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Knowledge Based Reorientation of Engineering Physics

Sanjay D Jain
Head of Knowledge Center
Priyadarshini Institute of Engineering & Technology, Hingna Road, Nagpur - 19

Vivek M Nanoti
Principal
Priyadarshini Institute of Engineering & Technology, Hingna Road, Nagpur - 19

Abstract

This paper is based on the application of our recent knowledge center initiative to the knowledge domain of physics in engineering curricula. This initiative aims at shifting the marks based orientation of the present education to knowledge, skills and wisdom. Thus in addition to the routine practice of covering the prescribed syllabi of physics courses in engineering programs for helping students to get marks and degrees we also made an attempt to uncover and discover these syllabi to reorient them in a knowledge based way. Our work brought to fore several motivations which promise to shape the career and life of engineering students by offering them the benefits of enjoyment, employment, empowerment and enlightenment. These pursuits also helped us to put in place a natural mechanism to fulfill the norms laid down by the accreditation bodies.
Keywords: Engineering Physics, knowledge center, knowledge spiral, accreditation

I. Introduction

In recent years there has been a growing awareness about the need to arrest the deteriorating standards of higher education in general and engineering education, in particular [1-5]. Though there have been several governmental and nongovernmental efforts in this direction a need for grass root initiatives has been expressed by the researchers for the overhaul of the existing system. Recently we took a Knowledge Center Initiative (KCI), which can effectively work at the grass root level to compensate for the lacunae of the present education system [6-8]. This paper is an attempt to present how this initiative helped us to develop a much wider and deeper knowledge perspective of physics than the present one in which it is treated as just another subject required to be passed for getting an engineering degree. The KCI also helped us in the accreditation process by improving our mapping of course outcomes (COs) with the program outcomes (POs).

II. Motivation

Engineer's council for professional development defines engineering as the profession in which knowledge of mathematical and physical sciences gained by study, experience and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the progressive well-being of humankind [9]. This definition brings out the core role of physics in engineering curricula. Physics leads science in the study of matter, energy and their interactions. Technology deals with applications of scientific knowledge and engineering concerns with practical use of appropriate technologies. This is borne out by a large number of examples in which physics provided breakthroughs that gave birth to and shaped new technologies [9, 10]. These examples aptly convince us that physics research of today is the engineering of tomorrow.

Considering these 'knowledge links', engineering programs are usually structured such that the syllabi based on physics are included in the initial semesters so that they lay the foundation on which students can build their structures of engineering knowledge. A fortified foundation can thus ensure super structures of engineering knowledge. However, the current examination oriented structures of education have almost obscured these close links. The motivation of the present work is to bring these links to the surface to acquire the desired knowledge based reorientation of these syllabi.

III. Methodology

Knowledge accrues in physics through the scientific method of seeking agreement between theory and experiment. Agreement between theory and experiment results in knowledge and disagreement between the two results in motivation for research that further leads to knowledge. Majority of the breakthroughs in physics have occurred though the use of scientific method. The accrued knowledge then becomes the input for the vast world of engineering applications. Thus physics advances knowledge in engineering through a three step process of observation (experiment), explanation (theory) and application. We used this process as a guiding methodology of the present work.

Considering students as the future researchers / entrepreneurs / technocrats we involved them and the faculty members in this reorientation work through activities such as curiosity corner, knowledge café, and knowledge clinic and through exhibitions on themes such as learning through eureka moments, struggle stories and quotations of scientists; researching into the utilitarian, seamless and frontier aspects of knowledge on the interface of physics and engineering; and learning by doing [6, 11]. The methodology is explained in details in our earlier papers [6-8]. In the present work we applied this methodology to the syllabi of two physics courses – Engineering Physics and Advanced Physics - prescribed for the B. E. program of RTM Nagpur university for semester I and semester II, respectively [12]. Table I compares the main ideas of our methodology with that usually implemented in the present system.

Table – 1
Implementation Methodology

Present System	*KCI*
Starts with syllabus and ends with marks obtained in exams. *Books which fulfill the exam needs, viz., which include answers to questions asked in exams, are preferred.* *Courses are covered mainly through monologue lectures in which participation / involvement of students is minimum.* *Exams comprise of questions such as 'define', 'derive' and 'describe' that test the ability of students to reproduce information. This often promotes rote learning.* *Students get mark lists in the end of semesters and a degree at the end of a program by clearing exams.*	*Starts with curiosity / need of a learner and ends with acquiring the desired knowledge / skill.* *Books which fulfill the knowledge needs, viz., authoritative, knowledge oriented books are preferred.* *Knowledge is imparted through interactive discussions in which participation / involvement of students is optimum.* *Usually there are no exams thus getting rid of rote learning. Learning pursuits comprise of steps to 'explore', 'investigate' and 'do'. This promotes creative and experiential learning.* *Learners are credited with research papers / articles, theses, products and patents through their knowledge pursuits.*

IV. OUTPUT

In Table II we present a few of the several examples of the output developed in the present work under the KCI. The output is in the form of the knowledge based motivations that were brought to fore by uncovering and discovering the different units of the syllabi mentioned above. In this Table we also make a comparison of this output with the output of a typical university based system in which these units are covered to prepare students to answer selected stereotyped questions that are repeatedly asked in exams.

