A Research Oriented Undergraduate Curriculum: Design Principles and Concrete Realization

Rajeev Sangal
International Institute of Information Technology
Hyderabad, India
sangal@iiit.ac.in

Abstract

A curriculum to support undergraduate research requires that the student should be able to identify an area and pursue it. To make it possible, a radical restructuring of the conventional curriculum is required. It has to provide for flexibility in choosing courses at an early stage, rescheduling of even the core courses, early exposure to skills, and layered learning through practice-theory-practice. This has been accomplished successfully at IIIT Hyderabad; fortunately, without any substantial reduction in breadth – whether in the sciences or the humanities. Outcome has been better educated students with broad outlook, and a questioning mind. It has also led to the creation of large research groups with critical mass and critical continuity, in the institution.

Curriculum making is always a difficult exercise – with much material to be covered in a limited period of time. However if the goals and the overall direction is clear, it helps in making curricular choices. Here, we describe the design of a curriculum to support undergraduate research in Computer Science and Engineering (CSE) and in Electronics and Communications Engineering (ECE). Such a curriculum has been implemented and is in operation at IIIT-Hyderabad. We discuss what choices need to be made for a research oriented undergraduate curriculum, and as an illustration, how these choices were implemented at IIIT Hyderabad in case of CSE and ECE.

1. Goals of Education

The goal of the UG program in engineering is to produce students with three qualities:

A. Analytical ability (ability to analyze given situations),
B. Building ability (ability to design with creativity), and
C. Caring and character (sensitivity to others and courage to act on one's beliefs)

These are the ABC of education. They are not to be construed in a narrow disciplinary sense, but in the widest possible context of life and living. A and B pertain to "how to do" and C pertains to "what" and "why" of life.

They include learning of skills and concepts in the discipline and allied areas, understanding of society and the individual in the larger social context, development of sensitivity towards other human beings and nature, and the ability to feel and reflect about oneself.

Certain meta-skills are also very important, for example, learning to deal with unstructured situations, ability to empathize, communicate, and learning-to-learn. Since this paper is about curricular design and not about the goals and their inter-relationships, a discussion on these aspects is left for another time and place.

2. Research Orientation and Human Qualities

Many students, when they enter engineering, are full of enthusiasm to understand new areas, to build systems and to experiment and play with them. For some, it might be a passing fancy but the real question is whether this enthusiasm can be tapped so that it leads to exploration and sustained pursuit by the student. If nurtured, what can follow is the development of a deeper interest in the chosen area or topic of study.

The curricula of BTech programs in CSE and ECE at IIIT Hyderabad were designed, in part, to capture this enthusiasm of the student at an early stage, and channelise it towards research right at the undergraduate level.

It is also recognized that it is not sufficient for a student to be good in a narrow area of study, but there must be a multifarious development of human qualities in his personality. If one keeps this as an equally important aspect, several new elements become a part of the curriculum.

In fact, the pursuit of the above two aspects (research orientation and human qualities) should not be carried out in an isolated manner, but in a closely intertwined manner. Research orientation cannot stand on its own without the student receiving a larger view of life and society, and gaining an understanding of human aspirations, social good, and enrichment of nature.

3. Guiding Principles for Research Orientation

The curriculum should encourage the creative expression of the student in the areas chosen by him or her in the light of the goals of the institution. For example, students entering engineering studies in a research oriented technology institution, should be encouraged to do research and undertake design. In fact, many students join such an institution with the enthusiasm to learn about technology and build things. One should be able to capture this enthusiasm and lead the student in fulfilment of his or her dreams. It would also indicate to the student that the fulfilment of dreams also requires hard work, and that it can be a journey of joy.

3.1 Catching the Enthusiasm – Can I Build a Talking Robot Here

If a new student asks whether he can build a robot or a talking machine or a wireless network, we should be able to answer him or her as yes (provided, of course, there is faculty in that area). If the student further asks when can he start, we should be able to answer now, and most importantly, draw a step by step plan for the student to purse his or her passion. This would require project work in conjunction with relevant courses. The curriculum should come in support of such a plan. It would mean the ability to schedule relevant courses to aid the research passion.

