GC 2012-5621: DEVELOPMENT OF A TEACHING LEARNING CENTRE AND ONGOING FACULTY DEVELOPMENT PROGRAMS - A CASE STUDY

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Development of a Teaching Learning Centre and On-going Faculty Development Programs - A Case Study

Abstract

Faculty development is a core strategy in continuing efforts to transform engineering education at any institution. Collaborations can strengthen faculty development initiatives, since the home institution has significant knowledge about its faculty members and the on-going dialogue about teaching and learning, while another organization can contribute expertise and experience that the home institution may lack. In this paper, faculty members at the Indian Institute of Technology Madras (IIT-M), India, a fifty-year old Institute of National Importance with an international reputation, and the Institute for Engineering Education and Innovation (IEEI) and the Center for Teaching Excellence (CTE) at Texas A&M University, USA, describe their on-going collaboration which started in 2009. One visible result of their collaboration has been the founding of a Teaching-Learning Centre (TLC) to establish sustainable activities for faculty development in IIT-M. The TLC, which emerged from faculty conversations about continuing efforts to improve teaching, will hopefully enhance efficiency of course delivery and raise interest and motivation levels of students in understanding engineering and science subjects.

As another concrete result of the collaboration, 3 three-day Faculty Development Programs (FDPs) and a one-week faculty interaction program, the first of their kind at IIT-M, were conducted for IIT-M faculty members from December 2009 to December 2011, initially by a team of experts from the CTE, and later by a joint team of Texas A&M and IIT-M faculty members. After due familiarization with the novel ideas on course delivery, taught and discussed during these programs, some of the IIT-M faculty members have applied a framework using a course delivery cycle to their classes.

It was observed that twenty percent of the FDP participants methodically incorporated these pedagogical aspects in their teaching practices. Experiences of the faculty members in terms of the three principal thrusts of the FDP: (i) constructing learning outcomes, (ii) adopting active and cooperative learning methods and (iii) implementing formative plus summative assessment strategies are analyzed to understand how they implemented these thrusts through pedagogical approaches appropriate to the IIT-M ethos, which is characterized by a large student population of diverse socio-economic-cultural backgrounds. Also, issues related to varying set of instructions to a diverse group of students are identified and possible solutions are discussed for further action to sustain the TLC activities for the benefit of the teaching-learning process in IIT-M.

Key words: faculty development program, teaching learning center, course delivery cycle, engineering and science education

Introduction

Today, amidst research findings on learning and increasing expectations of tertiary education graduates, assertions that faculty members in higher education teach how they were taught continue to summarize classroom observations around the world[1,2]. Content delivery via lecture continues to be the mainstream teaching approach, despite calls for a significant paradigm shift from "teacher centric passive delivery" to "learner centric active learning"[3,4]. To accelerate the paradigm shift, Faculty Development Programs (FDPs) are fast becoming an integral part of initiatives to enhance faculty advancement with respect to teaching[4-6]. Further, FDPs have been shown to influence the willingness of participants to adopt more "learner centric active learning" teaching approaches[7-10]. Some of the successful models were developed in engineering[8,11].

In India, initiatives for "teaching pedagogy" and curriculum development for school education have existed since the 1960s. There have been formal courses for teacher education culminating in degree programs like Bachelor in Education and Masters in Education offered by several universities and institutions and considered essential for teacher recruitment in schools. Since 1960s, bodies like the National Council of Teacher Education (NCTE) and the National Council for Education Research and Training (NCERT) have also been playing a significant role in building teaching capacity and curriculum development. More recently, roles for distance education and information communication technologies (ICT) in teacher education are being explored. Establishment of several National Institutions of Technical Teachers' Training and Research (NITTTRs) has paved the way for quality improvement of technical education at diploma/polytechnic level. The general consensus is that they have provided good results. However, there is a lack of well-structured FDP for engineering and technology education in India. In the higher engineering and technology education sector, the idea of the FDP remained neglected possibly due to twin perceptions: (i) a philosophical belief that this activity belongs to social scientists and is less relevant to engineering educators, and (ii) "hard disciplines [e.g., engineering] place greater importance [than soft disciplines] on student career preparation and emphasize cognitive goals such as learning facts, principles and concepts [i.e., content]"[12]. A large percentage of engineering faculty members still believes that "subject knowledge" is the only criteria for becoming an effective teacher in engineering institutions.

