The Kerala State Higher Education Council

Foundation Courses for Undergraduate General Programs

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Preface

Most of our universities required an illustrated version of the Guidelines for Foundation Courses of the Four-Year Undergraduate Program (FYUGP), a significant step towards flexible learning introduced as part of higher education reforms in the State committed to improving access, equity, and quality. Unlike the preceding system FYUGP opens multiple learning routes for students coming after higher secondary education.

Education is the process of formation of intellectual, psychological, moral, physical, aesthetic, and cognitive potentials. Higher education is the continuation of the process to help students develop intellectual curiosity, analytical faculty, and problem-solving skills that enable them to secure a profession including production of new knowledge that requires higher order cognition.

Whether you wish it or not we are constrained to be self-consciously realistic about the context of massification and student empowerment through flexibility of personalized options across multiple paths of learning with program outcomes of career demand. Student freedom is the catchword of the revitalized higher education, which gives learning total precedence over teaching and allows higher education anytime, anywhere, any level and any mode with the facility of Academic Bank of Credits, credit transfer, multiple entry, and exit. Further, there are nationally mandated UGC stipulations of quality benchmarks, institutional ranking frameworks, and standards of NAAC accreditation.

All this demands a radical reorientation at the level of students, teachers, and institutions. Higher Secondary Students must understand the new scenario of higher education and be aware of the freedom at their disposal to reposition themselves as curiosity driven self-directed learners. Their usual pattern of learning oriented to teaching and the yearly examination transforms into the one oriented to the primacy of learning and continuous assessment. Learning experiences hitherto confined to the classrooms are rendered plausible in wider and diverse learning spaces such as real-life situations, the local community, the global community of learners, websites, and industries. Websites full of Open Educational Learning Resources (OER) have come up as a veritable mine learning and teaching material.

Today artificial intelligence (AI) not only collects, classifies, correlates, processes, and analyses but also generates new knowledge in no time. ChatGPT through its advanced versions has made learning astonishingly easy and teaching as well as evaluation alarmingly difficult. AI driven Augmented, Virtual and Mixed realities rendered through headsets and spectacles combining the audiovisual with the tactile experiences provide an immersed life-like learning experience. Utilization of these sophisticated digital technologies is not optional anymore for both learners and teachers. Nevertheless, the hope is that the successful use of all this technology depends on the teacher's criticality, creativity, and ingenuity.

Given the option of priorities between web based self-learning and face to face teaching, many of us will privilege the latter. Most universities of high status and ranking feel disturbed by the influx of digital tools in the domain of teaching and learning. They tend to go slow in adopting the rapidly changing digital technologies for they are satisfied with the quality output of meritorious selection of students, regular mentoring, supervised learning, and continuous evaluation. For them a seamless integration of technology is not too difficult. However, countries whose higher education is shoddy need to be forced to catch up so that they are not far behind the global benchmarks.

Higher education in Kerala, a State of high literacy though, is almost entirely dependent on teaching rather than learning, and the assessment entirely dependent on centralized examinations rather than continuous assessment by the teaching faculty. Hence, even at the Postgraduate level learning is cognitively unchallenging. It is in this context Outcome based Education (OBE) aiming to learn and program outcomes of higher levels of cognition have been introduced as stipulated by the UGC.

What we really need are ways of developing students' general abilities for inquiring and thinking critically. Education must equip the younger generation for a life of joy, happiness, service, wisdom, and truth. This can be achieved by developing higher order cognition, which covers mental processes like creative thinking, reasoning, inquiring, critical understanding, and problem-solving. We need to help students understand foundations of knowledge that are beyond discipline. Two perspectives of foundation courses are presented in this report. One is to design foundation courses to dominantly meet a set of Program Outcomes chosen by the University or the Autonomous Institution. The other is to design all foundation courses from a trans-disciplinary perspective making foundational knowledge reach students not through description or explanation but through dialogues.

The Council is indebted to Professors Tara Mohanan and K.P. Mohanan for preparing Transdisciplinary Perspective and Professor N.J. Rao for preparing Programme Outcomes Perspective. We are thankful to Prof. Rajan Gurukkal and Dr. Ananya Das Gupta for the preparation of Foundation Courses 1 and 2 by way of illustrations. The Council is grateful to the entire members of the Committee for the benefit of discussion. Our thanks are due to Dr. Manulal P. Ram for the pagemaking.

Vice Chairman

Kerala State Higher Education Council

Programme Outcomes perspective on Foundation Courses for Undergraduate General Programmes

N.J. Rao

2.1 Introduction

The Foundation Courses are also known as Liberal Arts or General Courses. The purpose of these foundation courses is to impart knowledge, skills and aptitudes that are needed by any graduate from any general three or four-year undergraduate program. The competencies these courses aim to provide are also known as Generic Competencies or Professional Competencies, because they are required in any profession irrespective of the discipline. These are to be designed by Universities, Autonomous Institutions. The non-autonomous institutions follow the courses designed by the affiliating University. This document on Foundation Courses presents all the issues related to Outcome Based Education and the Accreditation processes presently operative in India. This document is indicative in nature, and every University and Autonomous Institution should design their own Foundation Courses in the framework and processes presented.

All courses including the foundation courses are to be designed in the framework of Outcome Based Education (OBE). OBE of General programs, as per the NAAC, requires the outcomes are defined at two levels:

- Program Outcomes and Program Specific Outcomes
- Course Outcomes
- Competencies

As the Foundation Courses are common to all programs, they address only the Program Outcomes. Every course (core or elective) other than foundation courses, projects, co-curricular activities, and extracurricular activities address a subset of the Program Outcomes and Program Specific Outcomes.

Program Outcomes: Program Outcomes are statements that describe what the graduates of the program are expected to know and be able to do. These relate to the knowledge, skills, and behaviour the students acquire through the program.

A course is an element of a general program consisting of several courses belonging to different categories including Foundation Courses, Discipline Core, and Electives. These courses are offered in a specified sequence over eight semesters.

Program Outcomes (POs) are the traits of graduates of any general degree programs, including transferable skills. These are program non-specific and are to be identified by the University/Autonomous Institute. POs presented here are based on a survey of such POs from several Institutions and Associations like AAHE and AAC&U. However, an Institution may consider selecting a subset or superset of these POs and even reword the selected ones to align with its Vision.

Suggested Program Outcomes

PO1. **Critical Thinking**: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

PO2. **Problem Solving**: Understand and solve problems of relevance to society to meet the specified needs using the knowledge, skills, and attitudes acquired from humanities/ sciences/ mathematics/social sciences.

PO3. **Effective Communication**: Speak, read, write, listen clearly in person and through electronic media in English and one Indian language, and make meaning of the world by connecting people, ideas, books, media, and technology.

PO4. **Individual and Teamwork:** Function effectively as an individual and as a member or leader in diverse teams and a wide variety of settings.

PO5. **Ethics**: Understand multiple value systems, including your own, the moral dimensions of your decisions, and accept responsibility for them.

PO6. **Environment and sustainability**: Understand the impact of technology and business practices in societal and environmental contexts and sustainable development.

PO7. **Self-directed and life-long learning**: Demonstrate the ability to engage in independent and life-long learning in the broadest context socio-technological changes.

PO8. **Design Mindset**: Represent and develop tasks and work processes for desired outcomes.

PO9. **Computational Thinking**: Understand data-based reasoning through the translation of data into abstract concepts using computing technology-based tools.

PO10. Effective Citizenship: Demonstrate empathetic social concern and equity-centered national development and act with an informed awareness of issues and participate in civic life through volunteering.

PO11. Global Perspective: Understand the economic, social, and ecological connections that link the world's nations and people.

PO12. Aesthetic Engagement: Demonstrate and master the ability to engage with the arts and draw meaning and value from an artistic expression that integrates the intuitive dimensions of participation in the arts with broader social, cultural, and theoretical frameworks.

It is not necessary to take all the twelve POs given. A subset or even superset of these POs can be considered. The wording of the selected POs can be altered in alignment with the vision and mission of the institute. The first ten POs are selected here for presenting some sample courses

Program Specific Outcomes (PSOs) are outcomes that are specific to a program. They characterize the specificity of the core (core courses) of a program. However, as foundation courses are program non-specific, they need not addressed by foundation courses

Course Outcomes: Course Outcomes are statements on what the students will be expected to do at the end of the course. The number of course outcomes need to be small, around six for a 3-credit course. These statements start with action verbs like understand, compute, determine, model, analyze, select, formulate, architect, specify, design, build, implement, operate, and test.