And here lies the curricular challenge. Different students might want to pursue different areas and therefore may have to do different courses. Different courses will have their own pre-requisite requirements. How can the curriculum support courses in many different areas at an early stage? The only way out is to build flexibility in the curriculum and to structure it suitably. Therefore, the challenge is to provide the student with flexibility in scheduling courses and yet satisfy the pre-requisite chain of courses! This challenge was effectively solved in the curriculum design at IIIT-H, and the important elements in the solution are given below.

3.2 Layered Learning – Practice–Theory–Practice

To develop a good grasp of the subject in the student, usually the theory is taught and the student is asked to apply it in diverse settings. This is done thru home assignments within a course. When done well, it develops good analytical ability among the students. Usually this is what distinguishes the good institutions from others.

However, this is not sufficient to develop a “deeper” understanding. Such an application of the theory when done only through home assignments and exercises, takes place in narrow contexts and does not develop problem solving ability in real life wherein one has to apply the theory covering topics spanning many different courses. One way to address the above is through projects as part of courses as well as independent projects in the curriculum. Perhaps, all universities have the final year BTech project, but it is too little, too late. Theory and practice should come in layers, several layers within the 4-year curriculum.

To develop the design and synthesis ability, the above is not enough. It is also important to learn to deal with unstructured situations. It should develop intuitions and creative ability. One way of achieving it is to reverse the theory and its practice and move to practice and then theorize, in other words, to explore through practice and follow with theory. One should expose the student to problem areas, ask them to apply their mind to come up with solutions, without waiting for the theory to be taught. There is another benefit in this approach. When the student learns theory later, he or she is able to appreciate the importance of concepts because he or she has already implemented or built things and has felt the need. (This matches with the urge in today’s youth to ask “why” before doing or learning anything. The practice helps provide such a question naturally. The courses or theory provides the answer.)

At IIIT-H the principle of layered learning has been adopted and the curriculum is designed accordingly. It implements both the idea of layers and the idea of developing intuitions through practice-theory–practice.

3.3 Skills Imparted Early – Using Power Tools

A very important part of layered learning in practice-theory-practice is to impart skills. These skills allow a student to build things based on imagination. Accordingly, special sequence of courses were designed at IIIT-H called IT Workshop and EC Workshop courses which allow a student to do rapid prototyping using software tools and hardware platforms as the case may be. For example, a sequence of 3 courses in software tools and scripting in the first three semesters of BTech in CSE, introduce the student to scripting, Unix utilities, socket programming, database access, graphic user interfaces, software systems analysis & design etc. And this is before they have done a full-fledged course on computer networking, database management systems, user interfaces and software engineering. In the third course in the sequence (in the 3rd semester), every student does a project – usually building a complete end-user application. The entire faculty, and not just the course instructor(s), participate in providing and guiding the projects. The experience is thrilling for the student, in building a life like application and see it work. Ability to solve real life problems through skills (to use tools and power tools) creates a great sense of empowerment in the student.

There is a sobering side as well. Many students get a feel of limitations of the systems they have built. Their attention is also drawn to a need for concepts. Later on when they do the proper theory courses (for example, in computer networks, DBMS, user interface, software engineering and compilers, etc.), they appreciate the relevance of theory, and see at least the direct need of some of the concepts (e.g., synchronization, normal forms of data, automata, etc). This acts as a motivation to learn theory, in general.

These layers are repeated in the overall academic setting. When the students do the next layer of practice, the learning is deeper and more intense, and so on.

3.4 Flexibility in Curriculum – Lean Core and Flexi-Core

It has been mentioned earlier that a research oriented curriculum requires space for elective slots during the early years. There are two ways to achieve this, and perhaps both can be pursued while making the curriculum.

First, the set of compulsory courses should be “lean”. Before deciding to put a course in the core or among the required courses, it should be carefully evaluated whether it ought to be there. Considerations for required courses are many, ranging form disciplinary integrity to pragmatic needs, but the core must be kept lean.

