Knowledge Center - A New Learning Paradigm for Engineering Education in India

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***Abstract*— Recently we started a knowledge center in our institute as a proactive initiative to compensate for the lacunae of our present education structures. Motivated by the aim to bring the focus of knowledge back into our education system, the initiative produced encouraging results. This paper discusses how, on one hand, this initiative has been useful in filling the gaps in the present system and how, on the other hand, it paved way for lot of further work that promise to keep the initiative growing. These results motivate us to suggest this initiative as a new learning paradigm for the overhaul of engineering education in India.**

***Index Terms*— Knowledge center, knowledge spiral, knowledge reforms, undergraduate research, accreditation, active learning, blended learning, open educational resources**

I. Introduction

In a recent paper [1], we discussed how knowledge centers (KCs) can harness education technologies, in synergy with the information and communication technologies, to facilitate the institutionalization of knowledge reforms in India. Several education researchers and reformers have expressed the need for such knowledge based alternative approaches to our current education structures for quickening our march towards a knowledge society [2]. The present structures are based mainly on the vision of Lord Macaulay who introduced the system about a century and half back primarily to serve the British rule.

The basic premise of this initiative is that the knowledge output of a learner can be optimized through the resonance between the natural propensity of a learner and the knowledge activity he/she undertakes. Thus promotion of natural learning based on the ignorance and curiosity of learners through a cafeteria approach can ensure their enjoyment, employment, empowerment and enlightenment.

As a first step towards experimentation of these ideas, a physics knowledge center was developed in our institute. In this paper we discuss the results of our recent research into this idea that addresses various issues related to educational technology, education accreditation, quality and assessment and teaching learning process. This research brought to fore how KCs can be effective in filling the gaps in the present system. It also revealed how it has the potential to create new gaps that can sustain and grow the initiative. The positive results of this experiment encouraged us to extend this initiative beyond physics and the central KC of the institute was formed recently that brought under its ambit a large number of knowledge domains relevant to the various science and engineering courses that are conducted in our institute. These results also motivate us to suggest this initiative as a new learning paradigm for the overhaul of engineering education in India.

II. Implementation of the KC Idea

The methodology of implementation of the KC idea is based on the optimum use of the unstructured character of knowledge. Thus, instead of fitting knowledge in any structure, the implementation focused on conveying how knowledge is there to quench someone's curiosity, get someone a job, prosper someone in a job or build someone's wisdom (to guide society in general, and youth, in particular), thus addressing the fourfold objective mentioned above.

Thus our initial attempts towards implementation of KC idea involved development of knowledge oriented learning material and conducting activities such as *Curiosity Corner* (for curiosity based learning), *Knowledge Clinic* (for diagnosis of ignorance and remedial learning) and *Knowledge Café* (for applications based learning). Our initial work pertained mainly to physics under which the university syllabus of physics was re-oriented, re-explored and re-presented to make it knowledge centric and knowledge intensive. The objectives of the initiative were addressed by developing learning material that conveyed knowledge of physics through spirals, stories, convincing examples, innovative experiments and applications [3-10].

Recently the idea was extended to various other courses that are conducted in our institute. As the center is developed in our institute, which is affiliated to the RTM Nagpur university, the objectives of our initiative could not be pursued quite independently of the institute and some relevance was required to be maintained to the courses and syllabi prescribed by the university. Keeping this in view the idea of KC was introduced to students as an initiative that offers them the freedom to uncover and discover the syllabi that they cover as a part of the examination oriented university structure. After the coverage of each unit the KC perspective of that unit was developed among the students and students were motivated to avail one more of the threes activities of KC as explained below.

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After a particular unit was completed and the test on that unit was conducted, the statistics of the scores revealed how many students grasped that unit from the view of examination. This helped the teacher to identify students for knowledge clinic (students with less than 50 % score belonged to this category).Though improvement in examination scores is not one of the keen goals of a KC, we included it for the reason that the center is situated in the educational institute, as mentioned earlier, and secondly, because we also observed that the initiative didn't clash with the scoring aims of majority of students (good knowledge seekers were also found to be good scorers). Inclusion of this goal resulted in better implementation of the KC idea. Knowledge clinic involved research into the weaknesses of students in understanding the taught topics and reproducing them in exams and providing remedial need based guidance to such weak students. The observations were recorded in the format shown in Table 1.

