Actualizing Students' Prior Knowledge in Engineering Education

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***Abstract*—This research aims to mitigate the inhibiting factors that prevent faculty and students from excelling in their roles in engineering education. The approach focuses on the identification and subsequent usage of "prior knowledge" one accumulates perpetually with the passage of time. The approach is expected to help students and faculty alike to share their under-utilized knowledge bank in a structured manner and correlate it with the subject matter under study. Such an analogical-bridging triggers a thinking process that facilitates transfer and learning of new knowledge through mechanisms of assimilation and accommodation. The concept of analogical-bridging has been explained with examples that can be bench marked for variety of subjects. Application of this approach to diverse academic disciplines indicates suitability and effectiveness of the concept, and is expected to produce desired results in improving general understanding of the discipline among students. As such, the approach is deemed to be cost-effective, and complements the existing instructional and educational approaches. It therefore merits consideration for adoption.**

Keywords— Prior knowledge, analogical bridging

I. Introduction

All humans possess some *kind* of knowledge that enables them to sort out their daily lives and survive; source, quantity, quality and form of knowledge could vary and may be considered a function of life experiences. By default, everyone perpetually keeps accumulating knowledge in different fashion and manner. In recent years knowledge management has been the focus of attention for researchers and is being investigated from different perspectives. Terms like formal, informal, implicit, explicit, common sense, social, innate, tacit knowledge are often being interpreted in different ways, context and manner [1]. This study, however, is neither about how humans acquire knowledge nor is it about how it is generated, shared, structured, codified or embodied. It rather focuses on one question, i.e., *can the prior knowledge be effectively used in engineering education*? In this sense, it attempts to answer the question of 'transfer' [2]. For this study the term *Prior Knowledge* is defined as net accumulated knowledge and skills an individual possesses regardless of its domain, source, form, acquisition, and manner that shapes the perceptions and concepts of the holder. It also includes latent component. Aspects related to Latency indicate those perspectives that do not form part of conscious awareness and usually are not focused by humans.

A series of studies have been conducted by the authors to fine tune a generic approach that could activate the latent part of prior knowledge [3]. It is interesting to note that, as per conservative estimate, out of 105,120 hours available during the first twelve years of education, i.e., K-12, (12 x 365 x 24 = 105,120) in most of the developing countries (like Pakistan), at least 12% (12,614 hours) are utilized in formal class room structured learning, 55% (57,816 hours) are spent in informal activities while the remaining 33% (34,689 hours) are consumed in sleep. Since major portion (55%) of time is spent in informal activities, it can plausibly be assumed that students find ample opportunities to acquire (informal) knowledge. No evidence is however available in the literature to suggest that students at some stage acquire the capability to organize formally and informally acquired knowledge in a structured manner. On the contrary, it has been established that even the best of the students with exceptional grades carry many "scientific misconceptions", for the contents they are taught in a classroom [4].

II. Cognitive Perspective

The approach presented here actualizes prior knowledge a student acquires (during K-12 years) in a novel manner permitting students to organize, manage and utilize their knowledge bank (personal possession), in a scientific manner, allowing them to create new schema. Such arrangements by default heighten their general understanding and intellectual capabilities thus enabling them to make sense of new subjects. The suggested approach may be better understood from a cognitive perspective where human mind is considered as an information processer [5]. Using the analogy of internet, imagine a human mind as a net comprising several different web sites, and representing various subjects or domains which have been developed on this net in different time frames. Regretfully, due to non-availability of unified standards, these web sites do not follow a unified strategy in their development. Hence, an inconvenient case-to-case basis approach is needed to extract information. Collectively all these web sites though possess a complete range of knowledge required to study engineering domains, yet they cannot be used objectively as knowledge is either inert, fragmented or is in isolated form [6]. Additionally, no in-built means are available to check the authenticity of the knowledge contained therein. In case of internet, despite all these short comings, a curious user can still extract and synthesize the desired information from these web sites by using an intelligent search engine with a focused approach. The search is also dependent upon hardware and software, internet access, and more importantly, intelligent interpretation of the available information. Currently, efforts are being made to extract semantic information with Artificial Intelligence (AI) employing various man-made techniques [7]. This indeed is a daunting task for AI experts because information is being extracted and synthesized by un-intelligent machines.