Second, one needs to bring in the concept of flexibly scheduled core (or flexi-core, in short). Flexi-core consists of required courses, but which can be scheduled flexibly by the student, particularly by those students who wish to pursue a research stream. In CSE for example, Database Systems, Computer Networks, Compilers, Artificial Intelligence etc can be classified as flexi-core. While they would have a recommended place in the curriculum schedule, they can be postponed or preponed by the student to be able to do a relevant course for the research stream at an early stage. For example, a student wanting to do research on distributed systems, can take up courses on queing theory and advanced operating systems between 4th to 6th semester, and delay the flexi-core courses on Artificial Intelligence and Compilers to later semesters. Similarly, a student wanting to work in Natural Language Processing can take AI and Linguistics courses early, and delay DBMS and Computer Networks.

3.5 BTech (Honours) - Beacon Lights for Research

A student interested in doing research in an area or stream within the undergraduate program must realize that it requires adequate preparation in terms of course work, self reading and focused work. To make all this visible to the student and then to recognize those students, who successfully complete it, a special degree is given called BTech (Honours). As a part of the degree, the student is required to choose a stream to register for project credits from 5th to 8th semester. He is also required to do stream courses from 5th to 7th semester which help in building the requisite background along with the projects. (For a list of streams and the courses that constitute it at IIIT-H, see Appendix 1.)

Thus, the curriculum opens out to support a student interested in pursuing an area. It allows him or her to pursue courses relevant to his or her research area at an early stage, and postpone other courses to later.

For the BTech (Honours) degree, there is an additional academic requirement of doing projects (worth 8 credits or 2 course equivalent) beyond what is required of all BTech students. This is rightly so, as it requires the students to put in extra efforts for a coveted degree.

3.6 Addressing Student Concerns – Making it Work

While the above issues are the key to implementing a research oriented curriculum, there are some practical factors that need to be handled. First, while a student might be willing to postpone some flexi-core courses, he should not feel handicapped because he has not yet learnt the requisite skills which one's peer would have learnt. Besides, some of the skills might be required to build prototypes for one's own research. The separation of skill based workshop courses (already described in section 3.3) play a crucial role in addressing such a student concern.

Second, for the student to choose a stream intelligently, suitable exposure needs to be provided. (Even though the student has made a much bigger choice of a branch at admission time with much less real information, our attempt here is to provide some real exposure and experience for making a more informed choice.) This is accomplished by making it possible for the student to take a first course in his or her stream right in the 4th semester. If the student has not decided on his stream area, he or she can try out first courses from a couple of streams. This provides a semester long exposure to the student about the area. This practically means that in the curriculum there should be at least two elective slots or more in the 4th semester.

The summer internship after the 4th semester provides yet another exposure to the area or stream to the student, this time on doing a project in the area. So when the student makes a formal choice of the stream at the beginning of the 5th semester, it is based on some real experience.

Third, the curriculum for BTech (Honours) is a strict superset of the BTech curriculum. If a student in BTech (Honours) feels that he or she has made a wrong choice of area or does not wish to be in the research stream, he or she can always come out of it and stop doing the extra work. He or she still qualifies for the normal BTech degree.

At IIIT-H, it has been seen that 30-40% of the BTech students opt for BTech (Honours). Seldom do they drop the option.

4. Convergence of CSE and ECE – Circuits and Programs

Increasingly today, a software engineer needs to understand the hardware device, and the hardware engineer needs to understand and write software. A number of new developments in hardware and software co-design are expected to bring the traditional CSE and ECE even closer together in the future.

The curricula for BTech in CSE and BTech in ECE need to be brought closer together. Even if total convergence may not come about, certain courses are prime candidates for initiating convergence and can be made a part of the core. For example, CSE core curriculum could include Digital logic[1], Basic Electronic Circuits and Signals & Systems, and ECE core must include Programming, Data Structures and possibly Discrete Mathematics. This would make it possible for the students to take relevant advanced courses across disciplines with relative ease.

