Learning and Teaching Engineering
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Pankaj Jalote

INDRAPRASTHA INSTITUTE *of*
INFORMATION TECHNOLOGY
DELHI

This Seminar

- Learning – what is it
- Teaching – what we mean by it
- Effective teaching and learning

- Audience – students/learners and educators
- One message for each

An Educational Program

- An educational program (Btech, Mtech) has a structure
  - Ideally the program should have some goals in terms of what attributes the graduates should possess
  - The overall curriculum has a network of courses organized in some order to develop those attributes
  - Each course is taught by some instructor(s) and contributes towards the program goals
- Program/curriculum design itself is a complicated task – often not derived from goals, and often no clarity on how courses contribute towards the goal
- Will focus on teaching and learning in a course

What is Learning

- "A relatively permanent change in knowledge that occurs as a result of experience"
- Learning is a *process* that leads to change in knowledge….

- Knowledge – what is stored in long term memory, which is relatively permanent (and not "short term" or "working" memory)
  - Declarative knowledge: about facts, what is true/false, propositions
  - Procedural knowledge: skills and rules, how to do things
    - Motor procedures: driving a car, playing tennis, typing,..
    - Mental procedures: solving equations, etc.

- From "Learning to Learn" by Wirth and Perkins; How students Learn by John Kihlstrom

Learning

- Each course should deliver some learning, i.e. a permanent change in knowledge (declarative and procedural)
- In most engineering / CS courses learning from a course for students is generally around:
  - Understanding of some concepts, phenomenon, system, connections, ... (declarative K)
  - Develoop skills for doing something – design, test, analyse, quantitative methods for X, compare, write, critique,… (procedural K)

Learning – How Students Develop Understanding

- Knowledge is memory of individual pieces of K about concepts (procedures, facts, etc), and a network of connections between them
  - Body of knowledge – the number of nodes
  - Richness/depth of Knowledge – the number and nature of connections
- Not only "knowledge base" of concepts, facts, procedures, …. but also connections between them
- Novice and experts knowledge organization differs
  - In the vastness of knowledge network
  - In the degree to which knowledge is connected
  - How meaningful are those connections

Learning – How Students Develop Skills

- Developing skills to do (complex) tasks require
  - Development of component skills, i.e. student is comfortable in doing the sub-tasks comfortably
  - Practice in integrating them effectively
- If students are weak in critical component skills – overall tasks suffer
  - Students must be asked to practice component skills in isolation before being asked to integrate them in larger tasks
  - Even small amounts of practice on developing components skills can vastly improve performance in the overall task
  - E.g. in a advanced programming course, we introduce a new platform, new language, and concepts; few exercises to train on platform, programming language help learn better
- Integrating component skills is demanding
  - Cognitive load can be high (more if students may not fluent in component tasks)
  - Suitable exercises for integration are needed

Constructivist View on Learning

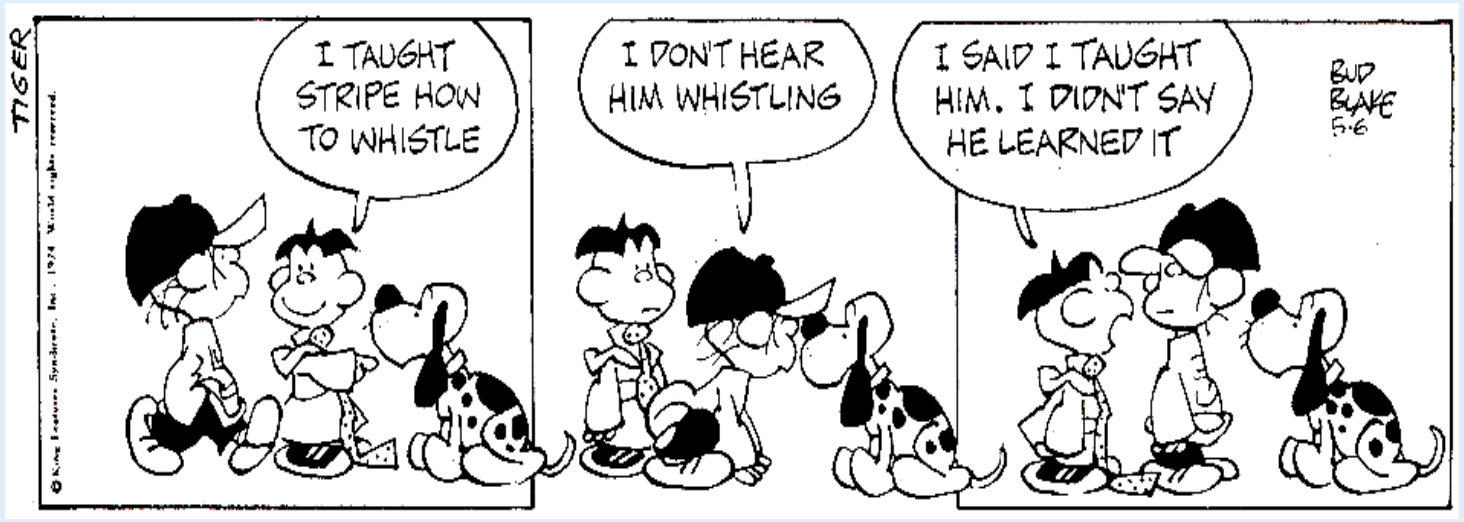
- Constructivist theories are widely accepted now
  - Learning is a constructive process
  - Learner builds an internal (and personal) representation of knowledge based on experience
  - The representations keep evolving based on experience
- Different from the model that student's mind is a vessel in which we put information / knowledge