Emergence of for-profit employers in faculty development

During the last decade in India, major employers of engineering graduates have observed in their recruitment drives that while thousands of students graduated with an engineering degree, only about 20% or less, were really "employable" directly. An analysis revealed that the root cause of this lack of "quality graduates" was the paucity of "trained" teachers, who are expected to ensure "quality" education. Consequently, major for-profit employers have initiated programs in faculty development. For example, WIPRO Technologies has initiated well-designed programs, e.g., Mission10X, for training engineering college teachers with respect to pedagogical aspects of the teaching-learning process. Infosys Ltd has actively participated in the Indo-US Collaboration for Engineering Education (IUCEE) program. Both Mission10X and IUCEE focus on faculty development across the engineering programs in India. However, training engineering college teachers across the large number of engineering programs in India is a huge task that requires multiple efforts across the diverse engineering disciplines.

Changes in the context for engineering education in India, e.g. greater diversity in backgrounds and preparation of the students entering engineering education, greater numbers of engineering programs, more alternatives in technologies for content delivery[13], and research findings on how people learn[14,15], have catalyzed dialogue about teaching-learning processes. Significant changes required in the present system for evolving the right mix of solutions to enhance the efficiency and effectiveness of teaching-learning process warrants a focused and dedicated effort in the creation of content and its delivery, pedagogy, and effective student-teacher interaction.

Generating Initial Interest in Faculty Development at Indian Institute of Technology-Madras

At the Indian Institute of Technology-Madras (IIT-M), similar to other institutes of higher engineering education in India, undergraduate and graduate teaching is a core activity and considerable faculty time is spent on teaching the growing population of students from diverse academic, socio-economic, and cultural backgrounds. In all the Indian Institutes of Technologies (IITs), effective teaching has been posing a challenge. The following are some of the systemic reasons for this:

- Current emphasis on content (curriculum and syllabi) and content coverage (instruction-centered teaching) as opposed to what students have learned and their preparation for future learning (learner-centered teaching). Issues of content coverage, particularly when an alternative approach to teaching is the topic of conversation, are raised across disciplines[16-19]. In *Teaching Tips*, a well-respected book on teaching, now in its 13th edition, the authors write "Although it may seem irrational to cover material when students are not learning from it, one should not underestimate the compulsion one feels to get through one's lecture notes"[20].
- Summative assessment is accomplished almost exclusively through timed, closed-book (with occasional open-book) examinations.
- Feedback from employers (mentioned above) about their expectations for engineering graduates and faculty intentions about the knowledge students will learn in an engineering program appear to be disconnected in several key aspects.

In addition to teaching, IIT-M faculty members are expected to be active also in research and/or consultancy in their area of expertise. Multiple expectations and uncertainty about priorities among these expectations have made it hard for faculty members to determine appropriate emphases with respect to development of their teaching. Some of the implications for these multiple expectations and uncertainty about priorities among these expectations include the following:

- Expectations for quality with respect to teaching (and research) have been emphasized in a limited manner through the annual Young Faculty Recognition Award, but consequences for failure to meet these expectations are not defined.
- Faculty members have not kept pace with research and development in teaching and learning. Part of the challenge is that research findings in teaching and learning are spread across multiple disciplines, e.g., psychology, education, cognitive science, neuroscience, and sociology.
- Time-efficient ways for members to learn about research and development in teaching and learning and then design approaches to incorporate these findings into their teaching have not been offered.
- Faculty members perceive reduction of motivation among students for learning, which may have been caused by the systemic shortcomings

Under the circumstances, it is becoming increasingly difficult for teachers to motivate students to concentrate on understanding the basics in a subject and sustain their interest in problem solving for attaining higher learning levels. A formal process of student feedback at the end of the semester has been one mechanism in place at the IITs to evaluate the course as well as the teacher. It is felt that in the absence of a formal exposure to the teaching-learning processes, this feedback serves only a limited purpose to judge the feedback in terms of style of teaching/content of the course material/delivery without ideas for possible improvement strategies. This realization called for a structured FDP at IIT-M for familiarizing faculty with the pedagogy and other skills concerning effective teaching-learning processes.