In contrast, the proposed approach is all about making him or her capable to extract semantic information from own mind that has the ability to know about 30~50 million facts about the world [8]. It amounts to converting human mind into a semantic web that would require its re-configuring, normalization and re-engineering of the connections by some expert.

Fortunately for engineering programs, unlike common belief, an individual is required to understand limited range of core concepts [9]. These core concepts may be considered as basic knowledge blocks because they are common to all scientific domains. The many core concepts of engineering and its vocabulary are directly linked and are an integral part of our social life. Invariably all humans have repeated personnel encounters and experiences about these concepts. Being so used to these concepts however we hardly think about them. These concepts, in different languages and cultures, are recognized in social context with multiple labels or tags; they appear to be latent in character and remain masked by default. The holder of such concepts is mostly unaware about their significance, relevance or manner in which these are employed in scientific domains.

Moreover, despite similarity in their usage, these concepts are linked with different terminologies thereby masking their true identity, e.g., the concept of *Resistance* from a social perspective is associated with flow or more precisely with movement. It has different names in different domains though in essence the fundamental concept, in social context, remains the same: in Electronics it is recognized with its original name; in Physics we use Friction; in Aerodynamics it may be assumed as Drag or Viscosity (in Fluid Dynamics); in Thermodynamics it can be considered Insulation; and in Civil Engineering the concept of Dam represents resistance to water flow. Evidently, understanding the concept of *Resistance* only once in all its manifestation of scientific context can put the student in better position to realize how this concept has been used in different domains and what benefits have been accrued. The developed approach primarily helps students to learn how to correlate their day-to-day understanding of words in a scientific context.

The approach can be better understood with another example which explains how a socially well-known concept of *Change* has been employed in scientific context. Reading and watching advertisement campaigns on bill boards is everyone's daily routine. In social context these boards are viewed as commercial marketing campaigns; on the contrary, scientifically it is the depiction of one of the unique human capability of storing information outside the body, achieved simply by changing the surface *(e.g., panaflex)* of board *(with ink)* by imprinting recognizable and retrievable symbols, e.g., alphabets or pictures. This concept of change has enabled us (humans) to store information outside our bodies for millions of years. Cavemen drawings, writings, printings, books, gramophone records, magnetic tapes, floppy and compact discs etc. are testimonials to the continuum of this simple idea. Encouraged with this idea, man ventured to replace the surface with *state* and that opened avenues for electronic storage. The concept of changing the voltage state with switch positions has evidently changed this world forever. Imagine if prior to learning about storage devices students are made aware that *through change phenomenon we can store information*, the subject becomes more interesting, relevant, and would make more sense to them.

III. Objective

The approach presented here is a pilot study and focuses on the engineering freshman of Pakistan. It will be expanded and extrapolated further at a later stage. Due to multiple reasons, e.g., nonstandard education systems, diverse mediums of instruction, multiple languages, etc., Pakistani students encounter considerable difficulties in undergraduate (UG) programs [10]. The objective is to enable and stimulate engineering freshmen in short time frame (one credit hour) prior to the commencement of UG programs, by employing their innate curiosity and latent possessed knowledge as main instruments for: 1) connecting real life issues already solved by scientific approach in a manner that should give a macro yet coherent overview about interconnections of domains and relevance of engineering; 2) creating life changing scientific awareness that should lead to augmenting their self-confidence;

and, 3) developing passion for the profession that should begin to transform their mindset and attitude [11].

IV. The Proposed Approach

A. The Need

Improving the education system and the learning environment for engineering requires considerable commitment, persistent efforts, and extensive resources. The various aspects to be considered include: 1) educational vision, student and faculty requirements, and prevalent constraints must be considered; 2) the approach must complement the existing system; 3) integrative approach that requires minimal resources be developed; and, 4) innate strength of society to deal with the inhibiting factors must be exploited. Understandably, all these factors are interlinked and the complexity of the problem is evident; and therefore only a comprehensive and practical approach requiring minimal resources would guarantee improvements in engineering education. However for this to be achieved, the authors have opted to propose an approach that may eventually provide the desired solution.