- Some consequences of this
  - Control over learning is therefore on the student
  - No short cut to learning – effort and active engagement is the only way
  - Teacher's role is to help a student learn – i.e. not "teach" but "facilitate learning"

Teaching a Course

- Instructor has to facilitate learning during his/her ”teaching”
- Instruments generally available
  - Give about 40 lectures, each of about 50 mts (structure of lecture not fixed)
  - Give assignments/labs to practice/learn concepts covered in lectures
  - Give projects for deeper understanding and learning team work
  - Give tests/exams – to assess (and help) learning
  - Create learning environments
- (Not discussing other forms of teaching – e.g. mentoring, guiding,…)

Teaching and Learning



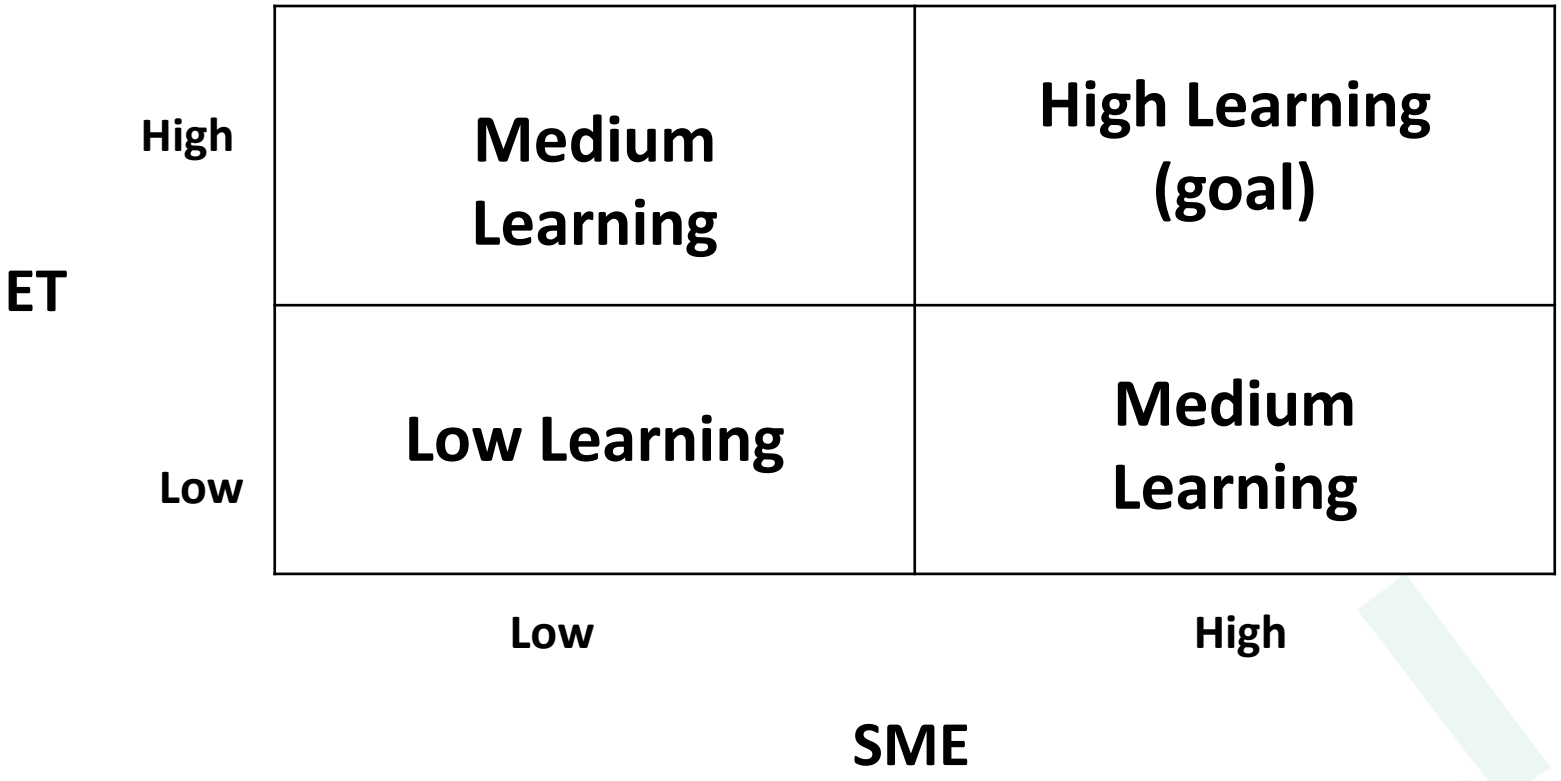
- Goal of teaching by teachers is learning by students
- There is no teaching without learning