Competencies: The course outcomes are elaborated, if necessary, into a set of competencies, say 15$\pm$5. Competencies are effective abilities, including attributes, skills, and knowledge, to successfully carry out some activity that is totally identified. The competencies require a small number (1 to 5) of instruction hours and represent well-defined goals. Each competency may be treated as one Instructional Unit.

2.2 Foundation Courses

The Foundation Courses address many of the Program Outcomes that every Institution is required to attain as required by NAAC accreditation. These generic competencies also change with time and fast changing technologies. For example, Information and Communication Technologies (ICT) significantly affect all aspects of life. 21st Century skills also include awareness of role of AI, Data Science, and international cooperation and collaboration to address all the issues related to climate and demographic changes and economic interdependence of all nations. We assume that 40 credits (which is also the recommendation of Vijayan's Committee of KSHEC) are allocated to Foundation Courses in a 3-year 120 credit as well as the 4-year 160 credit UG programs.

The Foundation courses are common for all students, and they can be grouped into five major baskets including Ability Enhancement Courses (AEC), Skill enhancement Courses (SEC), Mathematics, Natural Sciences, and Social Sciences Courses (MNSS), Computing Courses (CC), and Technology and Society Courses (TSC). Each category of courses can be of eight credits. Ability Enhancement courses (AEC) and Skill Enhancement Courses (SEC) constitute one of the requirements of the UGC. A brief description of these course baskets is given below.

(i) Ability Enhancement courses:

These are the courses designed specifically to achieve competency in a Modern Indian Language (MIL) and in the English language with special emphasis on language and communication skills. The courses aim at enabling the students to acquire and demonstrate the core linguistic skills, including critical reading and expository and academic writing skills, they would also enable students to acquaint themselves with the cultural and intellectual heritage of the chosen MIL and English language. Suggested set of courses.

- Critical Reading in Malayalam/Arabic/Hindi/Kannada/Tamil 1:0:1
- Composition/Writing in Malayalam/Arabic/Hindi/Kannada/Tamil 1:0:1
- Critical Reading in English 1:0:1
- Composition/Writing in English 1:0:1

The Boards of Studies of the Universities and Autonomous Institutions can design these courses.

(ii) Skill Enhancement Courses

Skills are psychomotor as well as cognitive. They are about the abilities that students develop to perform various tasks that require psychomotor skills. These skills should facilitate employment particularly in multiple entry and multiple exit situations in Undergraduate programs. These courses can be offered in 1:0:1 or 0:0:2 mode. Some examples of skill enhancement courses include.

- Yoga
- Art Appreciation
- Publishing Tools
- Video Capturing and Editing
- Photography
- Product Rendering
- Animation
- Laboratory Instrumentation (for various sciences)
- 3D Printing

- Horticulture Nurseries
- Water Treatment
- Instrument Maintenance
- Etc.

The Institutions can create many more skill enhancement courses, in addition to these, depending on local requirements. Boards of Studies can identify/design courses relevant to the program. Students can also be given choices taking scheduling and resource issues into consideration.

(iii) Mathematics, Natural Sciences, and Social Sciences Courses

Humanities and Social Sciences students should understand the nature of mathematics and natural sciences, while science students should have an appreciation of social sciences. However, all the courses in this category should be designed aiming at understanding of bigger questions in the fields of study and their methods. These courses can be further sub-grouped into Mathematics, Natural Sciences, and Social Sciences. Each group can have several courses from which students can choose on the advice of the Departmental Committees. Students of all programs can take two credits of Mathematics, three credits of Natural Sciences, and three credits of Social Sciences. Some sample courses are presented in the following.

Mathematics (2 credits each)

- Modelling Natural and Social Systems
- Modelling Biological Systems
- Modelling Physical Systems
- Modelling Chemical Systems

Natural Sciences (3 credits each)

- Knowledge and Inquiry across Disciplines
- Understanding Science
- Understanding Physics
- Understanding Chemistry
- Understanding Biology/Life
- Understanding Climate

Social Sciences (3 credits each)

- History and Philosophy of Science
- Brief History of the World
- Social Organizations and Constitution

- Institutionalism and Constitution
- Political Institutions and Constitution

As these courses are not textbook based, they must be specially designed. As Institutions are not used to these courses an organization such as KSHEC can facilitate the initial design (Course Outcomes, Instruction and Assessment) of these courses. Selected faculty of all Institutions need to be trained in offering these courses. Digital technologies can be heavily used in making the resources and make them available to both students and faculty.

(iv) Computing Courses

All walks of life are at present influenced by information and communication technologies. All graduating students should be able to use the digital technologies in their professions. All students also have computing devices (smart phones, tablets, and /or laptops) and have some familiarity in using these devices in their day-to-day life. The access to smart devices and internet will also increase at the institutional level. Besides, Kerala State is committed to ensure the access of digital technologies at the institutional level. Some sample courses in this category include.

- Computational Thinking 1:0:2
- Data Base Management 1:0:1
- Web Design 1:0:2
- Network Management 1:0:2
- Mobile App Development 1:0:2

(v) Society and Technology Courses (2 credits each)

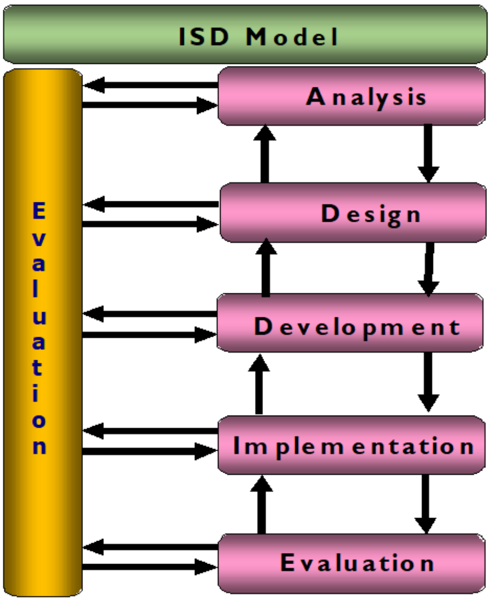
Society and Technology courses address the interface between technology and society. These courses are also multidisciplinary in nature. These courses must be specially designed as there will not be any textbooks available. But enormous resource material is available on the internet. But the challenge is to bring in this material into the confines of one-semester formal courses. KSHEC can facilitate the initial design (Course Outcomes, Instruction and Assessment) of these courses. Some sample courses of this category which can be offered as two credit courses include.

- Energy and Society
- Water and Society
- Climate Change
- Ecology and Environment
- Development (can be offered as a Service Course)
- Pollution
- Poverty
- Complexity
- AI and Society
- Population
- Progress to Resilience
- Food
- Flora and Fauna
- Oceans
- Education
- Schools in India
- Higher Education

Every student will take four courses (2 credits each) from this list. Course related to Environment is to be made compulsory to meet requirements of the UGC. These courses can also be categorized into four groups and a student is required to take one course from each group.

2.3. Guidelines for Designing Courses

The purpose of instruction is to help people learn and develop. The kinds of learning and development may include cognitive, affective, psychomotor, and spiritual. Instructional Systems Design (ISD) Models are the systematic guidelines instructional designers follow to create a workshop, a course, a curriculum, an instructional program, a training session, or the instructional materials and products for educational programs. ISD is a process to ensure learning does not occur haphazardly but occurs using a process with specific, measurable outcomes. The instructional designer's responsibility is to create learning experiences, which ensure that the learners will achieve the goals of instruction. ADDIE is a generic model for instructional system design. The "ADDIE Model" is a colloquial term used since the 1980s, also known as a military model of instruction, to describe a systematic approach to instructional development. It is not a specific, fully elaborated model, but an umbrella term that refers to a family of models that share a standard underlying structure. ADDIE is an acronym referring to the major processes that comprise the generic ISD: Analyse, Design, Develop, Implement, and Evaluate. These processes are sequential and iterative, as depicted in figure.



The basic engine of ISD models is the systems approach. The iterative aspect of the model is represented by arrows in both directions between phases, as depicted in figure. Activities in all phases are accompanied by formative evaluations, as drawn on the model's left side.

The design of a foundation course in a general program is done in five stages as per the ADDIE model. The Analyse, Design, Development, Implement, and Evaluate phase activities require an in-depth understanding of the present-day context and an awareness of technologies available. The instructor needs to appreciate the availability of many instructional methods and learning resources. He can now facilitate students to learn as per his/her view of good learning.

