology activities.

**Databases and electronic search tools**

Some of these tertiary information sources have been made interactive in the form of databases and search tools. Huge databases such as Engineering Village allow users to search for millions of scholarly documents using combinations of characteristics such as the affiliation of the author, subject terms, document type, chemical structure, etc. Citation database like Elsevier’s Scopus and Thomson’s Web of Science provide functions to assess the impact of a document in the research community after it is published, to trace the development of a subject area and to provide leads to other highly regarded authors or researchers in a particular discipline.

**Libraries and information resources**

The above description of major document types and tools in the body of knowledge in engineering is by no means exhaustive but should give a good overview of how different information needs can be met by various types of documents generated in the information cycle. Good libraries that cater to engineers and scientists provide a wide range of these documents. Many of these documents are increasingly available in electronic formats that are accessible online instantly and remotely, regardless of place. However, these e-resources are largely products of commercial publishers and their access is limited by licensing and access costs which a library has to manage. Most academic libraries provide full access to e-resources only to their staff and students and a limited extent to those outside academia. For users in Singapore, the National Library of Singapore also provides some e-resources, e.g. engineering databases to members of the public.

**Free Internet resources**

At the same time, more useful resources are now available freely on the Internet, thanks to funding bodies that support open access initiatives and the generosity of organizations and individuals worldwide in promoting learning and education. There is a strong open access movement to push publishers to allow authors of publicly funded research to make their findings and publications freely available in online repositories. Many universities now have institutional repositories that store and make accessible a version of journal publications by their staff members. For example, in Nanyang Technological University, we are slowly building up a collection of staff journal publications in our repository called DR-NTU (Digital Repository – NTU) which anyone with Internet access can use freely. Some universities, notably
Massachusetts Institute of Technology (MIT), Yale and Carnegie Mellon are also providing open courseware which is extensive course content available to the public, including syllabi, study modules and online lectures.

Managing information resources

Libraries play an important role in selecting resources that are reliable, dependable and suitable for the varied needs of their users regardless of whether they are paid for or available for free. Free information has greater added-value when it is organized and put in the right context. Libraries have a long history in managing and organizing information systematically to help users maximize their use. In the print world that dominated the information landscape until just a few decades ago, libraries developed a key strength in classifying and organizing information to give a sense of order to its tremendous growth.

For example, the simple act of classifying a document (whether print or electronic) establishes its relationship with other documents. This is a kind of knowledge in itself apart from the fact that it enables a more efficient search for information. Classification enables systematic browsing, which is a powerful way for life-long learners to learn about any topic and its relationship in the overall scheme of things. Step into a collection organized by Dewey Decimal Classification (DDC) or the Library of Congress Classification (LC) system and you will see the world’s knowledge spread out systematically in front of you to explore.

Though there is debate as to whether such methodologies are still useful in the overwhelming flood of information produced daily, the constant attention paid by libraries in managing and organizing their information collection can only lead to better ways of grappling with this difficult problem.

Librarians

Major resources in any library are the librarians and library staff. Increasing use of technology has freed librarians from back room work to focus more on user-oriented activities such as providing guidance on understanding and using various information resources. For example in NTU, most librarians take on a subject role, such as aerospace engineering librarian, civil engineering librarian, etc. and are responsible for procuring materials, resource management, consultation, outreach and teaching in the specific subject area. Through daily practice, subject librarians build up a good knowledge of the literature of the subject and their users’ information seeking needs and behavior. Through their network and understanding of the information industry they can help people find esoteric information sources and guide them in their information seeking process. For people embarking on independent and continual learning, librarians act as good guides and advisors as it is a profession dedicated to help people increase their current state of knowledge.

7. CONCLUSION

Continual learning is an inevitable part of today’s working life. Any individual living in a society that is undergoing rapid change has little choice but to adopt this approach for a satisfying and
successful career. Formal education in engineering school is not sufficient and is only a starting point for new engineers. Continual learning has been made easier in today’s environment, with instant and convenient access to billions of pages of information on the Internet, mostly at zero cost. However the deluge of information can also make continual learning distracting and difficult to pursue effectively. Libraries are oases in the sea of undifferentiated information. Their goal is not only to provide a more focused access to information but also to help people make sense of the information environment. Anyone engaged in continual learning will benefit from their encounters with libraries and the services that they provide.

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