

# Evolving ideas of teaching and research in engineering institutions during my journey in academics over five decades



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## 1. Background

Being in the academic field for over 5 decades, I felt that I should write my views on teaching and research, especially in engineering institutions, based on my experience. Frankly, I have been collecting my thoughts on this subject over the past several years, and I do express them in limited forums, like in my general talks I give while addressing the students and faculty in academic institutions. I am very hesitant to put my thoughts in writing, as it may invite criticism because many of the ideas go against the currently held views by most educational planners and administrators. Finally, I ventured to write this, mainly expressing my personal views, based on the changes I have been observing in the education field during my 5 decades of teaching and research in engineering institutions. Please note that these are my personal views, many of which may not be backed up by solid facts and figures.

I would like to emphasize that this article is only about teaching and research, and not about coaching and training. I feel that coaching and coaching institutions are meant to prepare for competition, like in games, and have limited or short term goal. On the other hand, training is for preparing someone to acquire a skill, mostly for living with that skill. But teaching is meant to prepare students for learning how to learn. Research is meant mostly for developing creative abilities, especially to generate new ideas. Hence all these four are for different groups of people with different aims, and there is no conflict or overlap among their roles.

I am expressing these views in the backdrop of the following developments in recent times. We often hear these days that we should have over 1000 universities, producing 10000 PhDs per year, and having online classes with over 100000 students per class. We seem to excessively focus on the number of PhD to be produced, and making the PhD degree mandatory for promotion even in ordinary teaching colleges. Since research is measured in terms of number of publications, citations and awards, people seem to be working towards them, instead of doing any serious research. The proliferation of journals and conferences is testimony to this. Also, there is a growing belief expressed by many planners and educators that teachers can/should be replaced by technology. In such an environment, it is difficult to convince even the administrators of teaching and research institutes that the real meaning of teaching and research is different from what is happening in their places.

In this article I try to give one view of teaching and of research, which many may not agree in public, but accept it as correct in private. This write-up also reflects my bias acquired over the past 50 years of my teaching engineering students and also doing research in engineering institutions. In the process of this writing I try to clarify the five terms

relevant to this topic, namely, education, learning, knowledge, teaching and research.

Let me assert that I am a teacher by choice, and not by chance or accident, and hence I kept away from administrative roles as far as possible throughout my career. Based on my teaching experience (this is my 50th year of teaching), I feel that teaching involves production, perception and learning of patterns. Here teaching refers to teaching human beings by human beings, and hence the link to the biological neural network (BNN), i.e., the human brain. The main feature of the BNN is pattern processing, which includes the multimodal nature of pattern perception and learning. The production part of teaching is the ability of the teacher to produce multimodal data of a concept, to convey the pattern to the listener. Note that the pattern exists in a high dimension space of the data, and it cannot be compressed. The listeners can then perceive the pattern in the multimodal data and attempt to learn by developing associations or links to the patterns already developed in the listeners' minds. The ability of capturing the pattern in the data and associating it with other patterns in the brain is the process of learning. The teacher enables this to happen by generating appropriate multimodal data. Thus significant effort on the part of the teacher is in generating the multimodal data for a given concept. The multimodal data here means the gestures through vocal, hand, facial and the general body movements, besides the other data, if any, such as slides, audio and video demonstrations.

The multimodal data need not be unique or precise. Actually being precise (in the form of definition or unique description) is not a virtue in teaching. Some variation helps the listeners to learn better. The pattern information in the generated multimodal data is captured by the multimodal nature of pattern perception and learning of the biological system, i.e., BNN. Interestingly, teaching is also a continuous learning process for the teacher, as while expressing the concept through multimodal data, the teacher comes up with better ways of producing the data for the same concept, based on his own feedback and the feedback from the listeners' reactions, in the form of gestures, questions and comments. A good teacher is one who can produce such multimodal data to convey the concept through the pattern information in the data. Thus there could be good teachers or bad teachers (initially in their career), depending on the effort they put in. But generally, there are no good or bad students. We will also see below that teaching almost becomes a prerequisite for research.