Initial Faculty Development Programs at IIT-M

The idea of the FDP at IIT-M emerged from conversations among faculty members who strongly felt the absence of knowledge of teaching and learning in planning of their courses. Faculty conversations about teaching and learning were complemented by simultaneous conversations among the IIT-M administration with experts in faculty development from Texas A&M University. From conversations within the administration emerged a conviction that assistance in faculty development was needed. IIT-M faculty members needed access to state-of-the-art, research-supported findings on teaching and learning. Research-supported findings would facilitate acceptance of these finding by IIT-M faculty members. Since there was a lack of this expertise in India, IIT-M decided to seek faculty development expertise from abroad. From these parallel, synergistic sets of independent conversations, among faculty members as well as administrators, emerged a decision to implement a FDP at IIT-M.

With joint faculty and administrative support, the first ever FDP at IIT-M was held in December 2009, facilitated by a team of three experts from Texas A&M University. Thirty-two (32) entry-level faculty members, mostly from the science and engineering departments, voluntarily participated. Feedback from participating faculty at the end of the program was quite positive. Constant post-FDP interaction among the participants generated great enthusiasm for implementing the ideas presented during the program in their courses. Thus some of the faculty members used a course delivery cycle (i.e., prepare course learning outcomes, design a course assessment plan, design learning activities, evaluate student learning, prepare revisions for the next time the course is taught) for implementation in their respective courses in the following semester and systematically implemented their newly learned teaching strategies.

Faculty members who applied approaches from the FDP also nucleated to form a “core” team that met to continue regular discussions on pedagogical teaching strategies based on their day-to-day classroom experiences. Periodic meetings among the core team members resulted in a consensus to conduct a FDP for engineering college teachers, not from IIT-M, who are studying in IIT-M for their higher degrees under a nationally-sponsored scheme called the Quality Improvement Program (QIP). The core team organized this event, which was attended by 24 participants, during August 2010. This event provided an opportunity for the core team members to apply their insights acquired during the 2009 FDP to develop teaching methodologies appropriate to Indian contexts and adapt their “teaching pedagogy” accordingly. The core team increased their self-confidence in conducting their own FDP.

The overall experience gained in the QIP was put to practical use in the organization of the second FDP held for IIT-M faculty members in December 2010 in collaboration with the Texas A&M team. The IIT-M core team members contributed to the program by sharing their experiences of implementing the teaching-learning processes. After the second FDP, some more faculty members joined the core team and planned another FDP for a fresh group of 24 engineering college teachers on deputation at IIT-M during August 2011. Based on feedback of the second QIP participants, the program was quite successful.

Development of Teaching Learning Centre (TLC)

These FDPs conducted at IIT-M on teaching and learning created enthusiasm and awareness on the significance of such programs which generated interest in fostering further faculty development activities to make them sustainable. During the processes of organizing the FDPs at IIT-M, some of the core team members were invited to other government and private engineering colleges to demonstrate teaching and learning methods to their teaching faculty. This exercise provided an opportunity for core team members to develop their ability to conduct such programs. The core team members also availed themselves of opportunities to attend national meetings on education related topics where teaching pedagogy was the focus. In these meetings, the experiences of new teaching methods for enhanced learning implemented at IIT-M were presented as a model for emulation at other Indian universities.

This core group of about 15 faculty members from among the participants of the 2009 and 2010 FDPs gradually evolved into a strong, cohesive and committed group that recommended establishment of a Teaching-Learning Centre (TLC) dedicated to overall enhancement of teaching-learning processes at IIT-M. From their initiative and with the full cooperation and support of the leadership and administration, the Centre was founded in August 2011.

The Vision of the TLC is to **be a Centre of Excellence and Innovation** in teaching-learning processes for a new and sustainable paradigm in higher technical education with the highest professional and personal qualities at the service of the nation. The Mission of the Centre is:

- **To foster** implementation of research-based, scientifically-proven, and innovative teaching–learning methodologies /technologies across IIT-M
- **To motivate** teachers and students towards an efficient and enjoyable educational interaction
- **To develop** a pool of world-class educators
- **To address** issues in the broader spectrum of education based on resources ranging from our philosophical heritage to modern psychology
- **To facilitate** a productive educational environment
- **To create** synergy among teachers, students and experts by facilitating continuous and seamless interaction
- **To instill** respect and love for life-long learning

The third FDP was held during December 2011 by the TLC wherein the core team members made substantial contributions in the planning and session delivery along with an expert from Texas A&M. Following that event, a one-day program for ‘Training-the-Trainers’ was also conducted by the Texas A&M expert. The participants were primarily IIT-M faculty members who participated in the core team. Topics for the workshop were (i) scaffolding, (ii) seven principles from *How Learning Works*[15], (iii) metacognition, and (iv) transfer. The Texas A&M expert also conducted "microteaching" consulting sessions. For each session, an IIT-M faculty member who volunteered would video-tape segment of a classroom meeting. The faculty member and consultant would meet for one-hour conversation to talk about observations and ideas based on the video. This was highly appreciated by the participants.