B. Considerations

The proposed approach is intended to bring quantum change in the outcomes; cover complete range of subjects; be affordable and inter-operable; and, be acceptable to academia. It is all about *enabling* engineering freshmen by: 1) making them passionate; 2) upgrading and synergizing their knowledge base; 3) developing requisite skills; and, 4) aligning an configuring them for engineering.

C. Active Learners

The concept (Figure 1) suggests a process through whic students can be empowered as education seekers or activ learners by gradually raising their interest in a subject to

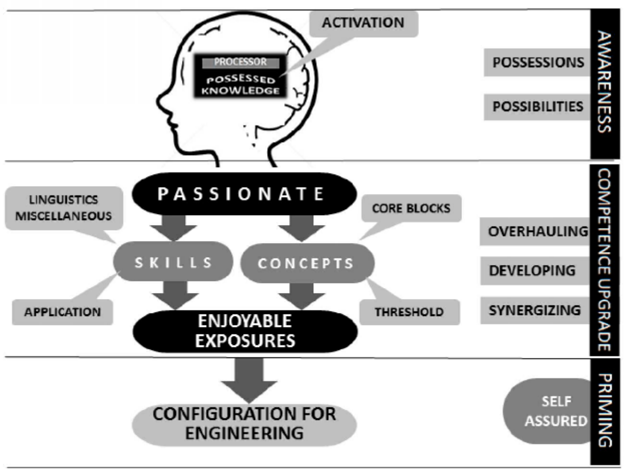

Figure 1 – Overall Approach

become their passion. To satisfy their passion for learning, students are to be connected with their own otherwise untapped reservoir of latent knowledge. Prudently the urge to learn will overwhelm constraints, if any, because nothing can withstand a fueled passion. This approach is being piloted by the authors and has shown promising results [11]. The approach does not, however, replace the prevalent educational system, it rather complements it. It augments producing active learners; motivated, thinking, and enabled students.

The success of the proposed "facilitative approach" is largely dependent upon three factors: 1) art of faculty to attract the students to a zone of interest; 2) ability of faculty to extract students' prior knowledge relevant to the topic of study; and, 3) skill of faculty in making students confident about the subject by connecting them with their prior knowledge. The faculty as a first step will be required to create inquisitiveness in students for learning. It is a known fact that curiosity breeds the urge and inquisitiveness to learn. By default, it sets the stage right and triggers a systematic process for student to eventually enter into the "Chain of Interest" (Figure 2). It may be comparable to pursuing a hobby. A hobbyist willingly participates in all related activities irrespective of its constraints; and, prepares intelligent solutions to overcome the constraints and takes charge of his/her own learning regardless of the source. The pleasure seeking passion becomes his/her driver. The common interest facilitates free flow of information amongst hobbyists enabling them to learn from each other. They continue to look for new methods and opportunities for conducting further experimentation and develop new methods and solutions.

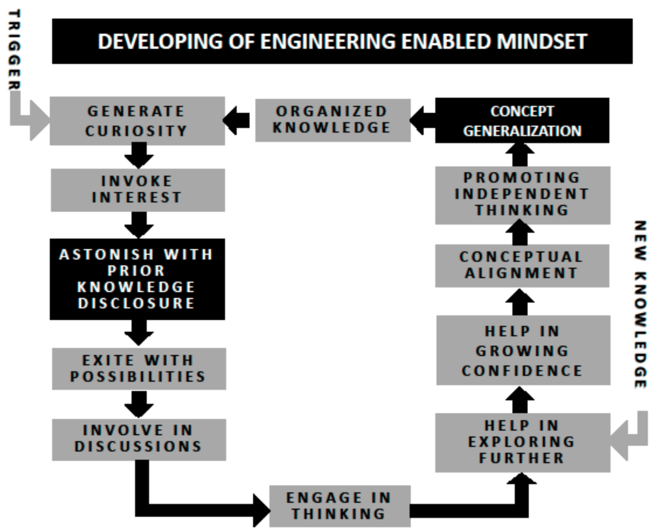

Figure 2 – Chain of Interest.