Coming to research, it is common to mention that there is a methodology for research, and that it can be described or discussed in a structured manner, as though it has some beginning and ending. But in my opinion, research has no methodology or structure to describe. Research is a process and not a product. It is for the process a person is credited with a degree such as Doctor of Philosophy. The thesis examiners, while recommending the award of the degree, usually mention that the candidate has demonstrated his/her ability to carry out independent research. In research, the candidate should demonstrate their ability to see the problems clearly, and in the process of finding solutions, they may generate more problems than solutions.

Research involves understanding and building links among the components of the problem, rather than breaking up the problem into sub problems, leading to destroying the problem itself. One can appreciate what constitutes great research, by recalling great research ideas, such as Maxwell's equations, Sabine's formula, Shannon's information theory, Kalman filtering, to name a few in my domain of research. Ultimately, both research and teaching are passionate endeavours, and cannot be done by mere training or coaching. In this context, let us recall how ideas of teaching and research have evolved

over the past several decades. First, we will consider teaching.

## 2. Evolution of Teaching

In 1950s, some of the teachers in schools and colleges used to teach with passion. For example, it was language and arts classes that were more interesting than science and maths classes. The teacher teaching Shakespeare drama used to enact the event in the play in the beginning of the class, and then explain the English part of it. Likewise, teacher of Telugu poetry used to start the class with pleasant rhythmical recitation of the lesson, and then explain the meaning of the poem, along with several linked stories. I was fortunate to have such teachers in my college. Where are those teachers now? In 1960s teachers try to prepare the lesson with a desire to communicate the concept to the students. Textbooks were very carefully and concisely written. Not many questions or worked out examples were available in the books. Also, the teachers did not focus much on working out examples in the classes. Since copies of the books were limited, students used to write notes carefully in the classes and supplement with additional reading material in the libraries. For some subjects, lab experiments supplemented the classes. There were fewer exams. Students were credited for asking good questions. There were not many questions in the books, nor there were many question-banks. Mostly, the annual exams were used to assess the candidates. The dynamic range of the performance of the students is indicated by the range of marks the class gets, mostly in the range of 0 to 70% marks. In fact getting more than 70% was rare and exceptional. Thus the students know where they actually stand in the class.

In 1970s, use of overhead projection of transparency sheets started for class room lectures. Then the teachers were busy preparing the transparency sheets, and thus in the class they were not developing the concepts with illustrations. The students tend to look at the projected material rather than watching the multimodal display of information by the teacher through his gestures, voice modulation, with on the fly illustrations and stories. Question-banks for various subjects were coming up, with even answers to some of the questions. This helped the teacher to set question papers easily. It also helped the students to follow the pattern of questions that the teachers would ask. Thus the students slowly lost their ability to make and ask their own questions. The teachers also are slowly trying to adopt to the pattern of the questions in the question-banks, instead of trying to create questions based on the interaction with the students in the class.

Slowly the credit system with electives also produced distance between teacher and students in 1980s. Teachers definitely lost touch with students, as they meet/see the students from different disciplines and departments assemble for the class hour and then disappear. With the wide variety of the background of the students, the teacher is forced to dilute the contents of the course, and also lost time for providing the background of the prerequisite courses for significant part of the course. Giving assignments and solutions to problems, and also continuous evaluation through frequent tests and exams, resulted in transferring the load of evaluation to teaching assistants, thus further reducing the contact between teacher and students. Also, the problems, questions, answers, etc. all of them were tailored to enable the teaching assistants to evaluate the students. In 1990s the curriculum, the course contents, teaching and evaluation became more structured towards grading the students. The concept of learning is either ignored or diluted. The craze for better grades/marks due to competition among students has increased, which has increased even the distance among the students, and the distance with the teacher still further.

In the decade of 2000, drastic changes took place in education system, with computers becoming easily available, and communication through internet making the distant people apparently closer, and the closer people distant. Many more worked out examples, with easily implementable software packages, have changed the way books are written. While it helped a few motivated students with better access of these resources, the general attitude of the students is to get some how good grades/marks and a good job after that. There is less exposure to concepts in the classes any more. And the teachers and the system also are tuning their activities to cater for the needs of the students rather than educating them. For example, the question papers are of objective type to tick an answer among the alternatives.