- Cartoon from “Learning to Learn”, Wirth and Perkins

Teaching a Course

- Need knowledge of the subject matter
  - If instructor does not have strong knowledge, must build it – no work around this
  - In India subject matter is often main bottleneck, hence that is the focus of most QIP programs
- Even with subject understanding, need to teach effectively to facilitate learning
  - Teaching may not be effective even with SME
- This talk assumes subject knowledge
- Main task of instructor – design all aspects of the course, and deliver it

Subject Matter Expertise (SME) and Effective Teaching (ET) Practices



Efforts Globally on Effective Teaching

- Many universities have T&L centres to help faculty
  - Eg. Wiki page lists more than 50 in US alone
- Even top research univs with best faculty have such centres
  - CMU: The Eberly Center for Teaching Excellence and Educational Innovation
  - Cornell: Center for Teaching Excellence
  - MIT: Teaching and Learning Laboratory
  - Berkeley: Center for Teaching and Learning
  - Purdue: Center for Instructional Excellence
  - GaTech: Center for the Enhancement of Teaching & Learning
  - UK: Many have been established
- In India the focus of most efforts is around QIP which is on subject matter
  - Where subject matter expertise is not there, this is suitable
  - Institutions where subject matter expertise exists can benefit from engaging more in T&L

Common Approach to Course Design

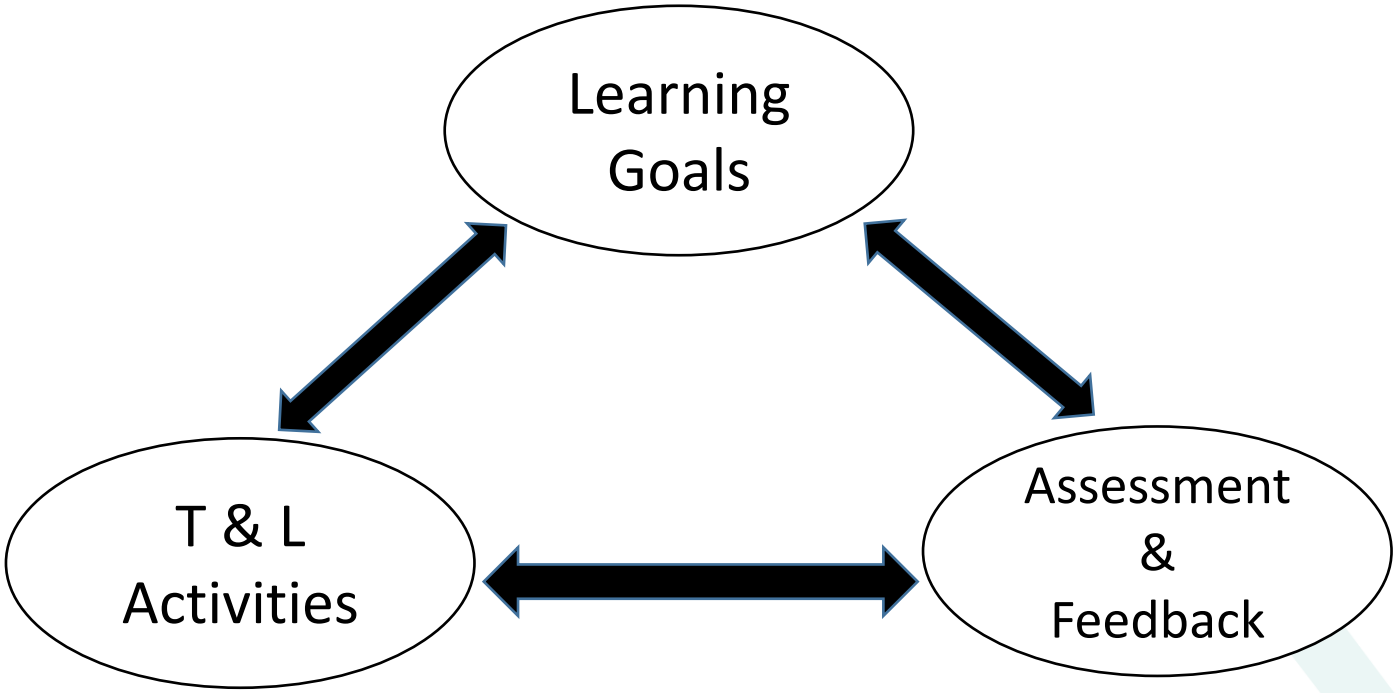
- List of topics approach – most common and widespread across the world
  - Designer identifies a list of topics considered “important” for the course to be covered
  - Focus is on what to include/exclude, so the list can be “covered” in 14/15 weeks
  - Lecturer then prepares lectures and delivers them as per the list
  - Tests are designed on the list of topics
  - Design is easy, teaching/lecturing is easy (both can be done from a text)
- This is teaching focused
  - Actually lecturing focused – not engaging/active
  - Limited value in learning (knowledge and skill development)

Teaching – Main Elements of Course Design

- Learning goals (outcomes) of the course
- Teaching and learning activities
  - In the class
  - Outside the class
- Assessment and feedback