TABLE I. KNOWLEDGE CLINIC FORMAT

Name and Roll No. of the Learner	Topics not followed/Concepts not understood	Expert's diagnosis and remedial steps	Retest 1 score	Retest 2 score

Students with better scores were motivated to avail the benefits of curiosity corner and knowledge café. Students were made aware that marks don't necessarily mean knowledge and there is a vast scope in probing the taught topics from the knowledge point of view. This included inspiring students to know further about the scientists and engineers whose knowledge contribution was more relevant to that unit, to develop deeper insights into theory through knowledge oriented resources and interactions with experts and to appreciate the applications potential of that unit through 'learning by doing' and visiting appropriate industries. Learning pursuits by students under these platforms were likened to be 'research at UG level'. Thus the student enrolled in the institute for a particular course became a researcher in the KC and the faculty member who taught that course became the guide. The format used for recording the details of the research process included data shown in Table II.

TABLE II. FORMAT USED FOR RECORDING THE DETAILS OF THE RESEARCH PROCESS

Learning motivations:
Details of the learning (research) process: Books read Net resources used Industries visited Experts with whom interacted
Details of the research output: Papers / Articles published Papers presented Projects / skills developed Dissertation completed Grades improved Any other achievement

III. KC OUTCOMES

A. Filling the Gaps: Institutionalizing Knowledge Reforms

Structured education compels everyone to follow the same syllabus, same examination pattern and same evaluation procedures. However, the natural ignorance, learning competence, learning pace and learning styles vary from individual to individual. The rigidity of the structure smothers this individuality. The KC initiative provided accommodative and inclusive solutions to these problems and thus provided an effective mechanism for filling the gaps in the system and institutionalizing the knowledge reforms.

The KC initiative has also put in place a mechanism to improve our natural preparedness for accreditation and reaccreditation purposes. The programme objectives/outcomes (POs) and course outcomes (COs) of any course / programme conducted in an educational institute are related mainly to the development of understanding, knowledge and skills related to that course / programme among the students and to inspire them for learning beyond the syllabus and for lifelong learning. The KC mechanism facilitated improvement of these aspects and led to better mapping of POs and COs and better attainment of the targeted COs.

The NBA document [11] lists the following as initiatives in teaching learning process (Sec. 2.2.1): initiatives in improving instruction methods, using real world examples, collaborative learning, the quality of laboratory experiments with regard to conduct, record observations, analysis etc. encouraging bright students, assisting weak students etc. All these initiatives are subsumed in the KC initiative and thus favourably impacted the teaching learning process. In particular, the last one, fitted quite well with our approach as curiosity corner and knowledge café brought out the excellence of bright students and knowledge clinic provided opportunities for weaker students to excel. An example of a case study based on research into the implementation of these ideas for the author's courses is discussed here.

B. Case Study

Name and level of the courses: Applied Physics I (B. Tech. I Semester) and Applied Physics II (B. Tech. II Semester)
Number of student enrolled for each course: 98
Number of units: 6 in each course out of which the KC activities could be actively undertaken in 3-4 units.
Number of students who availed the KC activities: approximately 25 for curiosity corner and knowledge café. The number for knowledge clinic varied for each unit.
KC sessions: The sessions were usually conducted beyond the working hours to gather the spirit of travelling that extra mile which makes the difference. The sessions were much different from the structured class room lectures and practical sessions in that the emphasis shifted totally from teaching to learning.
Research process: In the initial period the questions asked by students were answered by the guide. Queries of students and their solutions are available on the website developed by us for this purpose [12]. However, later we also experienced that it is

not enough to motivate students to be curious alone because only when curiosity drives one in pursuit of knowledge, the knowledge goals can be attained. So we emphasized more on 'curiosity leading to comprehension' and the answers were attempted by students in the form of research papers / articles. Table III lists some examples of the topics researched by students. Students were closely mentored in their research pursuits.