4.1 Making Convergence Work – Flexi-Core to Bouquet Core

Here comes another difficulty. If the new material in the convergent curricula, has to be covered, which is as much as two to three courses, the curriculum becomes too packed with compulsory courses. In other words, the core becomes fat and starts crowding out the space for electives.

And without early electives, (as early as in the 4th semester), the research oriented curriculum would not work. Thus, convergence can elbow out the research orientation.

The answer to this is to introduce bouquet core. Like flexi-core, the bouquet core courses can be scheduled flexibly by the student. However, unlike the flexi-core, not all courses in the bouquet core need to be taken. Doing a limited number (say, 6 out of 10 courses) is sufficient. It is based on the philosophy that if a student does the substantial majority of the bouquet core, the parts not taken by him or her either get covered thru peer learning or are left for self-learning. One has to resist the temptation of teaching too much!

During the major revision of its curriculum in 2008, IIIT-H went from flexi-core to bouquet core.

[1] A new course called Digital Logic and Processors, as a part of convergence, is now taught to students of both CSA and ECE at IIIT-H. It replaces the Digital Logic course.

5. Breadth in Science and Engineering

We have discussed so far on the research orientation in the context of the discipline (CSE or ECE). This section focuses on imparting the breadth of knowledge in science and engineering. In fact, research orientation could also be developed in the breadth.

5.1 Science Courses – Understanding Mysteries of Nature

The natural science courses impart a breadth of knowledge to the student. They not only help the student gain an understanding of nature but also illustrate how one can think and reason about the mysteries of nature along with an exposure to methods and techniques used.

The student should get an integrated view of understanding nature. Early partitioning, through separate courses in Physics, Chemistry and Biology affects such an integrated view adversely. Science should come as an integrated whole. Integrated courses, if suitably designed, develop a holistic view, while at the same time being rigorous.

5.2 General Engineering – Complex Systems

Courses in general engineering should give a flavor regarding other engineering disciplines to the student. They would show how simplifying assumptions are made in dealing with real life engineering problems. Domain knowledge is imparted to give the student an understanding of a different kind of problem solving from science.

Over the years, mankind has attempted to build complex systems through engineering, they span large geographical area, or high density networks on micro devices. Plethora of inter-dependencies among different aspects have to be taken into account in the design, building, and maintenance of complex systems. Examples are urban town planning with spaces for living, work, outdoors, education, health, entertainment and logistics; river water basins with man made dams and micro water sheds; electric grids with mega power plants, connected to large number of loads with complex monitoring for efficiency or robustness; etc.

Role of computational models in design, running, and repair of complex engineering systems has become crucial today. It is important to convey computational aspects with the domain knowledge.

IIIT-H has introduced “integrated science” courses and course on “complex engineering” as core course for all students of CSE and ECE. Computational aspects are given special emphasis.

An interesting aspect of this curricular design is that the research orientation which brings in depth in a chosen area of CSE or ECE does not entail cutting down breadth in science and engineering in a substantial way. The depth is achieved by early scheduling of relevant courses in the area within CSE or ECE rather than by cutting breadth.

It is also possible for the interested student to choose a stream in a computational domain area. At IIIT-H, computational domain streams are Computational Natural Science, Bioinformatics, Spatial Informatics, Intelligent Buildings, Computer Aided Structural Engineering, etc[2].

6. Humanities – Life and Living in Society

As the students come into engineering, more narrowly focused then ever before, both in their interests and training, it has become imperative to strengthen the Humanities course offerings.

The humanities courses provide understanding regarding the human being and the society. They could be offered in such a way as to relate to contemporary issues in life and society, rather than as disciplinary courses. For example, they could draw the attention to human sensibilities through art, literature, and human values. They can also try to connect the student to the larger social context.

Humanities projects is another way to bring studies in humanities close to their lives. These may include visits and surveys of nearby communities. Reading courses by which a student reads classics during the summer could also be started.