The average grades of students are thus jacked up, with almost making 70% or equivalent as a poor mark/grade, 90% is average and 99% or more as desired/required. Even the institutions were evaluated based on how many students get such high grades. Thus while it used to be difficult to get 70% or more up to 1970s, it turned out that it is now difficult to get less than 70% or equivalent grade. With far lesser effort on the part of the student, they are rated high, almost making it appear that all the students are in a small dynamic range at the top. Because of this, grades/marks cannot be used for discriminating the abilities of students any more. In addition, there are too many activities focussed around internet and mobile, with no time for concentration on learning. Learning is reduced to mere acquisition of skills/data, which was provided outside the classroom without teachers, like video lectures, online courses, etc.

The decade starting with 2010, with the availability of smart phones and internet connectivity, has changed the meaning of student and studies. There is very little attention in classes. Most lectures are reduced to mere projection of slides, with the intention of pumping the students with data. With online courses and mass learning classes, the purpose of education became giving certificates, diplomas and degrees. The focus is only on tools and their usage, which is more like a technician job. The emphasis on explaining and understanding concepts is gone, and the basic subjects are replaced with skill-oriented subjects. Throughout this evolution, instead of exploiting the technology for improving the quality of education, we seem to let the technology drive the education system. Thus education is viewed more from business point of view, and several business models have evolved for imparting education. There is very little learning in its true sense any more, at all levels starting from the primary level to the university level. We have almost reduced the role of a teacher to that of a facilitator/mentor, rather than that of teaching and learning.

### **3. Evolution of Research**

Let us review how the concept of research is evolving over time. In 1950s, there was hardly any serious talk about research. Very few people opted to work for research degrees. The few that were doing research were doing on their own interest, without expecting any return out of it. There was also very little support for doing research. Most people were happy with a basic degree to make some living after that. In 1960s, people, especially in the teaching profession at elite institutions, were doing research mainly for professional growth. At that time, many lecturers were working for PhD under the guidance of senior faculty, mainly at IISc and IITs. With very little access to computing and experimental facilities, they were able to do excellent research, as reflected in the publications in peer reviewed international journals. It is interesting to know that most of them did not know much about those journals, except by their access through libraries, usually 3 months or more after their release.

Availability of computing and experimental resources has improved significantly in 1970s, leading to computer-oriented research, but still most of the research was experimental or theoretical. This was the period when money for research was being made available at some of the leading institutions through sponsored research projects, mainly from government agencies. The computer-oriented research took a big leap in 1980s, with the availability of powerful (at that time) mainframe computers at several leading institutions and laboratories in the country. In that euphoria, less of practical/experimental work was being carried out, as every one was busy doing scientific programming for research.

In 1990s, the meaning of research is getting dwarfed. As many computer-oriented gadgets being made available, and doing work with computers becoming easier, all problems were oriented towards computer modelling and simulation. Also, it helped in thinking of bigger problems with large number of parameters for modelling and optimization. Setting up experimental facilities for verification of results and thinking of such problems reduced drastically. During that period, even writing abilities were also affected due to extensive use of word processing tools. Most research was aimed at collecting more data for analysis with computers.

In the decade of 2000, the experimental work in most engineering disciplines has practically vanished. Almost all laboratories were filled with computers, with prominent display of monitors and keyboards everywhere. It was almost difficult to find out to which engineering discipline a lab belongs to. Many of the research scholars did not have a feel of the values of the parameters in the real experimental facilities. On the other hand, for senior researchers, the computational facilities augmented their engineering skills acquired through experimentation. The 2000 decade also has seen the vanishing of writing skills among students completely, as most research scholars spend their time in typing and editing, as dictated by the tools such as Microsoft word.