The instructor can completely design his/her course using the ADDIE Templates for all the five phases given as Annexures. The sub-processes of ADDIE stages of designing a course in a general program are elaborated in the Indian context.

The courses are to be described as a set of Course Outcomes the students should attain. Every institution should have one common well-defined method of computing the attainment of course outcomes. Learning takes place in three domains: Cognitive, Affective, and Psychomotor. Every learning experience consists of activities in all three domains to varying degrees. At present there is better understanding of cognitive and psychomotor domains. There are several taxonomies of cognitive domain, all are projects in progress. Though not mandated by any agency, Revised Bloom's Taxonomy (RBT) of learning is de facto followed in India. RBT of cognitive domain is two dimensional with six cognitive levels (processes) and four categories of knowledge. The Pierce-Gray taxonomy of affective domain and psychomotor domain closely aligns with Revised Bloom's taxonomy of cognitive domain. The course outcomes in cognitive domain may be written following the structure proposed by Mager. According to this a CO statement can have four elements: Action, Knowledge elements, Condition, and Criteria. Of these elements the Action and Knowledge elements are compulsory, and the remaining two are optional. A course outcome written as per this structure can become observable and measurable which are two important characteristics of a CO.

It should be noted that majority of higher education institutes of Kerala State are non-autonomous and affiliated to a university. This requires design (course outcomes, assessment, and evaluation) of courses is done in centralized manner.

The single most crucial feature of the ADDIE model is the identification, at the beginning of instruction design, of instructional objectives, which we refer to here as outcomes. The activities in a phase will significantly depend on the nature of and the context of the course. The context is defined by the nature of the audience and their background, the environment in which the instruction occurs, and the technologies used.

Analyse Phase: As general programs are formal, elaborate mechanisms exist for selecting students to these programs, and the curriculum identifies the course structure and prerequisites of each course. The Analysis of audience and entry behaviours need not be undertaken for each course. The time and budget constraints also do not change from one course to the other very much. All courses are of one-semester duration and have a well-defined credit load. Therefore, the analyse phase's primary task is the identification of instructional goals (Course Outcomes). A Foundation course, described by its Course Outcomes, can only meet a subset of these POs. The sub-processes of the analyse phase for a Foundation course in a general program are.

1. Write the course context and overview.
2. Write 6 to 8 Course Outcomes for a 3-credit course that can be measured for attainment, and marking them with relevant POs, Cognitive Level, Knowledge Categories, and the sessions (classroom, tutorial, and laboratory) required.
3. Locate the Course Outcomes in the taxonomy table.

4. Write a minimum of four representative test items for each course outcome at its cognitive level and mastery level expected by the instructor, and sample solutions to these test items that would reflect the instructor's way of integrating course outcomes and selected POs.
5. Prepare Course-PO matrix (row), also known as course articulation matrix, of the course.
6. Elaborate Course Outcomes into 15$\pm$5 Competencies of the course to facilitate instructional planning.
7. Create the concept map of the course (optional).
8. Have the output of the analyse phase peer-reviewed and make the changes needed.

Worksheet for Analyse Phase and related instructions are presented in Annexure 1.

Design Phase: The design phase represents activities that enable the course designer to generate a plan according to which the instruction would be conducted, an assessment plan, and an Item Bank. These provide the basis for developing instructional material and learning material. The activities of the design phase for a Foundation Course in a general program may be listed as

1. Select delivery technologies.
2. Set targets for COs attainment.
3. Determine the assessment plan.
4. Create the Item Bank as per the assessment plan.
5. Have the outputs of the design phase, peer-reviewed, and modifying them if necessary.

Develop Phase: The develop phase represents activities that convert the blueprints created in the design phase to instructional materials and learning materials. Each competency represents one Instructional Unit. The activities of the develop phase of an engineering course consist of

1. Prepare the instructional plan.
2. Prepare a script for each Instructional Unit
3. Prepare instructional materials as per the script for all Instructional Units.
4. Select and/or prepare learning materials for all Instructional Units of the course.
5. Have the outputs of develop phase peer-reviewed and modifying them if necessary.

Implement Phase: Instructors conduct the course as per the instructional plan prepared in the Design Phase using instructional material and learning material prepared in Develop Phase. However, each instance of course conduct is likely to be slightly different based on the context and time of offering. Implement phase presents specifics of an instance of offering. It involves preparing and communicating the Syllabus of the course, planning resources for conducting the course, scheduling instruction, creating specific assessment instruments, giving feedback to students after every assessment, and tracking students' performance. The specific elements of the implement phase are.

1. Prepare Syllabus.
2. Plan resources needed.

3. Take student feedback during the session.
4. Create sample structures of Assessment Instruments.
5. Create Assessment Instruments to be used in the current semester.
6. Record observations on Assessment Instruments and Student Performance.
7. Give feedback to students after every assessment.
8. Track students' progress.
9. Have the outputs of implement phase peer reviewed and modify them if necessary.

Evaluate Phase: Every instance of course conduct should be evaluated to plan for improvements to the next instance of the course offering. The evaluation can be self-evaluation by the instructor as well as by peers. The activities of the evaluate phase include.

1. Collect student feedback at the end of the course.
2. Compute CO attainment and from there PO and PSO attainment.
3. Make summary observations.
4. Collect peer feedback.
5. Plan for reducing the CO attainment gap or increasing CO attainment targets.
6. Have the outputs of evaluate phase peer reviewed and modify them if necessary.

Worksheets for Design Phase, Develop Phase, Implement Phase, and Evaluate Phase are given in a more detailed document on Course Design.

ADDIE instructional system design and the suggested sub-processes for its five phases will facilitate teachers to design their courses in the framework of OBE and NAAC accreditation. The Worksheets presented in Annexure 1and elsewhere will ensure the quality of course design process.

2.4 Sample Courses

The sample courses are indicative. They present the Course Context and Overview, and Course Outcomes tagged with POs, Cognitive Levels, Knowledge Categories, and the number of sessions. Every University can redefine the courses including the titles of courses. Once these approaches and methods are accepted the courses can be designed in detail with the help of experts in the area. The companion document on Course Design for General Courses can help in designing the courses in detail. It should be remembered that the students learn according to their perception of assessment.

In all course descriptions we follow these abbreviations.

CL: Cognitive Level, R: Remember, U: Understand, Ap: Apply, An: Analyze, E: Evaluate, C: Create KC: Knowledge Categories, F: Factual, C: Conceptual, P: Procedural

Ecology and Environment

Credits: 3:0:0

Course Designers: T.V. Ramachandra and M.D. Subhash Chandran

Course Context and Overview

Ecology is the study of how living (biotic) and non-living (abiotic) parts of the environment interact and depend on each other. This means, it is the study of the inter-relationships between organisms and their environment. It includes how organisms are impacted by their environment and how they, in turn, impact their environment. The biotic, or living, things in an environment would include plants, animals (this includes humans), bacteria, fungi, and all other living things. The abiotic or non-living parts of the environment would include things like sunlight, soil, atmosphere, climate, nutrients, and water. In fact, if you partition ecology "eco" would imply house and "logos" would mean to study. So, we are studying about our house in the biggest sense, which is our planet Earth!

When we study the ecology of certain areas, we refer those areas with the biotic and abiotic factors as ecosystems. An ecosystem can be small like a puddle or garden in your backyard, with only a few organisms interacting or it may be large, like a forest with lots of organisms interacting in it. All living things in an ecosystem need energy to survive. One of the major functions of life in an ecosystem is finding energy and the main source of energy for life on earth comes from the sun. Plants use light energy from the sun to produce food. Organisms that use the sun for producing food are called **producers**. Algae, grass, trees, and vegetables are all **producers**. The cycle of organisms eating and being eaten is an example of interaction in the environment.

Organisms that get energy by eating other organisms are called **consumers**. Consumers eat producers or other consumers for their energy. This transfer of energy creates a food chain. Most consumers and decomposers get energy from more than one kind of food. Overlapping food chains create food webs. The populations (groups) of specific plants and animals that live together in an ecosystem make up a **community**. Each species occupies a certain role or "**niche**" in the community. A species "**niche**" includes how a plant or animal uses the living and non-living resources. No two species in a community have the same niche.

'**Environment**' refers to a surrounding where conditions influence development or growth. Various living beings like animals including man, birds, insects, rodents, and microorganisms like algae, fungi, protozoa, and non-living beings like the soil, the water, and the air are interrelated in this life sustaining system. It is a complex web in which man is only a small, tiny creature. Man, as such, lives in two environments. One is the natural world of plants, animals, soils, air, and water that preceded us by billions of years and of which we are a part. The other is the world of social institutions and artifacts that we create for ourselves using science, technology, and political organization. Both worlds are essential to our lives but integrating them successfully causes persistent tensions.