Six courses or about 15% of the curriculum at IIIT-H is devoted to the Humanities. Course offerings vary from art, dance literature (in Hindi, Telugu and English) to courses in sociology, work and life, political and economic thought, education, philosophical thought (e.g., Indian and Greek thought), dharma and constitution, non-violence, humane society, etc.

Great emphasis is placed on the Humanities. Its importance is brought out to students at IIIT-H at every major opportunity by the university's leadership. As a result, students and alumni with engineering background have started joining PhD in Humanities (though small in number).

6.1 Human Values and Self – The Human Core

Courses in sciences and engineering are externally oriented as they study nature or how to engineer. Most courses in Humanities today have also become externally oriented - where they study society or its aspects as an external object. The emphasis in such courses is on analysis and/or building, artifacts or systems (the AB of education). Caring and character (the C of education) is largely missed. There is a need therefore to have space in the curriculum to allow the students to explore and develop their self, leading to caring and character.

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[2] There are also 5-year integrated dual-degree "trans-disciplinary" programs spanning CSE and the respective domains (science, engineering and humanities) which are discussed later.

Human Values courses address this aspect. The goal of these courses is not to preach values, but allow the student to discover values already within himself or herself. The discovery begins with drawing attention of the student to the self, but then allow him or her to explore and experiment. Experimentation also leads to connecting with real life, and observing one's thoughts and feelings.

Human Values courses at IIIT-H get conducted in small groups through discussions and relate to the self. Issues discussed pertain to self esteem, peer pressure, relationships in family, feelings of trust, respect, affection, society and the self, nature and human being, etc. these are to be observed in oneself and explored further through self observation and experimentation in real life.

Jeevan Vidya as a humanistic-philosophy forms the base of the Human Values courses at IIIT-H, which are a part of the core courses. A slow but sweeping change has come about in the atmosphere of the institution.

7. Projects – Layered Learning Again

Independent Projects are an important part of layered learning. While projects within a course are important and contribute to learning of the material within the course, independent projects can straddle material from several different courses. They permit a synthesis across courses.

BTech project (typically, over the final year) is a part of most undergraduate engineering curricula. At IIIT-H, the BTech project is over 6th and 7th semester, thus allowing for an intervening summer for the students who wish to overreach. It also makes 8th semester available to those students who wish to write a research paper, or convert their implementation into a usable software, and is great for transfer of knowhow to the new students, who wish to continue the project.

Students in the BTech (Honours) program do project(s) through 5th to 8th semesters. These at times result in substantial work leading to research publications.

8. Integrated Dual–Degree Programs – Continuing the Research Momentum

A natural extension of the research oriented undergraduate program is the 5-year integrated dual degree program. It leads to two degrees at the end of five years, BTech (Honours) and MS by Research, typically in the same discipline (CSE or ECE). The fifth year is entirely for MS dissertation to do original research.

The student in the dual degree program chooses an area in his or her 5th semester as a stream, as a normal part of BTech (Honours). It is straight forward therefore to continue to work in the area in the fifth year and produce a solid piece of work in the thesis.

Students can either choose the dual degree at UG admission time or can opt to switch from 4-year single degree to dual degree by their 6th semester. The dual degree program as an option to switch has been running successfully at IIIT-H ever since its inception in 1998.

8.1 Trans-Disciplinary Programs

Science and mathematics entered engineering education in a big way in the 1960's leading to what began to be called science based engineering. Similarly, computing has entered the practice of engineering today. The practice as well as the theory in engineering is likely to be recast today. Therefore engineering education is likely to undergo a change like it did in the 1960s but this time based on computing. However, these changes would not be limited to engineering but would affect other domains as well, including the humanities.

To help create such a synthesis, IIIT-H has started three 5-year trans-disciplinary programs leading to the following dual degrees:

a. BTech in Computer Science, MS in Computational Natural Science
b. BTech in Computer Science, MS in Computational Linguistics
c. BTech in Computer Science, MS in Exact Humanities

These are integrated programs in which the study of the domain starts right from the first year, and is woven with the study of CS. They start research oriented project work from 6^{th} semester onwards, leading to a thesis in the fifth year.