TABLE III. EXAMPLES OF TOPICS RESEARCHED BY STUDENTS

Curiosity Corner
Basic structure of electron
An insight into the inside of earth
How we can define time? Does the time depend on motion or motion depends on time or both are interdependent?
Laser trapping of atoms
In the Apollo experiment how the distance between the earth and moon was determined with a great accuracy using a laser beam?
If we can have He-Ne laser, can we similarly get laser from other inert gases like Xe, Kr, Rn or other gases?
How huge stone blocks were placed to construct the pyramids?
How interference helps to measure the diameter of stars?
Can neurons be generated by genetic engineering?
Knowledge Café
Applications of Nd:YAG Laser in industry
How laser is used to read a CD?
How can we build our own laser?
Which lasers are used in industries to cut heavy metals?
How x-rays can be used to determine the crystal structure?
Knowledge Clinic
Why cooling is required in Ruby laser?
How does laser beam damage retina?
Why the interference pattern due to transmitted light is complimentary to the pattern obtained due to reflected light?
Why does laser phenomenon not occur naturally?
Archimedes principle was studied earlier by us only for exams and was not properly understood. I am interested to know it better.

Books: The examination orientation of our education structures has almost driven authoritative, knowledge oriented books out of our present system. However, such books become the primary resource in KC. In Table IV, an example that illustrates this feature is given.

TABLE IV. AN EXAMPLE TO ILLUSTRATE THE NEED FOR KNOWLEDGE ORIENTED BOOKS

The following question was asked under knowledge clinic.
In the derivation of the expression for surface tension using Quincke's method using the figure 305 in the book, 'Properties of Matter' by D S Mathur, S. Chand, on Pg. 466, it is mentioned that the lateral hydrostatic pressure due to a liquid over GLKA = ½ h ρ g, where GL = h ; ρ, the density of the liquid and g, the acceleration due to gravity. Why the factor of ½ appears in this expression?
The explanation was not available in the commonly referred books. After referring several books, a satisfactory explanation could be found in the book, 'Physics for Scientists and Engineers', by Jewett and Serway, Cengage Learning, on Pg. 394. (Detailed explanation is available on our website [12].)

Internet: There is an enormous amount of information available on the net and there is a growing tendency among students to copy from net. So attempts were made to convince students that information on net is not knowledge; it is the knowledge of the person who developed it for net. For converting the information from net to the knowledge of the learner, mentoring was done regarding the appropriate use of net resources based on the curiosity, need and competence of the learner.

Research Output: As everyone is curious in his / her own unique way learners were asked to work individually in the beginning. But later on depending on the commonalities of research interests, they were encouraged to work in groups for preparation of the final output. The output was presented by the groups before the class in the form of a paper / presentation / demonstration. Though we also aimed at guiding learners to prepare theses based on their research, we have not been able to achieve it so far. The efforts on these lines are underway.

The output of research into the diagnosis of weaknesses of students under knowledge clinic platform (Table I) provided clues for better remedial steps in both internal assessment and university assessment (as required in Section 8.5.2 of the NBA document [11]). In table V few of the remedial actions taken are mentioned.

TABLE V. REMEDIAL ACTIONS UNDER KNOWLEDGE CLINIC

1. Students were involved in peer learning by forming groups of two students in which a bright student assisted a weak student through peer instruction. It was encouraged as an activity for transfer of knowledge from 'knowledge haves' to 'knowledge have nots'. It was emphasized that knowledge is not depleted from the source when it is given away; on the contrary, it enhances.
2. Practice sheets were prepared for individual learners keeping in view their learning disability.
3. Learning material was developed in Hindi to enable students to grasp the basic ideas, which they found easier in writing in English after they followed them in Hindi.
4. More interactive sessions were devoted to solving numerical problems with emphasis on use of appropriate units.

Student's response: Students found the activities of curiosity corner and knowledge café interesting as they could enjoy the freedom of learning and the excitement of researching without any tension of examination and also improved their oral and written presentation skills. Those who took advantage of knowledge clinic showed improvement in their curricular performance.