In this Course, first, we introduce you to how life evolved on our planet earth. Ecosystems are constantly changing due to natural processes as well as due to human induced changes. Natural processes like earthquake, floods, volcanoes, etc. and human activities often replace grasslands and forests. Some changes to an ecosystem like a species becoming extinct may be hard to see, while others like forest fires or volcanoes are easier to see and understand. The study of ecology helps us understand these processes. Hence, we will take up discussion on abiotic and biotic components of the earth. All ecosystems depend on natural cycles, namely water, nitrogen, carbon, etc., which we will discuss next. Subsequently, we will present an overview of various biomes, wherever we live. We are part of a large ecosystem called a **Biome**. A **biome** is a large geographical area of distinctive plant and animal groups, which are adapted to that environment. The climate and geography of a region determines what type of biome can exist in that region. Major biomes include terrestrial (deserts, forests, grasslands, tundra, etc.) and several types of aquatic environments. Each biome consists of many ecosystems whose communities have adapted to the minor differences in climate and the environment inside the biome.

Living place of a plant or animal is known as a **habitat**. When we talk about an animal or a plant's home it is more like a neighbourhood. To survive in its habitat, an animal needs —food, water, shelter, and a place to raise its young. There are many diverse plants and animals that will share the same habitat. The animals and plants that live together in a habitat form a "**community.**" The community of living beings interacts with the non-living world around it to form the **ecosystem.** In the section on population, we shall discuss concepts of population and carrying capacity of an ecosystem.

Resources like water and food are limited, plant and animal species often compete for food and water. The only way that they can all live together is when they occupy slightly different **niches** as two species cannot occupy the same niche. A niche is the smallest unit of a habitat that is occupied by a plant or animal. The habitat niche is the physical space occupied by the plant or animal. The ecological niche is the role the plant or animal plays in the community found in the habitat. The last section focuses on issues such as i) Why rapid human population growth is the fundamental environmental issue; ii) how to sustain natural resources so that they are available to our next generation; iii) how human actions influence the environment of the entire planet and iv) global perspective of environmental issues.

Program Outcomes

PO1. Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

PO2. Problem Solving: Understand and solve problems of relevance to society to meet the specified needs using the knowledge, skills, and attitudes acquired from humanities/ sciences/ mathematics/social sciences.

PO3. Effective Communication: Speak, read, write, listen clearly in person and through electronic media in English and one Indian language, and make meaning of the world by connecting people, ideas, books, media, and technology.

PO4. Individual and Teamwork: Function effectively as an individual and as a member or leader in diverse teams and a wide variety of settings.

PO5. Ethics: Understand multiple value systems, including your own, the moral dimensions of your decisions, and accept responsibility for them.

PO6. Environment and sustainability: Understand the impact of technology and business practices in societal and environmental contexts and sustainable development.

PO7. Self-directed and life-long learning: Demonstrate the ability to engage in independent and life-long learning in the broadest context socio-technological changes.

PO8. Design Mindset: Represent and develop tasks and work processes for desired outcomes.

PO9. Computational Thinking: Understand data-based reasoning through the translation of data into abstract concepts using computing technology-based tools.

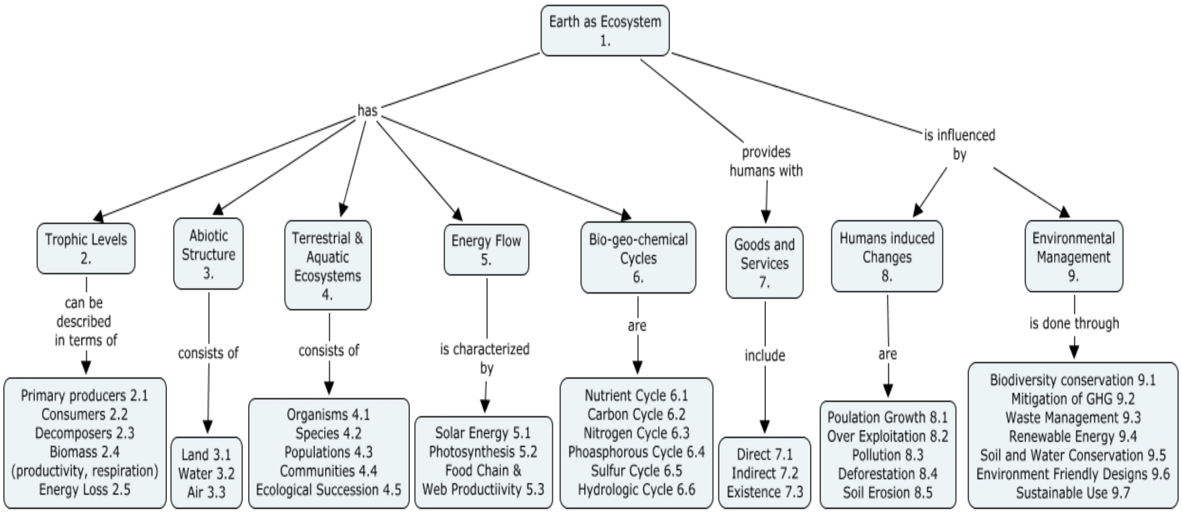
PO10. Effective Citizenship: Demonstrate empathetic social concern and equity-centered national development and act with an informed awareness of issues and participate in civic life through volunteering.

Course Outcomes: After completing the Course, the candidate should be able to

	Course Outcome	POs	CL	KC	Class (Hrs.)
CO1.	Demonstrate an understanding of energy, entropy, laws of thermodynamics	PO1, PO6, PO7	U	F, C	4
CO2.	Understand the relationships among biotic and abiotic components of an ecosystem.	PO1, PO6, PO7	U	F, C	4
CO3.	Compute the upper limit on the production of biological resources, including forests, fisheries, wildlife, and endangered species tracing energy flow.	PO6, PO7	Ap	F, C, P	5
CO4.	Compute energy loss from a producer to consumer	PO6, PO7	Ap	F, C, P	5
CO5.	Demonstrate an understanding of regional water cycle and global hydrologic cycles.	PO1, PO6, PO7	U	F, C, P	5
CO6.	Determine how the movement and storage of materials influences all physical, chemical, and biological processes on Earth.	PO6, PO7	Ap	F, C, P	5
CO7.	Analyze nutrient cycle for disturbed landscape versus the one with forests.	PO1, PO6, PO7	An	F, C	4
CO8.	Determine the changes effected by life on Earth on the cycling of chemicals in the air, water, and	PO1, PO4, PO6, PO7	Ap	F, C, P	4

	soil.				
CO9.	Understand the intricate relationships between different species and between species and their environment from the conservation of biodiversity perspective.	PO1, PO6, PO7	U	F, C	4
CO10.	Analyze the role of ecological succession in the restoration and recovery of damaged lands.	PO1, PO6, PO7	An	F, C	5
Total					45

Concept Map of the course



Course: Energy and Society

Credits: 3:0:0

Course Designers: N.J. Rao, B. **Sudhakara Reddy, and G. Anil Kumar**

Course Context and Overview:

Energy and Society is a course proposed to be offered in undergraduate Engineering and General programs either as an open elective or as a core course. To take this course, a student should have prerequisite knowledge of high-school Physics and Mathematics. They should have knowledge of energy, thermodynamics, and electricity at the high school and pre-university levels.

This course is designed to enable a student to appreciate the diverse aspects of energy and its impact on society.

Energy is the ability (or capacity) to do work. Energy forms the central force to drive all human or natural systems. Energy has many forms. It can be converted from one form to another. It can also be transformed from one grade of the same energy form to another. We require energy for lighting, heating, cooling, ventilation, cooking, cleaning, pumping, transportation, health, entertainment, and practically for everything we do.

Entropy is a thermodynamic property used to determine the amount of energy not available for useful work, such as energy conversion devices, engines, or machines. When these devices are used, entropy accumulates in a system and is removed by dissipation in the form of waste heat. The use of energy always results in increased entropy.

Energy is required for the survival of life. Energy is a crucial source of economic growth, industrialization, and urbanization. Access to energy is a prerequisite to improving the quality of life. Since the advent of the Industrial era, energy systems have enabled mechanization of all productive sectors. All production and many consumption activities involve energy as an essential input.