The programs started in July 2009, and are full of synergy. The students enrolled in the program are enjoying and hopefully, in time to come, will help create the new synthesis. The results of running these programs will be reported in due course.

9. Outcomes at IIIT-Hyderabad

A curriculum based on these principles has been in operation at IIIT-Hyderabad since its inception in 1998. In 2008, a major review was done which resulted in some amount of redesign of core courses, greater convergence of CSE and ECE, introduction of bouquet core (instead of flexi-core), a major revamp of Humanities courses and some structuring of elective slots. It was followed up in 2009 with the introduction of trans-disciplinary programs.

What have the outcomes been? BTech (Honours) program has been hugely successful. It was thought that only 1% to 2% students would be interested in research. But the numbers are close to 30% to 40%. It has led to the creation of large research groups with *critical mass* in the institution. Three of the research groups are the largest in this part of the world. Language Technology research group is 130 strong, spanning natural language processing, search and speech. Computer Vision group is 90 strong. And these groups have been created in a new institution only about a decade old.

Besides critical mass, it has also solved the problem of lack of *critical continuity* of manpower in research groups. By critical continuity is meant that continuity of the group activity is maintained because all the important members do not all leave at the same time.

Where there is a paucity of PhD students, most research gets done through MTech students. But MTech is a 2-year program in which the first year goes in preparing the student. Therefore, one year is available for thesis work. This means that when new students start on their research all the old ones have left or about to leave. It becomes impossible to maintain continuity of research within a group.

The research oriented undergraduate program solves the problem of critical continuity eminently as the BTech (Honours) students spend two years in the research stream, leading to a clear overlap of one year between the old students and the new. Dual degree students further deepen the links across batches as they spend three years as part of the research groups.

At IIIT-H, a result of all this has been not only research publications but also system building, both for research and applications. Transfer of technology to industry has also begun to happen because of the critical mass and critical continuity.

Those students who do not take the research option (that is, do not take the option of BTech (Honours)), are also recognized by industry for their high degree of skills. Feedback is also positive regarding their ability to deal with unstructured problems. Perhaps, "research aptitude" rubs on others through peer learning even when they have not participated in sustained research directly. Industry which produces products or engages in R&D hires most of the undergraduate students out of IIIT-H. An increasingly larger number of students is also going for higher studies.

There was apprehension when the program started that students are specializing too early. Perhaps they are choosing a stream when relatively young, however it is not coming at the cost of breadth. The option to quit the BTech (Honours) program at any time, has allayed these initial fears. (The student also has the option to change stream, if done early.)

Dual degree programs in the same discipline bring greater commitment to an area. But correspondingly students have greater facility to change their stream, as more time is available to satisfy the academic requirements, in case of a change. However, the sociological problem which arise when relatively weaker students opt for the dual degree program to gain admission into a prestigious institute, but do not do as well needs to be handled. (Incidently, trans-disciplinary programs are doing extremely well but they are too young to be evaluated at this stage.)

Humanities courses initially evoked the response from students that they had thought these subjects were "over with" after their school education. After all, engineering curricula in most institutions have no humanities courses. But soon this view changed. They found them to be exact and rigorous but different. Many students enjoy them.

Incidently, response towards science courses was similar – how would these be useful to me? The first integrated science course generated the response "Do I apply Physics while solving this problem or do I apply Chemistry?" But slowly they see a more holistic view. Some BTech students even switch over to science, but the numbers are very small.

Human Values courses were first introduced in 2005. The group discussions have been seen as a place where they can discuss their concerns about life and living with their faculty mentors and group members. The students say that the course has helped them, for example in controlling their anger and understanding their relationships. Sensitivity towards nature and wastage of physical resources (in particular, electricity and water) is another area of impact. Role of money and career choices are much discussed among the larger peer group but no immediate change in their decisions is visible at this time.

Overall there has been a change in institutional environment towards relaxation, more open discussions, and perhaps greater academic seriousness. It can be said that a seed has been planted, it can be judged later as to how well it sprouts.