C. New Ideas for Sustaining the Initiative

Our research into the institutionalization of knowledge reforms discussed above brought forth the vast but largely unexplored scope of the idea of KC and paved way for lot of further work that promise the sustenance and growth of this initiative. In particular, the initiative showed a strong promise in optimal fulfillment of the accreditation and reaccreditation needs of an institute through a systematic research into the teaching learning process. One of the important criteria in this regard is continuous improvement. For example, in Sec, 8.5.2 of the NBA document discussed above, if the set targets are attained, higher targets need to be set and attained for continuous improvement. This opens a vast scope for an open and live research into the process towards the target of 100 % results (and then towards targets of higher knowledge levels). As an institute such targets for all courses for all programmes can be an ambitious exercise in which the KC initiative can play a meaningful and catalytic role.

Another important area in which the KC initiative showed great promise is the area of research in education. Research, which concerns with creation of knowledge and is an expert centric activity, is often debated as independent of education, which concerns with dissemination of curricular knowledge and is a student centric activity. KC initiative bridges the two and stresses on research in education. The awareness and interest in the area of research in science and engineering education has been growing in recent years [13 - 15].

One direction of such research concerns with the behaviourial, cognitive and pedagogical aspects of learning and is based on learning theories, which describe how information is absorbed, processed, and retained during learning. Learning style theories propose that individuals learn in different ways, that there are distinct learning styles and that knowledge of a learner's preferred learning style will lead to faster and more satisfactory improvement [16].

Though we used educational technology for development of learning resources [1, 12] we haven't followed any single learning model in totality to maintain the comprehensive uniqueness of our initiative. This uniqueness focuses on engaging students in experiential and interactive learning rather than learning through formal lectures and rote note taking methods so that they develop independent and critical thinking and a passion for learning in self-directed ways, driven by their innate curiosity.

However, we present in Table VI how our initiative comes closer to one or more aspects of the different learning models [16]. There is further scope in improving this closeness for which the work is underway.

TABLE VI. CLOSENESS OF OUR INITIATIVE TO DIFFERENT LEARNING MODELS

Learning model	Aspects that comes closer to our initiative
Constructivism (Active learning, discovery learning, and knowledge building)	The teacher acts as a facilitator who encourages students to discover principles for themselves and to construct knowledge by working answering open-ended questions and solving real-world problems. To do this, a teacher should encourage curiosity and discussion among his/her students as well as promoting their autonomy.
e-learning	Bernard Luskin, an educational technology pioneer, advocated that the "e" of e-learning should be interpreted to mean "exciting, energetic, enthusiastic, emotional, extended, excellent, and educational" in addition to "electronic." Parks suggested that the "e" should refer to "everything, everyone, engaging, easy".
Hybrid learning or Blended learning	It may refer to approaches in which traditional classroom time is reduced but not eliminated, and is replaced with some online learning. *Flipped classroom* is an instructional strategy and a type of blended learning that reverses the traditional educational arrangement by delivering instructional content, often online, outside of the classroom and moves activities, including those that may have traditionally been considered homework, into the classroom. The flipped classroom intentionally shifts instruction to a learner-centered model.

We also found that our initiative can play a significant role in keeping pace with the advances and innovations in science, technology and engineering by addressing the interdisciplinary, multidisciplinary and seamless character of knowledge. This seamlessness is evident in nature, among professionals and in the world of work and research. Table VII illustrates few examples of the seamlessness of science and engineering, brought to fore as a part of this initiative [17].