As senior faculty, we were helplessly looking at how the students are busy spending most of their time in formatting, tuning the figures and tables for better display of the document, but at the cost of understanding the contents of their display. Research scholars spend all the time in front of a monitor, pretending as though they are doing serious research, whereas they are only searching all the time aimlessly. Due to fast switching, they also lost the ability to focus on any topic or equation or figure. Writing papers is reduced to writing reports with casual English and poor organization of the thought process in their minds. It is also obvious during this and the previous decade, that the aim was on getting more papers published. There is also proliferation of journals and conferences to meet this demand. It became a fashion/necessity that the conference deadlines decide on what to submit, and then quickly manage to write a few lines based on some simulation work. It is no more that you have 'something to convey' and hence write a paper. It has become a routine exercise to write something and submit. Some organizations also insist on journal papers for faculty promotions. To meet this demand, many online journals have come up, making a mockery of research and its reporting. With emphasis on numbers and quantity, plagiarism has crept in, and organizations proudly announce that they have acquired plagiarism detection software to check such happenings. What a tragedy we have ended up with in the domain of research.

We almost lost control on research in the decade beginning 2010. Proliferation of the so called institutions of higher learning, research universities, etc. with emphasis on number of PhDs and research papers, rather than quality, working towards awards and recognition, data-oriented computer based

research, all of this contributed to confusion on what is research, and how to do it. It appears that, instead of understanding research, and then doing it out of passion for it, it is routinely claimed that whatever any one is doing is research. Even the high school students or 1st year undergraduate students talk of doing research, without understanding the meaning of research. I hate to think of what is in store for us in the coming years.

It is unfortunate that the tremendous potential of the developments of communication and information technologies is grossly misused in teaching and research. Otherwise, these developments should have significantly enriched our learning and creative abilities through good teaching and research, and also should have produced excellent teachers and researchers. Unfortunately, we have misused the technology, by making teaching and research as business opportunities. Many start-ups and coaching centres (most of them have no idea of education) approach us with proposals that they can help us with tools/gadgets to improve our teaching and research abilities.

#### **4. Current Practices Affecting Teaching and Research**

##### **4.1 Teaching**

- Absence of good teachers: Students are not getting the high dimension pattern for absorbing the concepts.
- Projecting ppt slides: Missing or destroying the pattern information.
- Text books: Poorly written with too many distractions like unnecessary colours, worked out examples, programs and exercises.
- Worked out examples: No motivation for the student to think about a solution.
- Readymade programs: Students do not develop the logic for solving a problem.
- Learning from examples: Not thinking about concepts and logical reasoning.
- Learning by doing: Without understanding principles
- Too many distractions: Fast changing data, with no time to absorb the pattern, if any.
- Too much emphasis on applications without learning concepts.
- Too much of technology and gadgets.
- Continuous evaluation with too much focus on assignments and exams in a semester: This results in short-time remembrance, and forgetting them soon after the semester.
- Objective type questions: Working from the answer, and not solving the problem.
- Grading system with high grade points or marks: Misplaced emphasis and poor judgement of the standard of a student, thus conveying false impression of accomplishment, talent and abilities.
- Competition, rather than cooperation: Education is not a zero-sum game.
- Too many competitive exams with focus on problems and their solutions.
- Acquiring skills during school/college: This is a wrong notion, as education is meant for learning how to learn, and not how to acquire a skill. Skill development institutions are different, like polytechnics.
- Too high expectations of salaries and positions, without really deserving.
- Too much of societal and parental pressure on the students: Education is viewed as a business opportunity, and not as a process for learning.
- Summer and winter internships: Doctors do these after their studies, whereas engineers attempt to do it during their studies, without consolidating the subjects they studied.

##### **4.2 Research**

- Searching the web: Directionless most of the time

- Misplaced emphasis on research without passion
- Misplaced emphasis on degrees
- Poor writing abilities due to typing, cut and paste process, editing tools, etc.
- Poor reading abilities due to lack of concentration, and also due to poor quality of books
- Starting (catching them) young, especially for research is wrong, as it takes time to understand what research means
- Talking about research without knowing what it is
- Whatever one does is being projected as research, instead of doing real research
- Proliferation of research universities, without any significant research in them

#### 4.3 Management Perspective

- Looking at education as a business opportunity, and applying management principles, like for any zero-sum game.
- Aiming at products (students) for IT (information Technology) ready, skill equipped, technology ready, etc, is not appropriate for education.
- Should technology drive education, or education drive technology?
- Generalizing from a few successful/failure cases, as often used as case studies in a business model, is not appropriate for education.
- Goal of education: Need to improve the average for the prosperity of a nation, and not aiming at excellence in some specific items and individuals.