Faculty would be required to keep the interest of the students alive by astonishing them. The "act of astonishment" will be achieved by the faculty through the use of Latent Knowledge. Students will be disclosed that they already possess prior knowledge of the subject which they are about to study. After making them interested and willing learners, the next phase will be to excite them with the possibility of learning something new that relates to their own lives. This excitement is expected to involve the students deeply, thus creating conducive environments for engaging them in thinking process. Experts will now be required to facilitate their students in their efforts of making sense from the subject under study. The students due to their "prior knowledge" of subject are expected to feel more confident in proceeding further. At this juncture, experts would be required to verify the prior knowledge of the students and, if required, necessary alignment of concepts will be made.

This process will eventually make the students to think independently with confidence and will help them in generalizing the learnt concepts for using them in other domains. A thoroughly conducted session for "one concept" should suffice the students to fully understand its mechanics. This simple approach gradually brings students and faculty in the "chain of interest" which is vital for a learning process. For example, while explaining the concept of "density" (a smaller space is filled with more mass), faculty may like to establish its conceptual and analogical linkage with "traveling of passengers in a congested commuter van". Student's response to experts referring to a situation/word/expression, will eventually confirm if they have managed to access student's "latent knowledge".

V. THE METHODOLOGY

A. Scope

Considering the fact that an aspirant engineering student should be competent in many respects the authors opted to focus on six distinct areas for the freshman: 1) an overview of engineering domains; its relevance with real life and competence requirements for the students; 2) solid knowledge foundation; 3) providing clear picture about knowledge formation and connections that exist amongst different subjects and domains; 4) creating ability to model real entities and situations mathematically; 5) providing evidence that by just extrapolating prior knowledge new topics can be easily learnt; and, 6) introduction to linguistic tools for extracting information from the prior knowledge.

B. Curriculum

Keeping in view the overall objectives, different considerations and the scope, authors have designed a condensed 1:0 credit hour short course (16 contact hours) for the freshmen to be conducted in a one-week "Zero" Term prior to beginning the undergraduate engineering program in a major engineering university in Pakistan. All engineering freshmen are required to take this one credit hour course (EGR-100 Engineering Foundation Course) in a multi-media rich entertaining environment created to meet these objectives through specially designed curriculum (Figure 3). This curriculum aims to: 1) engage student intellectually; 2) heighten their curiosity for engineering; 3) improve their self-image and self-confidence; 4) build systematic excitement; 5) provide confidence that past academic short-comings, if any, are surmountable and student can take a fresh start anytime.

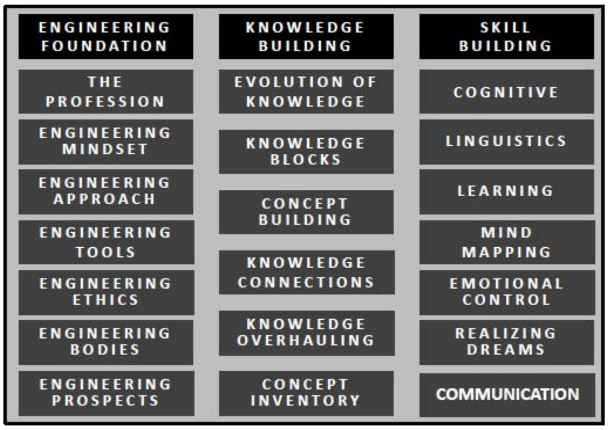

Figure 3 – Curriculum for Zero Term.