TABLE VII. SEAMLESSNESS IN SCIENCE AND ENGINEERING

Seamlessness in definition: Encyclopaedia Britanica (macropaedia, Vol. 18) defines engineering as the professional art of applying science to the optimum conversion of the resources of nature to the uses of mankind. As engineers use scientific principles to develop economical solutions to technical problems, science becomes an intrinsic and inseparable part of the entire engineering process.
Seamlessness in Nature: In nature there are myriad examples of science merging seamlessly with engineering that inspired scientific and technological innovations. Few examples are: emission of light by firefly (bioluminescence) inspired new innovations in lighting technology (electroluminescent LEDs); "ultrasonic eyes" of bats inspired techniques such as ultrasonography and echocardiography for medical imaging and diagnostics and aerodynamics of pigeon in flight inspired development of flying aircraft. Computer scientists and engineers have developed computational approaches and algorithms based on the way in which organisms behave in groups called, the *swarm intelligence*. The observation of designs and patterns in nature and their imitation to build engineering applications in a sustainable way has led to the evolution of a relatively new science called *biomimetics* or *biomimicry*.
Seamlessness among professionals: There are several examples of scientists making pioneering contribution to an engineering field and engineers making scientific discoveries. Few examples are: Fresnel, the French military engineer, made pioneering contribution to the science of interference and diffraction of light. Wallace Sabine, an American physicist, founded the field of architectural acoustics. Jack Kilby, an engineer at Texas instruments, developed an integrated circuit for which he received the Nobel Prize in physics in 2000. Bardeen, the first person to receive Nobel Prize twice in science, studied electrical engineering at University of Wisconsin and solid state science at Princeton University.
Seamlessness in the world of work: Knowledge of scientific processes is seamlessly subsumed in the engineering world of work, i.e., in the design of products and execution of projects. Few examples are: use of total internal reflection of light in fiber optic technology, fiberoptic endoscopy and fiber optic sensor technology; use of interference of light waves in engineering works such as testing of flatness of optical surfaces, testing of prisms and lenses for chromatic aberrations, measurement of thickness of thin films, collimation testing and measurement of wedge angles and use of photoelasticity (stress induced birefringence) to check and optimize the design of engineering components such as gears, turbine blades, beams and windshields.
Seamlessness in research: Scientific research is playing an increasingly important role in the field of engineering. Few examples of application of scientific research in engineering are: fusion physics research in nuclear engineering; quantum physics in quantum engineering, quantum computation and nanotechnology; biophysics in biomedical engineering, crystal physics in crystal engineering; geometrical optics in lens design engineering; and semiconductor physics in band gap engineering. In fact basic research at the forefront of physics and other sciences is included as one of the functions of electrical and electronics engineers [Encyclopaedia Britanica (macropaedia, Vol. 18)].

D. Knowledge Spirals as Open Educational Resources of KC

Another important KC outcome is a knowledge spiral, which can be looked upon as an open educational resource of KC. So far we have worked on such spirals for lasers and crystals [4,7]. On the eve of *International Year of Light and Light-*

based Technologies – 2015, declared by the UN General Assembly, we are currently working on the 'Optics Knowledge Spiral' (Fig. 1) that can be implemented in an 'Optics Knowledge Center'.

Knowledge spirals bring to fore an interesting interplay between tacit knowledge and explicit knowledge. The concept of tacit knowledge is a cornerstone in the organizational knowledge creation theory of Nonaka [18, 19]. Tacit knowledge covers knowledge that is unarticulated and tied to the senses, movement skills, physical experiences, intuition, or implicit rules of thumb whereas explicit knowledge is the one that is uttered and captured in drawings and writing. Knowledge alternates between tacit knowledge that may give rise to new explicit knowledge and vice versa through the processes of socialization, externalization, combination, and internalization. For example, the optics knowledge spiral accommodates the tacit knowledge of a lens maker who doesn't have an explicit knowledge of geometrical optics and the explicit knowledge of geometrical optics possessed by a student who cannot make a lens.

CONCLUSION

In this paper we discussed the results of the recent experimentation of our knowledge center initiative. The results are quite encouraging as the initiative provided a compensatory mechanism to overcome the lacunae of the present higher education system and improved our natural preparedness for accreditation and reaccreditation purposes. The initiative also opened up lot of further scope in pursuits of research in education and in keeping pace with scientific and engineering innovations. These results bring out the potential of this idea as a new learning paradigm for overhaul of engineering education in India and quicken her march towards the goal of an ultimate knowledge destination.