Table – 2
Comparison of Output developed under KCI with that in the Present System

Subject and Unit	*Covering the syllabus in the present system prepares students to answer questions of the type 'define' / 'derive' / 'describe' on the following topics.*	*Uncovering and Discovering with the KCI helped us to develop motivations of the type 'explore'/'investigate'/'do' about the following topics.*
Engineering Physics (EP) Unit - I: Quantum Mechanics	*Planck's theory of quantization De-Broglie theory of dual nature of light*	*Quantum particles like phonon, magnon, polaron and graviton* *Wave particle duality of light in eye and lasers* *Photo devices, quantum devices, electron microscopy* *Characterization techniques like electron diffraction and neutron diffraction*
EP Unit - II: Wave Packet & Wave Equations	*Wave packet Heisenberg's uncertainty principle* *Schrödinger equation and its solution for one dimensional infinite potential well, Barrier Tunneling*	*Use of wave packets in the fields of communication engineering and space technology* *SQUID (superconducting quantum interference devices)* *Scanning tunneling microscope, Q dots and Q corals* *Quantum optics, quantum engineering, quantum computation*
EP Unit - III: Crystal Structure	*Crystal structure, SC, BCC and FCC unit cell characteristics Miller indices, Inter-planar distance Bragg's law of X-ray diffraction, Voids*	*Crystals around us in nature and technology: minerals, rocks, snowflakes, gems, metals, carbon, and salts; more complicated structures such as protein, cholesterol, penicillin and vitamin B12;* *Protein crystallography; Piezoelectricity; Crystal polarimetry; Crystal engineering* *Cambridge Structural Database; Nobel laureates in x-ray crystallography*
EP Unit - IV: Semiconductor Physics	*Band-theory of solids Fermi-Dirac distribution Function Intrinsic and Extrinsic semiconductors PN-junction diode, Tunnel diode, Zener diode, LED Transistor, Hall effect*	*Understanding how semiconductors, which were considered useless 100 years back turned into the most useful materials* *Band formation in different semiconductors, band gap engineering* *Different semiconductor devices and junction devices* *Physics involved in the discovery and development of transistor* *The Chip Revolution*
Advanced Physics (AP) Unit - I: Lasers & Wave Optics	*Coherence of a light wave Three Quantum Processes Metastable states, Pumping schemes He-Ne, Ruby and Semiconductor lasers* *Laser Applications* *Interference in thin films Wedge shape thin film, Newton's rings Anti-reflection coating Thin film applications*	*How the invention of laser is looked upon as a solution looking for problems* *Measuring distance between moon and earth using a laser beam* *Applications such as Laser printer, CD, bar codes, cloth cutting, drilling, welding, marking, alloying, wire stripping, machining and polishing* *Applications in fiber optic communication, applications as a surgical and diagnostic tool and applications in defense*

		Applications of Interferometretic techniques to determine various material properties and to test surface finish of devices Design and development of thin films for desired applications
AP Unit - II: Electron Ballistics	*Motion and energy of charged particles in uniform electric and magnetic fields Crossed electric and magnetic field configurations, Velocity filter*	*Study of electric field and magnetic field in nature and technology through phenomena such as lightening and northern lights and applications such as electrostatic precipitator, ink jet printer, magneto hydrodynamic (MHD) devices, accelerators and TV tubes*
AP Unit - III: Electron Optics	*Bethe's law, Electric and Magnetic focusing, Electrostatic lens, CRO, Bainbridge mass spectrograph, Cyclotron*	*Design and development of the electrostatic and magneto static lenses and their applications in devices like CRT and TV camera tubes CRT applications such as data display tubes in computers, radar technology and electronic phototypesetting CRO as an 'eye' of an electronic engineer; Different mass spectrographs*
AP Unit - IV: Optical Fiber and Nano-science	*Optical fibers: Propagation by total internal reflection, structure and classification Attenuation and dispersion Light sources and Detectors Applications as sensors and detectors Classification, Synthesis, properties and Applications of Nano-materials*	*History, design and development of fibers with low attenuation, low dispersion and high data transmission capacity Application of fiber optic sensors for measurement of parameters such as pollutants, blood pressure and positions of earthquake faults Fiber optic smart structures Surprises in Nano science, Government and non-governmental initiatives in Nano science and nanotechnology Nanoparticles and Nano-whiskers for use in apparel, footwear, paints, wound dressings, appliances, cosmetics and plastics Applications of Nano-science in drug manufacturing and drug delivery Nano-enhanced paints, Nano-enhanced construction ceramics such as floor and wall tiles and Sanitary ware, Nano-enhanced cement*

Table II reveals how, on one hand, the present marks based orientation severely restricts the knowledge potential of physics and how, on the other hand, the KCI approach brings out its vast and deep scope in engineering education. Thus the present work also helped us in addressing the objectives of Outcome Based Education (OBE) in a better way. With the present system we could map our COs (the CO of each unit pertained to introducing and familiarizing students with the basic ideas in that unit and numerical problems and engineering applications based on these ideas) effectively only with PO1 that pertained to engineering knowledge. But the mapping was poor for other POs as there was either a very slight correlation or no correlation between the COs and these POs. With KCI, we could improve the correlation of COs with POs such as PO2 (Problem Analysis), PO3 (Design/development of Solutions), PO4 (Conduct Investigations of Complex Problems), PO5 (Modern Tool Usage) and PO12 (Life-long Learning).

Some of the motivations developed in the present work were converted into small (UG level) research / investigative / work-based projects that resulted in output in the form of research papers / articles in newspapers, magazines, journals and conferences and working demonstrations [13-20]. These outputs have become our resources in the knowledge center for arousing the curiosity of learners and facilitating them in setting the knowledge goals that promise to shape their careers and lives through benefits of joy, job, wealth and wisdom. These pursuits also helped us to put in place a natural mechanism to fulfill the norms laid down by the accreditation bodies. The encouraging results of the present work have opened a lot of scope in undertaking such studies in other knowledge domains of engineering curricula. This work is underway.

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