This course will start with an understanding of the centrality of energy in life. Then it presents the non-renewable and renewable energy chains and the different elements of it, particularly concerning India. The cost and performance of these energy chains are estimated. Critical factors that influence the performance of the energy chains are explored. Energy usage is characterized by the increase in entropy in a system. The concept of entropy is introduced from a thermodynamic perspective, and its relation to human progress is analyzed. The course will also trace the brief history of the world from the standpoint of energy usage.

The impact of energy use on the quality of life of society and the environment, energy efficiency, institutions governing the planning and management of energy systems will be explained as part of the course. The course will also look into the near future concerning energy.

As part of the course, students will be encouraged to conduct an energy audit of small energy systems to understand and evaluate energy use in different settings such as a household, a neighborhood, or a small commercial establishment. They will also assess the 'ecological footprint' of individuals, families, institutions, and regions.

The course's instruction will involve lectures, group discussions, case studies, seminar presentations, and a mini project. The subject matter will be illustrated with demonstrations and examples. Student and group activities will allow students to experience the central role of energy and entropy in everything we do.

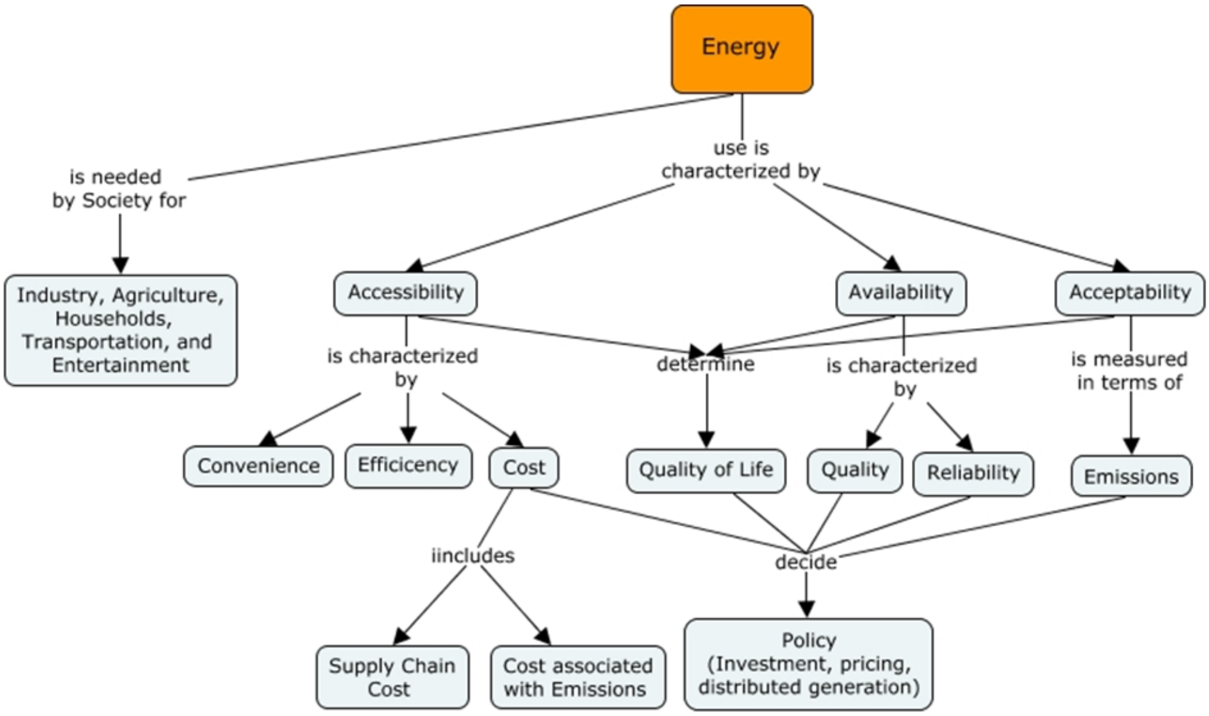
Program Outcomes:

PO1.	**Critical Thinking**: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.
PO2.	**Problem Solving**: Understand and solve problems of relevance to society to meet the specified needs using the knowledge, skills, and attitudes acquired from humanities/ sciences/ mathematics/social sciences.
PO3.	**Effective Communication**: Speak, read, write, listen clearly in person and through electronic media in English and one Indian language, and make meaning of the world by connecting people, ideas, books, media, and technology.
PO4.	**Individual and Teamwork:** Function effectively as an individual and as a member or leader in diverse teams and a wide variety of settings.
PO5.	**Ethics**: Understand multiple value systems, including your own, the moral dimensions of your decisions, and accept responsibility for them.
PO6.	**Environment and sustainability**: Understand the impact of technology and business practices in societal and environmental contexts and sustainable development.
PO7.	**Self-directed and life-long learning**: Demonstrate the ability to engage in independent and life-long learning in the broadest context socio-technological changes.
PO8.	**Design Mindset**: Represent and develop tasks and work processes for desired outcomes.
PO9.	**Computational Thinking**: Understand data-based reasoning through the translation of data into abstract concepts using computing technology-based tools.
PO10.	**Effective Citizenship**: Demonstrate empathetic social concern and equity-centered national development and act with an informed awareness of issues and participate in civic life through volunteering.

Course Outcomes: At the end of the course, the students should be able to

	Course Outcome	POs	CL	KC	Class (Hrs.)
CO1	Understand the centrality of Energy in Life.	PO1, PO6, PO7	U	F, C	4
CO2	Understand the characteristics of renewable and non-renewable energy supply chains.	PO1, PO6	U	F C	6
CO3	Understand the relationship between entropy and progress.	PO1, PO6, PO7	U	F, C	5
CO4	Understand the impact of energy on the quality of life.	PO1, PO6	U	F, C, P	5
CO5	Determine the impact of energy use on the environment.	PO1, PO4, PO7	Ap	F, C, P	6
CO6	Determine the relationship between energy use and the economy.	PO1, PO4, PO6	Ap	F, C, P	6
CO7	Understand the working of energy management systems in India.	PO1, PO6	U	F	4
CO8	Conduct an energy audit.	PO4, PO6,	Ap	F, C, P	5
CO9	Analyze the present energy scenario and options for the future.	PO1, PO4, PO6	An	F, C	4
				Total	42

Concept Map of the Course



History and Philosophy of Science

Credits: 3:0:0

Course Designer: Rajan Gurukkal

Course Context and Overview

This is a 3-credit Foundation Course that seeks to provide a social history of the emergence of science together with its philosophical aspects. It covers the socio-political context of the development of knowledge production involving ideas, observations, and experiments as well as the process of methodological changes involving logical criticisms and refined reasoning for enhanced reliability. The main content of the philosophical part covers: 1) deductive, empirical, and inductive reasoning of axioms, laws of fundamental scientific theories; 2) philosophical interpretation of scientific knowledge.

It enables students to examine the interplay between attempts at explanations of the physical phenomena around us and the critical examination of the logic of explanations. The Course is expected to facilitate students to understand the intertwined and non-linear ways of discovering by scientists and their sceptical scrutiny by philosophers, both supplying new ideas for furthering the process. Students will learn how each landmark interpretation opened a door to the new world of ignorance for scientists to improve discoveries and philosophers to sharpen the logic of intellectual explanations. This has been a continuous process of falsification and substitution of explanations with alternatives in the light of new evidence. This is not to mean that Philosophy always follows scientific discoveries. Sometimes philosophical speculations and methodological preoccupations anticipate scientific discoveries. In short, it briefly explores the story of production and systemic transformation of knowledge over centuries with a view to enabling students to understand research, pathbreaking interpretations, and philosophical exercises as continuous and mutually linked up processes.

History and philosophy of science as a combine allows students to stand back from the specialised concerns of their other subjects and gain some perspective on what science is, how it came to acquire its current form and how it fits into contemporary society.

The students will start by learning features of early knowledge systems of astronomy, mathematics, and philosophical questions like modes of inquiry, analytical skill, logical argument, and criticism with reference to Indic, Hellenistic, Chinese, and Islamic cultures. Next, they learn subsequent development by way of mile-stone discoveries in various cultures followed by the path-breaking turns in Europe's Natural Philosophy with Isaac Newton and the Newtonian Era of Enlightenment, Reason, and the making of science. Our next point of focus is the hermeneutic turn the history of science takes with Einstein and further through Quantum Physics heralding the New Science of Uncertainty. In the concluding part, a review of the latest trends in science may be explored.