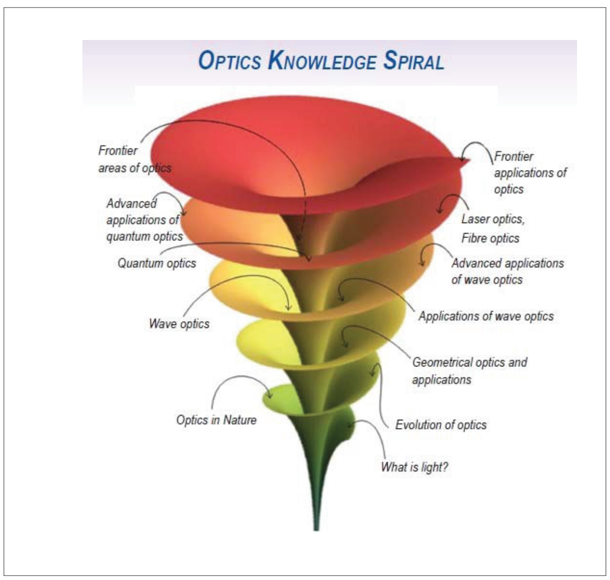

Fig. 1. Optics Knowledge Spiral

REFERENCES

[1] S. D. Jain, C. G. Dethe, and G. G. Sahasrabudhe, "Role of educational technologies in reemergence of India as a knowledge society", IEEE Xplore India Conference (INDICON), 2012 7-9 Dec., P. 819 – 822.

[2] S. D. Jain and C. G. Dethe, "Knowledge Center Initiative for Transforming India into a Knowledge Destination", paper submitted for 3rd IEEE Inter. Conf. on MITE, to be held at Amritsar, Punjab, 1-2 Oct. 2015

[3] S. D. Jain and G. G. Sahasrabudhe, "Engineering physics", Universities Press, 2010

[4] S. D. Jain, and G, G. Sahasrabudhe, "Teaching Laser", Journal of Research: 'The Bede Athenaeum', Vol, 3, issue 1, 2012, pp. 56-60

[5] S. D. Jain, "Physics – A philosophy of nature" – compilation of articles published in 'Hitavada' on the eve of International year of physics, SGR Publishers, Nagpur, 2009 (ten of these articles are republished in bulletins of IAPT and NCSTC during 2006-07.)

[6] Sanjay Jain, "Advancing physics learning through understanding errors", IJPRET, vol. 2 (9), 2014, pp. 293-299

[7] S. D. Jain and V. B. Sapre, "Knowledge world of crystals-atoms in order", IJPRET, vol. 3 (3), 2014, pp. 26-45

[8] S. D. Jain and C. G. Dethe, "Story of semiconductors- how useless turned useful", Science Reporter, vol. 51, no. 9, Sept. 2014, pp. 34-37

[9] S. D. Jain and V. B. Sapre, "The story of crystals", Science Reporter, vol. 51, no. 12, Dec. 2014, pp. 14-19

[10] S. D. Jain and V. M. Nanoti, "Decoding the enigma called light", Science Reporter, vol. 52, no. 5, May, 2015, pp. 14-21

[11] www.nbaind.org/files/draft-sar-ug-tier-II.pdf

[12] https://sites.google.com/site/sjainknowledgecentre/

[13] Jon Ogborn, 'Physics Now', Commision 14, Physics Education, by International Union of Pure and Applied Physics, 2004

[14] B. Jesiek, K. Beddoes, D. Sangam and M. Borrego, "Mapping Local Trajectories of Engineering Education Research to Catalyze Cross-National Collaboration", www.Sefi.be/wp-content/abstract 2009/Jasiek.pdf

[15] A. K. Parashara and Rinku Parashar, "Innovations and curriculum development for engineering education and research in India", Procedia - Social and Behavioral Sciences, vol. 56, 2012, pp. 685 – 690

[16] en.wikipedia.org/wiki/Learning_theory_(education)

[17] S. D. Jain and V. M. Nanoti, "Story of seamless science and engineering", accepted for publication in Science Reporter

[18] I. Nonaka, "A dynamic theory of organizational knowledge creation", Organ. Sci. 5(1) 14–37.

[19] I. Nonaka and G. Krogh, "Tacit Knowledge and Knowledge Conversion: Controversy and Advancement in Organizational Knowledge Creation Theory", Organization Science, Vol. 20, No. 3, May–June, 2009, pp. 635–652