10. Summary

We have described a research oriented undergraduate curriculum and the issues which arise in its design. The major design principles were:

a. Catching the enthusiasm of students – Empowering them to build or to do research.
b. Layered–learning – Starting from practice and intuitive understanding and going to theory with its abstractions, and repeating it in layers.
c. Structuring the research option through streams as a part of BTech (Honours).
d. Breadth in science and engineering covered through a set of courses, which emphasize integrated view of their respective domains and familiarize the student with their methodology.
e. Humanities courses woven into the curriculum to explore relationship to life and society.
f. Human Values course to focus on the self, including thought and feelings, but without preachings and dos and donts.

The major issues which came up and were handled were:

(i) Flexibility in curriculum was introduced at an early stage to handle different course requirements for different streams. Flexi-core and bouquet core were introduced to provide the requisite space at an early stage.
(ii) Skill courses were specially designed as separate workshop courses to impart skills early.
(iii) Humanities courses were introduced to expose students to issues in wider society and human sensibilities. Human Values course was introduced to focus on self and apply in one's life - namely, in thought, feelings, behavior and work.

Outcome of the research oriented curriculum has been exceptional. By providing critical mass and critical continuity, it has facilitated the emergence of strong research groups. Breadth in general and humanities in particular has helped shape the student thinking towards broader and more humane outlook.

Acknowledgement

The research oriented CSE curriculum was implemented at IIIT Hyderabad in 1998, right from its starting. Many of the ideas presented here evolved through experimentation there. They led to the development of flexi-core and workshop courses, first of which were taught by the author.

A number of people have contributed to the development of ideas presented here. Kamal Karlapalem as Dean (Academics) carried the core ideas forward in the curriculum revision of 2008. PJ Narayanan introduced the idea of bouquet core. Convergence between CSE and ECE was given a greater push by RN Biswas. Integrated science courses were designed by Krishnarajulu Naidu originally, and by Harjinder Singh later. Engineering courses for complex systems were proposed by KS Rajan. Humanities courses were structured by Navjyoti Singh.

The importance of domains and IT was originally emphasized by Raj Reddy and Narendra Ahuja, which eventually led to the development of trans-disciplinary programs.

Finally, thanks go to the exceptional faculty and the enthusiastic students at IIIT-H who made the curriculum a reality.

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Appendix I: Streams and their Courses

- Data Engineering
  Database Systems, Data Warehousing and Data Mining, Web Data and Knowledge Management, Advanced Database Systems, Distributed Database Systems, Topics in Database Systems, Topics in Data Mining
- Language Technologies
  Natural Language Processing, Natural Language Processing II, Natural Language Applications, Natural Language Dialog Systems, Information Extraction
- Security, Theory and Algorithms
  Computational Geometry, Cryptography and Network Security, Topics in Information Security, Systems and Network Security
- Visual Information Technology
  Graphics, Pattern Recognition and Statistical Methods, Image Processing, Machine Learning, Computer Vision
- VLSI and Embedded Systems Stream
  Analog and Mixed Signal Design, Advanced CMOS VLSI Design, Modeling and Simulation of High-Speed VLSI Systems, Embedded Robotics
- Robotics Stream(for ECE students)
  Embedded Robotics, Mobile Robotics, Linear Control Systems, Computer Vision OR Image Processing
- Robotics (for CS students)
  Embedded Robotics, Mobile Robotics, Multi Agent Systems, Introduction to Cognitive Science
- Communication Stream
  Communication Theory II, Wireless Communication, Error Correcting Codes, Antennas and Propagation, Information theory and coding
- Signal Processing Stream
  Adaptive Signal Processing, Multi-rate Signal Processing, Image Processing, Neural Network

Appendix II: BTech (CSE) Curriculum for first six semesters (disciplinary courses only)

Each course is given with an ‘(L-T-P-C)’ block which denotes the number of lectures, tutorials, practice or lab sessions followed by credits that course carries.