Program Outcomes

PO1. Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

PO2. Problem Solving: Understand and solve problems of relevance to society to meet the specified needs using the knowledge, skills, and attitudes acquired from humanities/ sciences/ mathematics/social sciences.

PO3. Effective Communication: Speak, read, write, listen clearly in person and through electronic media in English and one Indian language, and make meaning of the world by connecting people, ideas, books, media, and technology.

PO4. Individual and Teamwork: Function effectively as an individual and as a member or leader in diverse teams and a wide variety of settings.

PO5. Ethics: Understand multiple value systems, including your own, the moral dimensions of your decisions, and accept responsibility for them.

PO6. Environment and sustainability: Understand the impact of technology and business practices in societal and environmental contexts and sustainable development.

PO7. Self-directed and life-long learning: Demonstrate the ability to engage in independent and life-long learning in the broadest context socio-technological changes.

PO8. Design Mindset: Represent and develop tasks and work processes for desired outcomes.

PO9. Computational Thinking: Understand data-based reasoning through the translation of data into abstract concepts using computing technology-based tools.

PO10. Effective Citizenship: Demonstrate empathetic social concern and equity-centred national development and act with an informed awareness of issues and participate in civic life through volunteering.

Course Outcomes: After completing the Course, the students should be able to

	Course Outcome	POs	CL	KC	Class (Hrs.)
CO11.	Explain the nature of history, philosophy, science, and scientific method	PO1, PO3, PO7	U	F, C	8
CO12.	Understand how knowledge was produced during Greek, Roman, Indic, Chinese and Islamic societies, and during Renaissance period.	PO1, PO3, PO7	U	F, C	6
CO13.	Understand epistemological turn of Natural Philosophy during 16th to 18th centuries through	PO1, PO3,	U	F, C	7

	the works of scientists of that period including Copernicus, Kepler, Galileo, and Newton	PO7			
CO14.	Understand the nature of scientific methodology as developed in science since 19th century	PO1, PO7	U	F, C	8
CO15.	Understand the hermeneutic turn the history of science takes with Einstein and further through Quantum Physics heralding the New Science of Uncertainty.	PO1, PO7	U	F, C	6
CO16.	Analyze how scientific revolutions take place	PO1, PO7	An	F, C	4
CO17.	Evaluate ethical implications of scientific progress through current developments in science	PO1, PO5, PO7	E	F, C	6
				Total	45

(CL: Cognitive Level, KC: Knowledge Categories, U: Understand, An: Analyse, E: Evaluate, F: Factual Knowledge, C: Conceptual Knowledge)

References

1. Thomas Kuhn (1970), The Structure of Scientific Revolutions, Enlarged Edn. London: University of Chicago Press.
2. Timothy McGrew, Marc Alspector-Kelly & Fritz Allhoff (2009), The Philosophy of Science: An Historical Anthology, New Jersey: Wiley-Blackwell
3. Karl Popper (2002), The Logic of Scientific Discovery, 2nd Edn. Paperback, London: Routledge
4. Sundar Sarukkai (2020), What is Science? New Delhi: National Book Trust of India
5. Rajan Gurukkal (2019), History and Theory of Knowledge Production, New Delhi: Oxford University Press,

Course: Computational Thinking

Credits: 1:0:2

Course Designer: L. Srinivasan

Course Context and Overview

Computational thinking is a problem-solving approach that draws upon concepts from computer science, enabling individuals to formulate solutions to a wide range of real-world challenges with the potential to be executed on a theoretical computer. As the influence of computing extends across various domains in contemporary society, encompassing not only software development and engineering but also reaching into business, the humanities, and everyday life, the mastery of computational thinking has emerged as an indispensable skill in the 21st century. This methodology rests upon four foundational principles: decomposition, identifying patterns, representing, and abstracting data, and crafting algorithms.

Currently, computational thinking is broadly defined as a set of cognitive skills and problem-solving processes that include (but are not limited to) the following characteristics.

- Using pattern recognition to arrive at abstractions by logically organizing and analysing data.
- Breaking down interactions between abstractions into smaller parts (Decomposition)
- Represent the interactions using techniques such as iteration, symbolic representation, and logical operations into a serious ordered step (algorithmic thinking)
- Implementing possible solutions using the abstractions Identifying, analysing processes. (Procedural Thinking).

This course is offered as an undergraduate foundational course. The course does not assume any prior exposure to computer programming or exposure computational thinking. The course will predominantly run as "Non-Programming Course '' where the data types basic (Integer, real numbers, text) and composite (arrays and structures) data types are used to represent information, and pseudocode is used to represent procedures. Optionally a subset of Python language can be used in the implementation of the course.

Program Outcomes (POs):

PO1. Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

PO2. Problem Solving: Understand and solve problems of relevance to society to meet the specified needs using the knowledge, skills, and attitudes acquired from humanities/sciences/ mathematics/social sciences.

PO3. Effective Communication: Speak, read, write, listen clearly in person and through electronic media in English and attest one Indian language, and make meaning of the world by connecting people, ideas, books, media, and technology.

PO4. Individual and Teamwork: Function effectively as an individual and as a member or leader in diverse teams and a wide variety of settings.

PO5. Ethics: Understand multiple value systems environmental contexts and sustainable development.

PO6. Environment and sustainability: Understand the impact of technology and business practices in societal and, including your own, the moral dimensions of your decisions, and accept responsibility for them.

PO7. Self-directed and life-long learning: Demonstrate the ability to engage in independent and life-long learning in the broadest context of socio-technological changes.

PO8. Design Mindset: Represent and develop tasks and work processes for desired outcomes.

PO9. Computational Thinking: Understand data-based reasoning through the translation of data into abstract concepts using computing technology-based tools.

PO10. Effective Citizenship: Demonstrate empathetic social concern and equity-centered national development and act with an informed awareness of issues and participate in civic life through volunteering.

Course Outcomes: At the end of the course the student should be able to

CO	**Course Outcome**	**PO/ PSO**	**CL**	**KC**	**Class Hrs.**	**Lab Hrs.**
CO1.	Define Abstraction by observing patterns in each life situation including language, art, mathematics, and science.	PO1, PO2, PO9	U	C	3	6
CO2.	Identify objects (instances) of concepts in each life situation including language, art, mathematics, and science.	PO1, PO2, PO9	U	C	4	12
CO3.	Write pseudocode to represent a scenario of interaction between the objects in given life situation including languages, art, mathematics, and science using symbolic representation, expressions (arithmetic/ logical), conditional, iterations and named procedures	PO1, PO2, PO4, PO9	C	C, P	4	30
CO4.	Verify the pseudocode for clarity, accuracy,	PO1,	E	C	4	12

	and precision.	PO2, PO4, PO9				
Total Number of Hours					15	60

Course: Database Management Systems

Credits: 1:0:1

Instructor: Gururaj P.

Course Overview and Context

Database management system course on Database Management Systems, taught hands-on with simple real-life examples and generalizing the concepts with specific examples with which the students can relate.

Program Outcomes

PO1. Critical Thinking: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

PO2. Problem Solving: Understand and solve problems of relevance to society to meet the specified needs using the knowledge, skills, and attitudes acquired from humanities/sciences/ mathematics/social sciences.

PO3. Effective Communication: Speak, read, write, listen clearly in person and through electronic media in English and one Indian language, and make meaning of the world by connecting people, ideas, books, media, and technology.

PO4. Individual and Teamwork: Function effectively as an individual and as a member or leader in diverse teams and a wide variety of settings.

PO5. Ethics: Understand multiple value systems, including your own, the moral dimensions of your decisions, and accept responsibility for them.

PO6. Environment and Sustainability: Understand the impact of technology and business practices in societal and environmental contexts and sustainable development.

PO7. Self-directed and life-long learning: Demonstrate the ability to engage in independent and life-long learning in the broadest context socio-technological changes.

PO8. Design Mindset: Represent and develop tasks and work processes for desired outcomes.

PO9. Computational Thinking: Understand data-based reasoning through the translation of data into abstract concepts using computing technology-based tools.

PO10. Effective Citizenship: Demonstrate empathetic social concern and equity-cantered national development and act with an informed awareness of issues and participate in civic life through volunteering.