### 5. Some Points for Good Teaching and Research

#### 5.1 Points for Good Teaching

- Teaching refers to teaching human beings endowed with biological neural networks (BNN) for pattern processing
- Being precise is not a virtue in teaching: Learning takes place only when there is some vagueness, as precision involves only listing of facts.
- Multimodal nature of pattern perception and learning by BNN requires that teaching should cater for it.
- Teaching is a continuous learning process.
- Learning is the ability to absorb the pattern in high dimensional space, and hence the teacher needs to create the pattern in high dimensional space.
- Learning by doing works only when the process of learning is understood.
- Reducing the problem to sub problems or divide and conquer paradigm is not relevant most of the time in teaching, as it destroys the pattern information in the problem (as in .ppt slides)
- Difference between teaching (making the students learn the constraints hence acquire knowledge) and coaching (involving taking students along a specified path). (Compare construction of sentences naturally and those following strict rules of grammar, or compare printed characters and written characters) - Disadvantage of continuous evaluation/grading: Likely to disrupt long term retention.
- Teaching is a prerequisite for research, as it enables creating/generating multimodal patterns of a concept. (Recall the missing art of storey telling in teaching these days)

#### 5.2 Points for Good Research

- Research is a process and not a product: PhD is a recognition for the process.
- Research has no methodology, as the underlying process is unstructured.
- Research is not only finding solutions to a problem, but ability to see the issues in the problems, and this in turn may generate more problems than solutions.
- Research is a passionate endeavour.
- Research involves, reading, writing and sharing ideas with

- colleagues for comments and criticism.
- Research is a cooperative effort, and not competitive. IPR (Intellectual Property Rights) issues need to be addressed in this context, and not in a commercial context.
  - Research involves developing and building links among patterns, and not breaking them up.
  - Research needs concentrated effort without too many distractions.
  - Mere search inhibits research.
  - Discipline in writing is essential, and hence the need to focus on writing for journals instead of for conferences.
  - Research guide is like a coach for a game, as his goal is to act as a critique, and not as a promoter of the effort.

## **6. Summary, Conclusions and Recommendations**

### **6.1 Summary**

In this article I tried to explain the evolution of teaching and research over decades, and in the process we can get to understand the meaning of the terms like coaching, training, teaching and research. Coaching refers to taking the student along the path of the solution, like taking someone to a destination by hand-holding. Obviously the student will not know how to go by himself later when the need arises. Training refers to making the student to acquire a skill, so that he can use that skill repeatedly in a job. It does not involve any creativity or learning. Teaching refers to the process of generating a multimodal and multidimensional data to convey a pattern to the listener, which he/she can easily absorb due to pattern processing ability of the human mind.

Research involves ability to create new patterns based on the patterns already acquired through learning. It is important that people understand the meaning of learning, knowledge and education. Learning involves perceiving patterns in high dimensional data, and developing associations with the existing patterns in human mind. Knowledge refers to understanding the constraints from examples, so that the legal variations are captured within those constraints. Finally, education means learning how to learn, which is made possible mostly by teachers.

### **6.2 Conclusions**

Despite the fact that over the past few decades we are continuously making changes in the education system at various levels, there is hardly any positive comment on the standards of the education system, especially in the teaching and research domains. It is fashionable to compare us and our system with systems in other countries, especially with China and USA, in terms of papers published, number of PhDs, awards, percentage gross domestic product (GDP) spent on research, etc. But it is unlikely that even with increased investment to higher levels, we can make any significant progress, as it appears that we are moving in the wrong direction. In my opinion, teaching and research are local and culture-specific. Borrowing or copying other models will not work. A country's progress should be measured in terms of (a) increase in the average level of education (b) increase in number of good teachers who will make it possible, and (c) research will follow automatically. The effects of current fall in standards of teaching and research may take us to such low levels very soon, that we may reach a point of no return in about 5 to 10 years, if corrective mechanisms are not put in place now.