Data Acquisition and Analysis

In order to analyze the impact of the various FDPs conducted in association with Texas A&M, feedback from the ninety participants of the FDPs was requested to have a database to facilitate future activities. One-fifth of the FDP participants responded to the questionnaire that asked:
(a) To what extent had participants incorporated learning outcomes for their courses and reflections about applying learning outcomes in teaching–learning processes?
(b) To what extent had participants incorporated 'active and cooperative learning methodologies' and reflections on its application?
(c) To what extent had participants designed an assessment plan for their course and reflections about its use?

One fifth of the faculty responded to the questionnaire. The following paragraphs illustrate how various ideas that were emphases of the FDP were being applied by participants:
(1) Learning outcomes
(2) Active and cooperative learning
(3) Assessment
(4) Minute papers.

(1) **Learning Outcomes:** All faculty members who responded have attempted to write learning outcomes (LOs) for their courses and shared them with the students at the start of course. This suggested that respondents thought the discipline of learning outcomes was appropriate and valuable for their courses. It also suggests that survey respondents were not representative of the 90 FDP participants; instead, it suggests that only FDP participants who were applying some of the ideas from the FDP responded to the survey. LOs for 20 courses [undergraduate (UG), post graduate (PG), and mixed students group (7 UG, 7 PG, 4 mixed and 2 doctoral)] were available from this feedback. Most faculty members stated that writing LOs helped them prepare course content, delivery and assessment plans. Typical examples of LOs written by faculty members are provided in the Appendix.

Twenty faculty members using learning outcomes in their courses suggests that a paradigm shift in teacher preparation for the course is occurring. Student anecdotal responses to these changes, mostly collected orally by the faculty members who responded to the questionnaire, suggests that although a large number of students were positive, a fraction of students were indifferent. Interestingly, there was no negative feedback on LOs from any of the students. Some of the faculty members took the opportunity to explain the purpose of LOs to the students in their very first lecture; and student responses suggested they appreciated faculty efforts to bring in positive change in teaching–learning processes.

(2) **Active and Cooperative Learning:** During the FDPs, the faculty participants were introduced to various active and cooperative learning (ACL) methods[21]; think-pair-share[22],

bookend lecture[23], e-techniques, projects, and jigsaw[24]. The most common methods that faculty members used were the bookend lecture and project methodology. However, some faculty members tried e-techniques and the jigsaw method in their courses. Anecdotal/oral feedback from undergraduate students indicated that the project mode proved more effective in motivating students' learning. The group discussion method, wherever tried, was hindered by the classroom seating arrangements that are classic students-in-rows-facing-a-lectern types. This arrangement makes it difficult for faculty members to move around the classroom and observe students interacting. In a self-study course for a class of 15 senior-level students, a faculty member used the jigsaw method successfully and students were positive about its application. The class was divided into 5 groups and each group was assigned a portion of the course material. Students worked in the group to learn the material assigned and each student prepared notes for his/her sub-portion and conducted lectures for the rest of the class. In this manner, each group became an expert on one topic and helped the others learn that topic. The performance of the students in the final exam for this course was significantly better than that for the traditional classroom version. More material could also be covered in this format where the students took responsibility for their learning.

In large undergraduate classes of about 80 students, student feedback indicates that the use of teams for tutorial sessions fosters a positive learning experience. In these sessions, the instructor and one or two teaching assistants are present to answer questions but the students are able to work in a largely self-sufficient manner within their groups. Despite competitiveness inherent in students at IIT-M, it emerged that students are interested in and find it fruitful to be a part of a learning group where they share the knowledge among their peers rather than being passive learners.

(3) **Assessment:** From responses received, it is evident that changes in assessment procedures from what is usually recommended in the IIT system have not occurred. Factors that hinder this shift are the large classes and the lack of trained TAs who can reduce the additional workload (or its perception) on the instructor that formative assessment may require. The usual assessment pattern uses a summative assessment procedure that consists of two periodical quizzes during the course and an end-of-semester examination. However, some faculty members enthusiastically used minute papers[25], quizzes through Moodle software, and assignments without marks as their formative assessment procedures. Oral feedback from students reveals that they liked formative assessment, whenever tried by the teachers, and thought it led to improved performance in examinations.