C. Exploitation of Prior Knowledge

In order to accrue maximum benefits, extensive usage of prior knowledge is being contemplated in this approach. For this, authors have proposed multi-prong strategies:

- **Reducing Knowledge into Linguistic Elements.** Students are to be demonstrated that much of the scientific knowledge can be reduced to: a) nouns; b) adjectives; and, c) verbs. This assertion is being made by the authors purely on linguistic basis. All languages are known to be comprised of these three elements. The proposed reduction will permit student to extract maximum information from the "words that contain concepts" using specially designed templates. Authors have developed three standard generic templates each for the noun (entity), adjective (property) and verb (process or state) considering well known scientific exploratory requirements. For example, *Heat Transfer* as we all understand is a verb. The generic verb template (Figure 4) gives cues and clues to its user to actively investigate the topic. The template suggests that all verbs have inputs and outputs so it must be investigated what are these in case of *Heat Transfer*. The template highlights the presence of other factors, e.g., participants in different roles, environment, aspect of control, measurements, time & management related aspects, other possible processes (transformation, consumptions, exchanges, changes, etc.). In this way learner can use his/her prior generic knowledge, e.g., about measurement, to find why, how, what, and when something is measured in *Heat Transfer*. Zero term is extensively used: a) to introduce these templates to the freshman in detail; b) how to break down any concept into verb, noun and adjective; and, c) how to use these templates.

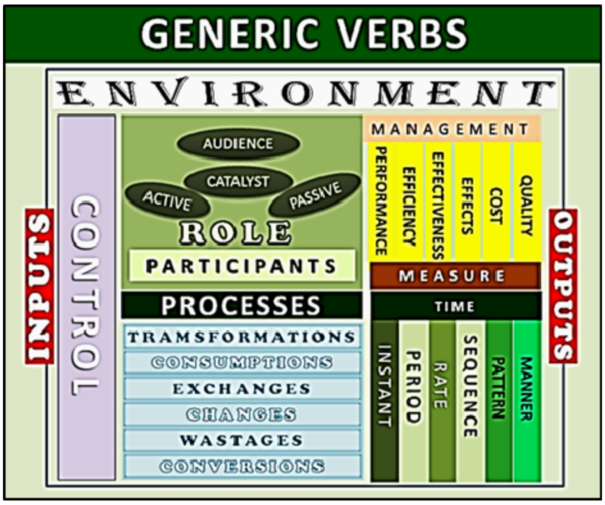

Figure 4 – Elements of a Generic Verb.

- **Reducing Knowledge into Conceptual Elements.** Taking lead from mathematics and famous mathematical equations used in engineering disciplines, authors opted to determine common factors of these domains. Consequently fifteen such concepts (Figure 5) have been identified which are invariably used in the science subjects. One time understanding of these concepts with relevance to real life scenarios would facilitate the student to comprehend the subjects in a better manner. These concepts, identified by authors as *basic knowledge blocks*, are: 1) change; 2) measurement; 3) control; 4) process; 5) representation; 6) time & space; 7) energy & force; 8) function; 9) variables; 10) parameters; 11) flow & resistance; 12) relationship; 13) model; 14) system; and, 15) organization. Subsequently, linguistic roots and origins of these concepts have been traced in real life. This way a semantic link has been established and is found to be useful for student in using their prior knowledge. As student fully understand these topics in social context, it becomes easy to comprehend their use in scientific format. For example concept of *control* in social sense means "to direct the actions or function of (something): to cause (something) to act or function in a certain way" [12] whereas in scientific sense where things are to be more specific and concrete it implies that value of a *parameter* must adhere to the required specification. Here evidently concept of *parameter* and possibility of *change* becomes more significant. Moreover *relation* of *change* with *time & space* and the manner it occurs, as we all understand, is also important. Now, if we *measure* the *change* and we have the *energy & force* then *change* can be *controlled*. In this example, evidently within the ambit of term *control* some other concepts are also important and in social context we all do understand them, though in isolated form. During zero term such connections are made visible to the student to the extent that these do not remain latent any more.

- It can be visualized that deep study of just one word can clarify such like terms as mentioned above. With clarity of basic concepts, students will be intellectually in a much better and confident state to do independent investigation, e.g., how an aircraft's speed governor controls the speed of a propeller? They would now be aware that there ought to be: 1) a defined requirement; 2) a purpose to control; 3) a mechanism to control; 4) an arrangement to sense variations and provide corresponding corrections; and, 5) a range of tolerance limits that are to be adhered to. The students will be able to generalize similar concepts in diverse domains, e.g., controlling of financial markets, traffic flow, blood pressure, etc.