- Weakness in any leads to reduced learning

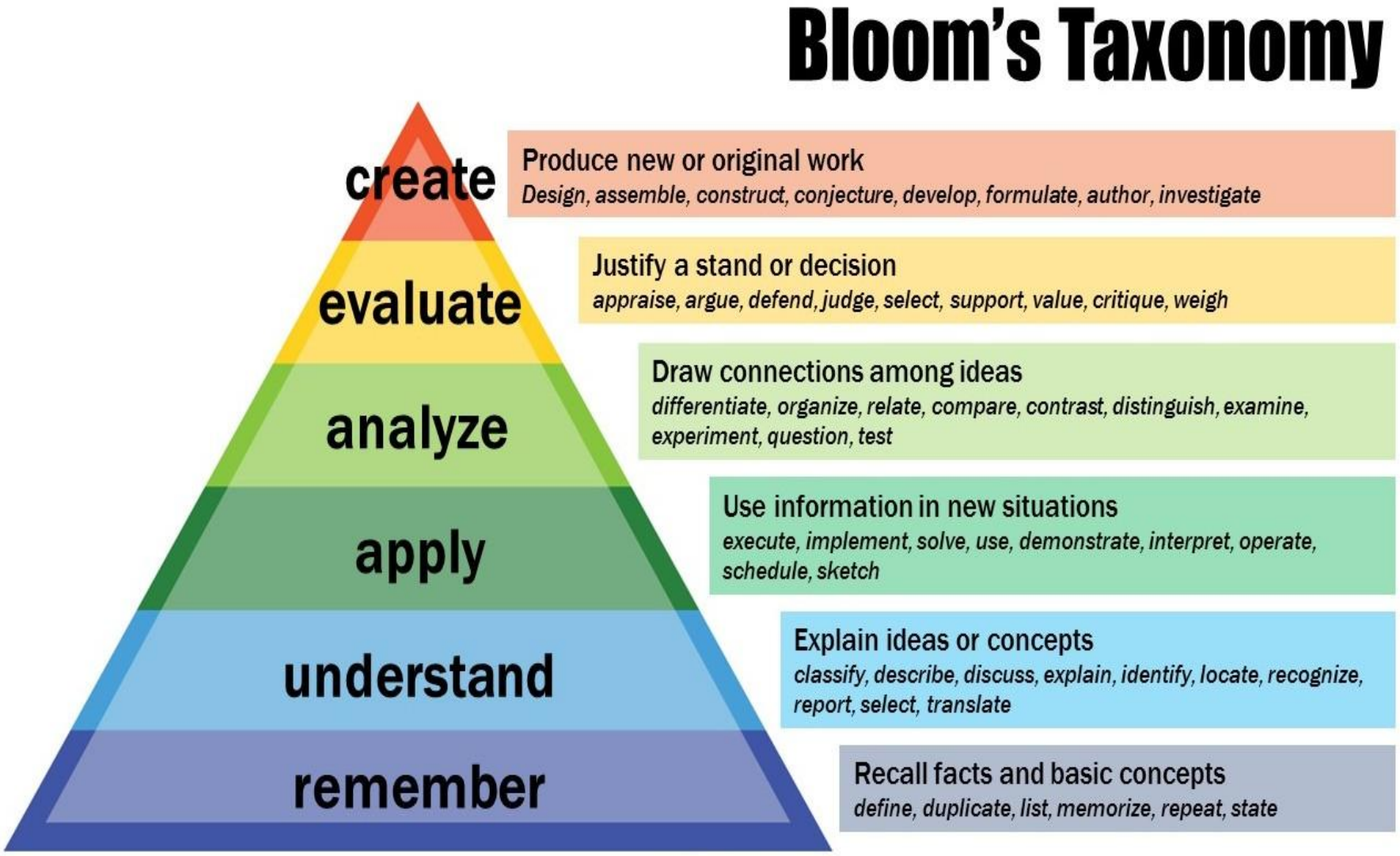
Integrated Course Design



Learning Goals

- Learning goals – what the student has learned at the end of the course
  - It is the post condition on the state of students mind
  - (Pre-condition is on knowledge at the start of the course)
- Learning goals are a few for a course, and can be stated as a few points, each starting with ”at the end of the course, the student shall…”
  - Goals have to be reasonable – they can be achieved (given the pre-condition, constraints), are not too easy, require the expected effort, can be assessed
  - Goals are in line with the overall program objectives, and provide the learning the courses that depend on it require
- Bloom’s taxanomy helps in specifying course outcomes in terms of learning goals for students

Bloom's Taxonomy (figure from Vanderbilt.edu)



Intro to Programming – Goals 1

- This course provides students with an entry-level foundation in computer programming
- The goals of the course are to develop the programming ability in students, and to improve their proficiency in applying the computing fundamentals to their field of study
- Topics include overview of high level languages,..

- Teaching centric view – “course provides”, “to develop”, “topics include”
- With learning focus, we need to make statements on learner’s knowledge/ability at the end of the course

Intro to Programming – Goals 2

- [At the end of the course the student will:]

- Be fluent in the use of procedural statements — assignments, conditional statements, loops, method calls — and arrays.
- Be able to design, code, and test small Python programs that meet requirements expressed in English
- Understand the concepts of object-oriented programming as used in Python: classes, subclasses, properties,...
- Have knowledge of basic searching and sorting, and basic vector computation

Teaching (& Learning) Activities

- This is where we spend the most our time – preparing lectures, tutorials, assignments, thinking of examples, case studies, roleplays…
- Teaching must be consistent with goals – must lead to students achieving learning goals
  - If teaching (including all activities) not consistent with goals, goals unlikely to be met
  - E.g: Giving long lectures (students “receive” info); have tests, mid-sem, end-sem for deciding grades: limited in what learning it can deliver
- A good teaching plan will
  - Identify important concepts for the course, arrange them in week-wise sequence
  - Identify nature of in-class T&L activities – lectures, discussions, problem solving, case studies,…
  - Identify out-of-class learning activities for students - assignments, labs, problems, projects, … (most important for learning)
  - Provide feedback: Just asking students to do is not sufficient – must provide prompt feedback for learning