Course Outcomes

	Course Outcome	PO/PSO	CL	KC	Class Hrs.	Lab Hrs.
CO 1	Organize data as a table to represent entities involving concepts of objects, invariants, coherence, and coupling.	PO2, PO9	Ap	C, P	3	4
CO2	Implement a database as a repository of tables and metadata with 2-tier, 3-tier, and 4-tier database architecture.	PO2, PO9	Ap	C, P	3	4
CO3	Design a database involving data models, schemas, data types, keys, constraints, and instances.	PO2, PO9	Ap	C, P	2	4
CO4	Perform basic CRUD operations on a single table using the concepts of DDL, DQL, DML and DCL.	PO2, PO9	Ap	C, P	3	6
CO5	Perform aggregation using GROUP BY and ORDER BY operations	PO2, PO9	Ap	C, P	2	6
CO6	Implement indexes on single and multiple keys of database.	PO2, PO9	Ap	C, P	2	6
Total Number of Hours					15	30

Textbooks

1. Abraham Silberschatz, Henry F. Korth, and S. Sudarshan: Database System Concepts.
2. Elmasri and Navathe: Fundamentals of database Systems.

References

1. Jeffrey D. Ulman: A First Course in Database Systems.
2. Charles Severance: Python for Everybody (Chapter 15).

Course: Academic Writing

Credits: 3.0.0

Course Designer: Anannya Dasgupta

Course Context and Overview

This course is an introduction to the genre of the persuasive essay - written to persuade readers of an argument with the help of evidence - in that it will focus on the academic essay and all its elements that are required for students to demonstrate in college level writing. The courses will have between **3-5 readings** - exemplary examples of effective persuasive writing from long-form journalism, science communication, academic journal articles and book chapters from different academic disciplines in the social sciences and humanities.

The readings will be the basis for learning the **features of academic writing - both formal and conceptual.** In other words, as a part of the reading strategies students will learn to identify structural elements that academic writers adhere to such as - types of paragraphs, elements that make up different paragraphs - especially body paragraphs, the mechanics of quote use to produce evidence, citation systems, the relationship between in-text citation, footnotes / endnotes and the works cited list. Strategies to recognize the conceptual features in the readings will involve **identifying the main argument and the smaller claims** that support it as drawn from the different sources used to **build evidence**. Students will learn to track the strategies different authors use to make an argument and develop that idea through the length of the essay. Students will learn to read and think through the process of writing. To enable reading strategies, students will learn to **demonstrate reading comprehension** in accurate summaries, do descriptive writing and distinguish where in their readings, authors use summary and description and where their observations begin to add up to moves towards analysis.

The academic writing part already begins with the reading strategies and targeted worksheet exercises which will include responses crafted into paragraphs no more than 250-300 words that follow all the rules of formal paragraphing. Some strategies crucial to how text is generated by thinking about source readings and writing it out include - close / attentive reading (as written out), and ideas generated by connecting ideas in the different assigned readings that may be on disparate, unconnected topics**.**

Strategies of close reading and forming connections will be broken down to smaller exercises for what constitutes analysis - or coming up with an explanation for what a reading or idea means, from which one may draw the ideas for one's argument. To begin to put all the reading strategies, and tools of analysis together, students will be assigned essay prompts to begin learning the drafting process of academic essays as one of reading-writing-reviewing-rewriting. The essay prompts assigned will allow a gradual building up to a 1500-1700 essay draft that draws on the readings as sources for evidence.

So far, as is evident, the premise of academic writing is that it is built on the work of existing research and scholarship (or source material) that one reads and puts together in conversation to come up with a new insight, or new idea of one's own. **The goal of writing academic essays is to produce new ways of looking at source texts, to carefully observe them for their content, structure, and techniques of analysis to be able to connect ideas to produce new knowledge**. However, to reach this end goal one must **practice reading-writing-reviewing-rewriting** in multiple drafts of incremental word limit as assigned in class. A very important part of the drafting process is learning how to receive and give feedback for revision. Different feedback methods such as instructor feedback, peer review and self-review will help students effectively work with feedback for revision.

The pedagogy of the course relies on the **workshop-method** where student participation and response drive the success of the course. Classroom discussions and oral presentations and responses complement the written assignments in learning to express and communicate complex ideas clearly and gracefully. Along with methods of argumentation the course will also address the appreciation of style, question of voice, and the joys of learning to construct thoughtful and elegant sentences. Finally, the course will put the **ethics of scholarship** into practice. What constitutes plagiarism? What can we do to avoid it? What do we need to know about generative AIs like Chat-GPT before we use them? What kind of uses of CHAT-GPT fall within the realm of plagiarism, and how might it be avoided?

Program Outcomes

PO1. **Critical Thinking**: Take informed actions after identifying the assumptions that frame our thinking and actions, checking out the degree to which these assumptions are accurate and valid, and looking at our ideas and decisions (intellectual, organizational, and personal) from different perspectives.

PO2. **Problem Solving**: Understand and solve problems of relevance to society to meet the specified needs using the knowledge, skills, and attitudes acquired from humanities/ sciences/ mathematics/social sciences.

PO3. **Effective Communication**: Speak, read, write, listen clearly in person and through electronic media in English and one Indian language, and make meaning of the world by connecting people, ideas, books, media, and technology.

PO4. **Individual and Teamwork:** Function effectively as an individual and as a member or leader in diverse teams and a wide variety of settings.

PO5. **Ethics**: Understand multiple value systems, including your own, the moral dimensions of your decisions, and accept responsibility for them.

PO6. **Environment and sustainability**: Understand the impact of technology and business practices in societal and environmental contexts and sustainable development.

PO7. **Self-directed and life-long learning**: Demonstrate the ability to engage in independent and life-long learning in the broadest context socio-technological changes.

PO8. **Design Mindset**: Represent and develop tasks and work processes for desired outcomes.

PO9. **Computational Thinking**: Understand data-based reasoning through the translation of data into abstract concepts using computing technology-based tools.

PO10. **Effective Citizenship**: Demonstrate empathetic social concern and equity-centered national development and act with an informed awareness of issues and participate in civic life through volunteering.

Course Outcomes: Upon Completion of the Course students will be able to

	Course Outcome	POs	CL	KC	Class (Hrs.)
CO1.	Summarize the argument of the readings and identify the formal features, including types of paragraphs, argument and evidence, citation style, notes, and works cited list, of academic essays by formulating and asking questions with help of text.	PO1, PO7	U, An	F, C	8
CO2.	Make connections between readings using the techniques of analysis and argumentation	PO1, PO7	An	F, C	8
CO3.	Format an academic essay as per the recommended style guide and citation system.	PO3	C	C, P	3
CO4.	Draft paragraphs/papers narrating the argument, the clarity of the author’s voice, sophisticated arguments, and how students understand to form complex ideas	PO1, PO7	C	F, C, P	15
CO5.	Revise a given draft though peer review, self-review, and taking and giving feedback	PO3, PO4, PO7	Ap	F, C, P	4
CO6.	Identify and fix common patterns of grammatical and syntactical errors while paying attention to sentence construction and style.	PO3	U, Ap	F, C, P	2
CO7.	Perform group discussions and oral presentations.	PO1, PO3, PO4	Ap	F, C, P	2

CO8.	Avoid plagiarism in your essays and reports including from generative AIs such as Chat-GPT	PO5	Ap	F, C, P	3
				Total	45

Suggested Readings:

1. Appadurai, Arjun. "Gratitude as a Social Mode in South India" Ethos 13.3, 1985, 236-245
2. J. Derrick. "Silencing". *A Language Older Than Words*, Chelsea Green Pub. 2000, pp. 1-16.
3. Koenig, John. "Beautiful new words to describe obscure emotions." TED Talk. Video. https://www.ted.com/talks/john_koenig_beautiful_new_words_to_describe_obscure_emotions/transcript?language=en
4. Philip, Kavita. "The Internet Will Be Decolonized." *Your Computer Is on Fire*. Eds. Thomas Mullaney, Benjamin Peters, Mar Hicks, Kavita Philip. MIT Press, 2021, pp. 90-115.
5. Sandikei, Özlem, and Güliz Ger. "Veiling in Style: How Does a Stigmatized Practice Become Fashionable?" Journal of Consumer Research, vol. 37, no. 1, 2010, pp. 15–36., https://doi.org/10.1086/649910 .

A Trans-disciplinary Perspective on Foundation Courses for Undergraduate Programs

K P Mohanan and Tara Mohanan

Abstract

This article seeks to make a case for a trans-disciplinary perspective in the design of a common undergraduate foundation program for all subjects. Such a program would serve to counter the fragmentation of knowledge and inquiry in both education and research that began when 'natural philosophy' evolved into 'science' and 'humanities', and subsequently, mathematics became distinct from the sciences. This perspective deviates from the familiar frameworks of separate discipline-specific foundations. The transdisciplinary perspective leads us to require the specification of transdisciplinary learning outcomes in the curricula of programs, thereby integrating and going beyond the kinds of learning outcomes specified in Revised Bloom's taxonomy. We also make a case for distinguishing between two kinds of Learning Outcomes: (i) those that exist in the mind of the learner (educational goals), and (ii) those that manifest themselves as behavioural correlates of those outcomes (educational objectives) and can be specified as performance indicators.