- Semester #1

ICS101 Computer Programming	**3-1-3-5**
ICS102 IT Workshop I	**2-0-3-3**
IEC101 Digital Logic and Processors	**3-1-3-5**
IEC102 Electrical Science I	**3-1-0-2**

- Semester #2

ICS103 Data Structures	**3-1-3-5**
ICS104 Computer System Organization	**3-1-0-4**
ICS105 IT Workshop II	**2-0-3-3**
IEC103 Basic Electronic Circuits	**3-1-3-5**

- Semester #3

ICS211 Algorithms	**3-1-0-4**
ICS231 Operating Systems	**2-1-1-3**
ICS241 Introduction to Databases	**2-1-0-2**
ICS261 IT workshop III	**3-0-3-3**

- Semester #4

CSC371 Artificial Intelligence (*)[3]	**3-1-0-4**
CSC251 Graphics (*)	**2-1-0-2**
CSC311 Formal Methods	**2-1-0-2**

- Semester #5

Bouquet Core	**3-1-0-4**
Bouquet Core (*)	**3-1-0-4**
Research Stream/CS Course	**3-1-0-4**
CS Elective (*)	**3-1-0-4**

- Semester #6

Bouquet Core	**3-1-0-4**
ECE Elective	**3-1-0-4**
Research Stream/CS Course	**3-1-0-4**
Bouquet Core	**3-1-0-4**

There is a Math course in each of the first three semesters. Semesters #7 and #8 have several electives in the discipline and humanities etc.

Appendix III: BTech (ECE) Curriculum for first six semesters (disciplinary courses only)

Each course is given with an '(L-T-P-C)' block which denotes the number of lectures, tutorials, practice or lab sessions followed by credits that course carries.

- Semester #1
  Same as CSE curriculum
- Semester #2
  Same as CSE curriculum except EC workshop replaces IT workshop
- Semester #3

ECE205 Linear Electronic Circuits	**3-1-3-5**
ECE241 Signals & Systems	**3-1-0-4**
ECE260 Electrical Science II (H1)	**3-1-0-2**
ECE325 Embedded Hardware Design	**3-0-3-4**

- Semester #4

ECE335 Communication Theory I	**3-1-0-4**

[3] (*) means flexi core. These courses can be postponed by the student and an elective can be taken instead. This allows, for example, stream courses to be taken up by the interested students as early as in 4th semester.

ECE341 Digital Signal Processing **3-1-0-4**
ECE339 ECE Lab **0-0-3-1**
ECE361 Introduction to VLSI (*) **3-1-0-4**
ECE291 Electronics Workshop II **1-0-4-4**

- Semester #5

  ECE381 Electromagnetic theory * **3-0-0-4**
  EC Elective **3-0-0-4**
  EC Elective **3-0-0-4**
  EC Elective **3-0-0-4**

- Semester #6

  Communication Networks * **3-1-0-4**
  EC elective **3-1-0-4**
  CS Elective **3-1-0-4**

There is a Math course in each of the first three semesters. Semesters #7 and #8 have several electives in the discipline and humanities etc.

Appendix IV: Bouquet Core Courses

Out of the courses below, at least three foundation courses and three systems courses are to be done.

- Foundation Courses (3-1-0-4))

  CSC311 Advanced Algorithms and Theory of Computation
  CSC471 Pattern Recognition and Statistical Methods
  CSC315 Principles of Programming Languages
  CSC381 Numerical Techniques and Optimization
  CSC318 Principles of Information Security

- Systems Courses (3-1-0-4)

  CSC431 Distributed Systems
  CSC441 Database Systems
  CSC335 Computer and Communication Networks
  CSC419 Advanced Compilers
  CSC461 Software Engineering

Appendix V: Weightage in Curriculum for Different Areas

Course Type	BTech in CSE/ECE		BTech (Honors) in CSE/ECE	
	% (Rounded)	minimum credits	% (Rounded)	minimum credits
Discipline	49	83	47	83
Math and Science	19	32	18	32
Engineering	05	08	05	8
Humanities	17	28	16	28
Projects (including workshops)	10	17	14	25
Total	100	168	100	176