(4) **Minute Papers:** Faculty experiences with using minute papers clearly suggest that there is a definite lack of interest among students in writing minute papers at the end of each class. To overcome this difficulty, some faculty members planned a schedule of receiving the minute paper at the end of a topic, instead of at the end of each teaching session. This has been a new feature in the Institute and requires planning and adaptation time. One instructor, who collects feedback at the end of each course using a questionnaire, found that even in classes where the students did not regularly turn in minute papers, they indicated that it was a useful instructional technique because they felt they could exercise the option whenever they felt the need. This instructor found the minute paper very useful, not only for dealing with fuzzy topics in a timely manner but

also because it generated some thought-provoking questions from the students, some of which she then included in assignments or tests.

The survey results indicate that writing LOs for courses assist faculty in content preparation and assessment planning. Systematically introducing ‘breaks’ in the lecture, involving students in cognitive activities appropriate to the lecture content seems to have a great impact in the learning process and is appreciated by the students. The minute paper was attempted as a formative technique with limited success due to the lack of enthusiasm from students and their lack of awareness about positive impact on their learning. More efforts are required to sustain enthusiasm among students regarding minute paper feedback.

Collaboration

The collaboration between IIT-M and the Texas A&M has proven to be very successful. It should be noted that IIT-M (like other Institutes in the country) did not have much knowledge about research on learning and teaching, and little experience in organizing FDPs to enhance the teaching-learning processes. A few of the faculty members who joined the Institute in the past few years had been exposed to “effective teaching” programs while doing their doctoral work abroad, mainly in the US universities. But their limited experience could not be transformed into a sustainable Institute-wide program. The Institute needed education experts with research and teaching background and practical experience in organizing FDPs to enthuse and excite the IIT-M faculty members, especially the new faculty who will serve the Institute for the next 30-35 years, to learn and practice proven teaching pedagogy. The experts from Texas A&M, in less than three years of on-going interaction, have addressed this need. They have greatly impressed the IIT-M faculty with their knowledge, experience and ability to communicate, and established a rapport with the young faculty members of the Institute. The collaboration has truly laid a strong foundation for the sustainability and success of the TLC efforts in enhancing FDPs at IIT-M.

Immediate Upcoming Programs

The TLC core team has recognized the importance of disseminating its knowledge and experience acquired over the last three years to larger groups and hence a FDP will be conducted for engineering college teachers shortly. This will be the first such program by IIT-M. Also the core team will organize a Training Program for thirty IIT-M teaching assistants, many of whom are likely to become faculty members and influence teaching–learning processes on their own. Based on the experience of the last three years, the TLC core team was emboldened enough to organize a training program for engineering college teachers to improve their self-awareness and realize higher goals in education, and will repeat this program in June 2012.

Conclusion

The collaboration with education experts from Texas A&M University has proven fruitful for IIT-M in (i) generating awareness and interest in “teaching methodologies”, (ii) preparing approximately 90 faculty members through a three-day FDP, (iii) developing a core team of about 15 dedicated faculty members committed to take the process forward, and finally (iv) enabling the establishment of a Teaching Learning Centre, arguably the first of its kind in the institutes of higher engineering education in India. Support from the IIT-M leadership is essential for the success and sustainability of the FDPs. There is a realization among IIT-M faculty members who have attended the FDPs that practicing the new teaching methods would enable them to don a new role as 'learning facilitators' rather than the traditional role of 'knowledge providers', which in turn would enhance students' preparedness to take their cognitive activities through higher levels of Bloom's taxonomy[26]. On the other hand, the very fact that only 20% of the total number of FDP participants responded to the feedback regarding the impact of FDP on their teaching indicates that many faculty members might lose, over the course of time, the initial enthusiasm generated while attending the FDP. It is realized that systematically planned follow-up meetings and constant interaction among the participants, through the newly formed TLC, is essential to sustain their enthusiasm and motivation to take forward the pedagogical approaches in teaching-learning.