### **6.3 Recommendations**

- Make classroom teaching more purposeful and interesting, rather than dispensing with classroom and student-teacher interaction. For this we definitely need more teachers.



- Emphasize writing and reading, not typing, editing and searching.
- Make an effort to teach in a way that students learn.
- Learning is an effort to understand legal variations of an idea or concept, like construction of sentences with deviations from grammar/syntax.
- Think about problems, not solutions. Write your thoughts, express them and discuss.
- Solutions to problems are always worked out in mind first, and the gadgets are useful mostly to verify those solutions in mind. Otherwise, gadgets can reduce the degrees of freedom in our thought process.
- Search only with a purpose in mind. Otherwise, searching can distract and disturb our pattern formation and hence research abilities.
- Restore the missing art of storey telling in engineering presentations and teaching over time.
- Recall great research ideas, processes and results.

## **7. Final Remarks**

Currently the tremendous progress in technology and communications is being grossly misused, thus reducing our abilities to do good teaching and research. This needs to be corrected, and hence this article. Note that good teaching and research evolve with good environment and practices. They cannot be created by a procedure or a rule. I strongly believe that a country's progress should be measured in terms of number of teachers, especially good teachers, it produces, and not in terms of number of PhDs, or number of papers published, or number of award winners, or number of universities, etc. This is because, each teacher can brighten the lives of 30 or more students in a class, some of them may become teachers a few years later. Note that teaching is not a zero-sum game, as in the case of business. Here there is only gain, and no loss whatsoever. This is the beauty of teaching and research.

I would like to end this write-up by recalling (in a lighter vein) my observation on how books in engineering have evolved over the past six decades since my student days. In 50s, books were written, carefully explaining the concepts clearly, with hardly any questions at the end of the chapters, at least in some good books. The idea probably was to make the readers and students think on how to make a question or how to ask a question to the teacher in a class. Thus the books in any subject also were about 300 pages or so. In 60s, many books have questions at the end of the chapters, and there were also books with mainly problems on a particular subject, like Parker Smith's "Problems in Electrical Engineering". Thus the students and teachers started looking at those problems for both exercises as well as for question papers for examinations.

In 70s, books started giving not only problems at the end of chapters, but also answers to the problems. This helped the students to work towards getting the answer to the question, rather than understanding the question and attempting to solve the problem. In 80s, the books started giving worked out examples within each chapter, enabling students and teachers to focus more on those things rather than the text part describing the concepts. The sizes of the text books also became bulky, as most books are over 600 pages or more. In 90s, books started giving programs for some problems within the text itself, making it even easier for the student to simply run the programs and look at the results. This made the students skip reading even the solutions of the problems carefully, leave alone reading the text, which habit has almost vanished among many students.

In the decade of 2000 something very significant has happened in engineering studies. Books like "All in ONE" with only problems and solutions for many subjects in each engineering branch have appeared in the market. Both students and teachers

focussed mostly on these books mainly from examination point of view. This has resulted in the erosion of class room teaching of concepts completely, as the engineering education system geared up only for conducting exams and giving grades to students. It appears as though whatever the students learn is from the example problems and solutions given in such books.

At this stage in the middle of the 2010 decade, it is difficult for me to guess what is in store for engineering education by the end of this decade. From this development, I could bring an analogy of human learning vs machine learning. One of the elusive goals of scientists and engineers is to make machines learn like human beings, so that machines can be made to perform tasks similar to those by human beings. But we seem to have achieved the goal of making machines and human beings similar in their learning abilities, by making human beings also learn from examples, just as we make machines learn from examples in machine learning. Thus we made both of them nearly same by making humans do the way the machines do, rather than the other way. Can we call this as a great achievement in education over the decades?