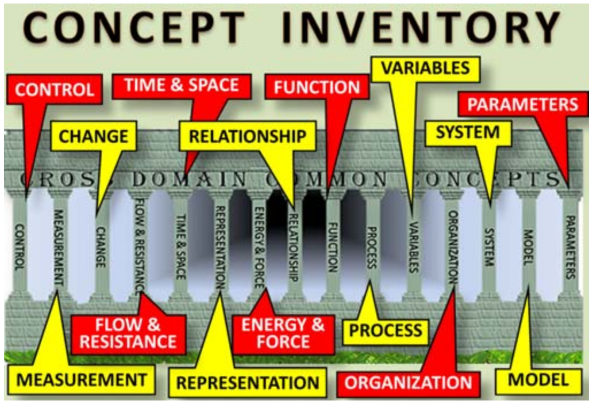

Figure 5 – Fifteen Basic Concepts.

- **Componential Analysis.** In order to provide better insight to students about different ideas prevalent in culture, authors are in process of compiling thematic dictionaries in regional Pakistani languages which will permit to view a word into its "sub conceptual components". The approach is influenced by the idea of componential analysis [13]. For example in English language we have quite a few words which represent physical movement of an object, e.g., running, jumping, swimming, crawling, vibrating. Anyone familiar with the language, despite understanding the difference in the type of movement, may not be able to explain the phenomenon to a computer. Converting such movements in binary code on the basis of what is present or missing can explicitly highlight the latent information. This approach permits to provide latent knowledge an explicit dimension.

- **New Terminologies.** For establishing a positive connection between individual's neural network and terms used in different domains, a need has been felt to coin new terms with public participation. The purpose is to introduce linguistic-hybrids by combining parts of local (Urdu language) and English language words. Such association is common in English language where many technical terms have been introduced using Latin or Greek prefixes or suffixes. Local language part of the term will activate neural network (prior knowledge) whereas English language part will be used to establish interface with text books mostly available in English language.

- **Use of Common Sense.** The role of common sense has remained a matter of interest for researchers [14]. Evidently common sense leads to understanding which does not come with knowledge alone rather it is a result of experience. It is the application of known set of knowledge in unknown situation. For example, generally everyone is aware about the concept of light, heat, temperature, distance, day and night with reference to sun. No formal literacy is required for understanding these concepts. The need therefore is to provide requisite awareness so that socially learnt concepts can be used in formal education. Threshold Concept [15] has been considered useful for activating common knowledge supposedly heavily grounded in prior knowledge.

VI. APPLICATION

This approach is not intended to replace the existing system or curriculum, therefore it is expected to play a limited yet significant role, i.e., to provide clearer understanding (breadth, depth and application) of the core concepts. The approach was piloted in the newly designed Short Course (EGR-100) in Summer 2013 with encouraging results. The Course has been introduced as part of the undergraduate curriculum in a major engineering university in Pakistan since Fall 2014. So far approximately 2000 students took the course with excellent student feedback and statistically significant improvement in their attitude towards engineering ($r=0.578$, $p< 0.001$, $N=1770$). University student course feedback survey and Pittsburg Freshman Engineering Attitude Survey (PFEAS) in pre, post format were used to measure student feedback, and student attitude toward engineering respectively. This approach will be extended to different domains and basic concepts of these domains will be clarified through especially designed *zero lectures*. In addition to freshmen the approach may be equally effective for sophomores, juniors, seniors, and even for the faculty. Departments may run refresher classes in the form of “zero term and zero lecture” using this approach, at the beginning of each academic session.

VII. CONCLUSION

Retrospective review of the proposed approach amply highlights that it has been designed with the fusion of many disciplines; education, human psychology, linguistics, knowledge management being the pronounced ones. In contrast to the common perception that educational constraints in developing world are insurmountable, the proposed approach conceptually provides a viable and cost effective mean to nullify the role of the inhibiting factors. Broadly, the proposed approach can also be symbolized as a “classic case of self-reliance” that can be achieved by an individual using “personal possessions”, i.e., curiosity and prior knowledge, for breaking the shackles of constraints.

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