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Appendix: Learning Outcomes for Selected Courses Designed by Faculty Members Who Attended FDP

CE 4410: Structural Masonry (Undergraduate Course, Instructor: Dr. Arun Menon)

	Topics	**Learning outcomes**
1	**1 Introductory lecture** Overview of masonry in ancient and modern times; Standards; Structural-functional requirements	• To ***list*** historical and modern masonry materials • To ***trace*** development of masonry structures • To ***define*** structural/functional design requirements • To ***list*** relevant codes
2	**Masonry materials and assemblages** Properties and experimental testing (masonry units, mortars, grout, reinforcement and assemblages)	• To ***list*** test methods for masonry materials • To ***estimate*** strength and durability parameters and to compare with code requirements • To ***compare*** different code requirements • To ***identify*** parameters affecting strength and durability
3	**Behavior of masonry assemblages** Axial compression, flexure, shear and combined loading, deformation characteristics	• To ***describe*** the failure mechanisms under different types of loads • To ***identify*** mechanical properties influencing behavior under these loads and list respective experimental tests • To ***determine*** strengths under failure modes
4	**Design/analysis of masonry members** Design for axial compression (concentric, eccentric); Flexure design of walls; P-M interaction, Shear wall design; beams, lintels, arches, pilasters - Unreinforced, reinforced, pre-stressed masonry; codes.	• To ***compute*** loads/combinations • To ***determine*** load capacities of structural members, estimate stresses • To ***develop*** and use an interaction diagram • To ***dimension*** members, ***determine*** percentage of reinforcement • To ***summarize*** in a technical report and ***identify*** strengths and weaknesses of research
5	**Constructional aspects**	• To ***identify*** construction methods/practices that affect strength/durability of masonry
6	**Design of masonry buildings** Single-story, multi-story load-bearing structures	• To ***identify*** critical design features • To ***estimate*** the design loads/combinations • To ***dimension*** and ***detail*** different structural components • To ***propose*** design alternatives

CY5540: Introductory Biochemistry (Postgraduate Course, Instructor: Dr Nandita Madhavan)

- **Identify** the thermodynamic and kinetic parameters that affect a reaction
- **Explain** the effect of the reactant and reaction conditions on the reaction outcome
- **Propose** reasonable mechanisms for organic reactions
- **Develop** experiments to support your hypothesis
- **Recognize** basic and 3-dimensional structure of biomolecules such as carbohydrates, lipids, proteins and nucleic acids
- **Associate** biological activity of biomolecules with their 3-dimensional structures
- **Illustrate** the various metabolism pathways in the body
- **Predict** enzyme catalysis mechanism based on structure.

- **Distinguish** between various pathways of enzyme action

ME1100: Thermodynamics (Undergraduate Common Core Course, Multiple Instructors)
The student should be able to:

- **Formulate** a system or control volume type analysis in practical energy conversion problems and **apply** energy/ mass balances correctly
- **Represent** various energy conversion processes using thermodynamic state diagrams
- **Estimate** property changes in substances through appropriate property relationships or property tables
- **Evaluate** the ideal and actual performance characteristics for various devices/ processes, by applying I and II laws of Thermodynamics.

EE1100: Basic Electrical Engineering (Undergraduate Common Core Course, Multiple Instructors)

- **Define** different electrical quantities like potential, current, field, power etc. and derive one from the others whenever possible
- **Identify** circuit components (R,L and C) and identify different configurations in which these components may be connected to each other in a circuit
- **Describe** the fundamental physical laws governing the electrical quantities in DC & AC electrical circuits, DC & AC electrical machines and electronic devices
- Systematically **apply** these laws to simple/moderately complex problems to solve for unknowns like currents, voltages, impedances, speed, torque etc.
- **Plot** these solutions for different values of other known circuit parameters and arrive at a trend
- **Use** the solutions/plots to reason the working of an electrical system and distinguish between what is a logical or absurd result
- **Apply** all of the above background to design a circuit for simple specified functionality
- Over a period of time, **develop** an intuition towards elementary analysis of electrical systems
- **Apply** this intuition and reasoning to observe and question the world around you (outside of the class)
- **Communicate** objectively with peers and other electrical engineers about your observations

CE 3040: Environmental Engineering (Undergraduate Course, Instructor: Dr Indumathi Nambi)

- **Define** water and waste water quality parameters and list the permissible limits set for each of them.
- **Identify** the appropriate treatment technology for water and waste water based on the quality of inlet water
- **Design** water treatment and wastewater treatment units