Teaching Activities to Promote Learning

- Lecturing with active elements
  - Lecturing itself more suitable for factual knowledge, lower levels
  - Is more effective for higher levels when made more active by short in-class interjections or exercises (discuss in next session)
- Doing experiences
  - Solving problems (in class, tutorial, outside class)
  - Doing labs/experiments
  - Doing projects – designing, building, writing a report/summary,…
  - …
- Observing experiences
  - Instructor solving a problem (in lecture, tutorial)
  - Showing a simulation on how something works (in lecture/tut)
  - Observe a plant/machine in operation (lab, visit,…)
  - …
- Reflection (thinking / meaning-making)
  - Summarize, explain (in class, to myself, in a presentation/rept)
  - Explain how is it connected to other/prior knowledge
  - How is it related to the context, my life/work…
  - These can be done alone or with others – e.g. dialog, discussion, explaining to others,… can help meaning-making

Teaching Activities - Plan

Week/Lecture	Topic	In-Class	Outside class tasks
n	Conditional statements	Lecture, with some programming demo	Ask students to write 2 programs using conditionals and nested cond…
	Tragedy of the commons	Flipped class room – brief quiz on the reading material given earlier, followed by discussion and problem solving	Students reads the paper / note. Ask students to write a small essay on a contemporary issue where this plays out
	Memory hierarchy	Lecture; examples of mem structure in today's PC; some photos and videos	Assignment to solve some memory hierarchy problems – impact of levels and size

Assessment

- Assessment has two main objectives in a course
  - Support students' learning
  - For assigning a grade about the students' learning
- Assessment necessarily implies
  - Some student output which is assessed
  - Giving feedback – essential for learning
- Goals which are not assessed satisfactorily – are not likely to be achieved by students
- Assessment is an integral part of "teaching", if objective of teaching is learning
- Frequent assessment with proper feedback is one of the most effective tools for learning – much research to support this

Assessment and Feedback

- Assessment has to be aligned to goals – students will finally align their learning to assessment
- E.g. Let us take the Intro to Programming Course
  - Say has a goals – “able to design, code, test, small programs”, as well as regular on “understand x, y, z”
  - Grade largely based on final exam
  - Faculty gives good lectures, gives good assignments also (but with no weight)
- Q: Will this deliver the post condition
  - Probably no – as students will finally work towards the exam that will give them the grade/score
  - If a student learns well (how to program) – may get a poor grade
  - That is why in most good institutes, assignments, projects, etc are given weight for final grading
  - [That is why skill development is almost impossible in the affiliating mode]
- If assessment not consistent with goals, goals are not likely to be achieved
  - Common occurrence – exams only on simple concepts (gradeability)

Assessment Instruments

- Anything that a student does which we evaluate and give feedback (incl by marks) is assessment
  - Assignments
  - Presentations
  - Projects
  - Viva-voce
  - Term papers, reports
  - Quizes, tests, exams,…
- Assessment should have learning value

Designing Assessment Instruments

- Together the assessment plan should be consistent with the learning goals
  - They should directly support learning goals
  - So, if a goal is “understand”, we should have some assessment to check the level of understanding
  - If a goal is “can analyse” we should have some assessment to check the analysis capability
- Assessment need to be consistent with teaching also
  - Fairness: Student should be assessed only what has been “taught” in the course
  - If much is “taught” but assessment is on too little, learning suffers

Summary: Message to Students

- Learning – permanent change in knowledge (decl., procedural) as a result of doing a course
  - Learning happens by students – it is not something done to the student by the instructor
- Learning is your responsibility – instructor's is to facilitate this learning by you
- No learning without effort and active engagement
- At the end of course – ask yourself what you have learned (have you satisfied the learning goals)
- Demand learning from your instructor/college – not easy exams/grades, or less work

Summary: Message to Instructors

- Goal of teaching by us is learning by students
  - Learning: permanent change in K due to the course
- Teaching is far more challenging and interesting, when learning (rather than delivering) is the goal
- Ensure that the three dimensions are designed and delivered properly
  - Learning goals,
  - Ttaching (and learning) activities both inside and outside the class
  - Assessment (using various instruments)
- Proof of ”teaching” is in ”students learning”