3. 1 Introduction

The document, *Kerala State Higher Education Curriculum Framework for Undergraduate Programs* (May 2023) offers guidelines, in four appendices, for (a) the Social Sciences, (b) the Sciences, (c) Commerce and Management, and (d) Languages. What follows is an attempt to integrate these different guidelines into a single perspective for a foundation program for undergraduate education.

In some ways, this foundation program is similar to the General Education Program for undergraduate students in North America. However, it is distinct from foundation programs in India and abroad that we are aware of in two important ways:

1. Most General Education programs are conceptualised in terms of categories of requirements and offer a basket of courses for each requirement. The faculty members teaching these courses need not have a shared value system of education. Given that the goals of a program are derived from its value system of education, these programs end up with goals that are not entirely coherent.

   In contrast, what we are proposing is a **coherent curriculum** with a ***shared value system*** that yields a clearly articulated set of ***outcomes of learning*** in terms of the understanding, abilities, habits of mind, and attitudes resulting from the program, without disciplinary groupings.

2. The proposed Foundation Program is grounded in an understanding of ***Academic Cognition*** and ***Trans-disciplinary Academic Epistemology*** **—** what is common to the ways of knowing, inquiring, exploring, problem solving, and thinking critically, as well as modes of justification, across diverse academic disciplines ranging from mathematics and computer science to the physical, biological, mental, and societal sciences, and the humanities.

The concept of Academic Cognition incorporates the intuitions of what NEP 2020 calls ***Higher Order Cognition*** and what is called Higher Order Thinking Skills in discussions of (Revised) Bloom's Taxonomy. But it goes beyond them to crystallise the essentials of what is of 'higher' order in cognition and thinking, by grounding them in a transdisciplinary academic epistemology. Such grounding shapes the formulation of curricula for educational programs, where the term ***curriculum*** includes the *educational goals, educational objectives, learning resources, classroom pedagogies,* and *assessment,* in both programs and in individual courses.

In this article, we present an outline of what a transdisciplinary foundation program for undergraduate education must offer as part of General Education, regardless of the demands of specialisation for subject majors, and choice of careers after graduation. We also discuss how the transdisciplinary aspects of the capacities of academic inquiry and critical thinking can be built into the educational goals of the learning resources, pedagogies, and assessment of undergraduate curricula, forming the foundations for research in graduate programs.

3.2 Educational Goals

3.2.1 Terminology vs. Concepts and their Consequences

Since the publication by the UGC of *Learning-Outcome Based Curriculum Framework for Undergraduate Education* (2020) (https://www.ugc.gov.in/e-book/locf.pdf), the terms Learning Outcome Based Curriculum Framework (LOBC) and Outcome Based Education (OBE) have begun to appear in the vision and mission statements of all educational policies and programs, and even outlines and descriptions of courses. The terms spring up even on the websites of commercial organizations that offer training programs in meeting the demands of OBE, for colleges and for faculty members.

The Wikipedia entry on Outcome-based education (https://en.wikipedia.org/wiki/Outcome-based_education) tells us that OBE came into international prominence in the Washington Accord created in 1989 (https://en.wikipedia.org/wiki/Washington_Accord_(credentials)). It also mentions that India is one of the signatories of the accord. It is not surprising, therefore, that the use of these terms has gone viral.

It is relatively easy to sprinkle talks, videos, and documents with the terminology that the stakeholders expect to and want to hear and see. The challenge lies in clearly articulating the concepts denoted by the terms, and drawing out their logical consequences for educational goals, learning resources, pedagogies, and assessment. In the rest of this section, we turn to that challenge.

3.2.2 Learning Outcomes

We would agree that happiness, sadness, fear, and anger are emotions or feelings that exist in the minds of individuals. The emotions/feelings are not themselves observable. What we *can* observe are the facial expressions of those individuals, the words they use, and their actions.

Coming to learning outcomes, let us begin by stating the obvious: learning is a process that happens in the learners' minds. It follows, then, that learning outcomes are the outcomes of that process. Given this, we may identify two distinct meanings for the term *learning outcome* (LO): a learning outcome as

A) What comes to exist in the learner's ***mind*** as the outcome of the learning process: the ***mental capacities***, including a range of *abilities* and *skills*; the *understanding* that underlies those capacities; habits of mind, attitudes, and values. Like the emotions and feelings mentioned above, these outcomes are not directly observable.

B) What can be observed and measured in the learners' ***behavior*** — the counterpart of facial expressions, words, and actions. These observable and measurable indicators of what we judge to be the learning outcomes, form the ***data*** that provide evidence for our conclusions on what the learners must have acquired because of our educational interventions, and how well they have acquired it.

To distinguish between (A) and (B), we may use the following terminology:

Educational goals: the desired outcomes that a program, course, textbook, chapter, or class session aims at. ((A))

Educational objectives: the observable behavioral correlates of those goals, the ***data*** that can be used as ***evidence*** for the learners' having acquired the goals that a program, course, textbook, chapter, or class session expects them to acquire. ((B))

The above conceptual distinction, and the accompanying terminological distinction, is analogous to the distinction between mass and weight on the one hand, and the readings on the instruments we use to measure mass or weight on the other. The numbers that we observe on a weighing machine are analogues of (B), while weight and mass, which are not directly measurable, are analogues of (A). The ***theory*** of physics is what we fall back on to accept the readings on a physical balance as a reliable measure of mass, while the readings of a spring balance are what we take as a reliable measure of weight.

Learners' performance in an examination, class test, assignment, project, survey, or interview is a methodological strategy for gathering data on the educational goals that we cannot directly observe. Hence, the design of these strategies constitutes an important consideration in determining whether a student's answer to a given question in an examination or test, or a student's response in a survey or interview can be taken as reliable operationalization of what we seek to measure.

We cannot arrive at decisions on the relation between (A) and (B) without explicit theories of:

1. the educational goals that a curriculum aims at,
2. the pedagogical strategies that serve as the means to achieve those goals; and
3. the design of assessment tasks to measure how well these means achieve the desired goals.

3.2.3 Specifying the Educational Goals

3.2.3.1 Understanding vs. Proving

The UGC document *Learning-Outcome Based Curriculum Framework for Undergraduate Education* discusses learning outcomes under four headings, namely:

Graduate attributes,
Qualification descriptors,
Program learning outcomes, and
Course learning outcomes

We will restrict our scope to the graduate attributes and qualification descriptors.

The graduate attributes:

"reflect the particular quality and feature or characteristics of an individual, including the knowledge, skills, attitudes, and values that are expected to be acquired by a graduate through studies at the higher education institution (HEI) such as a college or university. The graduate attributes include capabilities that help strengthen one's abilities for widening current knowledge base and skills, gaining new knowledge and skills, undertaking future studies, performing well in a chosen career, and playing a constructive role as a responsible citizen in the society." (p.6)

The qualification descriptors indicate:

"the generic outcomes and attributes expected for the award of a particular type of qualification (for e.g., a bachelor's degree or a bachelor's degree with honours). The qualification descriptors also describe the academic standard for a specific qualification in terms of the levels of knowledge and understanding, skills and competencies and attitudes and values that the holders of the qualification are expected to attain and demonstrate.” (p,8)

The term ‘understanding’ appears under both these descriptions, and throughout this document, in Bloom’s Revised Taxonomy, and in all discussions of curriculum design in educational discourse.

Let us consider what it takes to understand the concepts denoted by the words that appear in textbooks ranging from primary school to master’s programs. As an example, that we are all familiar with, take the basic concepts of geometry expressed by the words *point*, *line*, *triangle*, *square*, *rectangle*, and *circle*. Even preschoolers have a level of understanding that allows them to pick out, say, triangular cutouts from a basket of cutouts of diverse shapes, colors, materials, and sizes. This level of understanding is pre-academic: when preschoolers demonstrate their understanding of circles by drawing a circle, or picking out circular cutouts, they are not going by the definition of the concept of circle as a trajectory of points equidistant from a center, let alone the formula for circles in coordinate geometry. What does it take for institutionalized education from primary school to PhD to move from the preschoolers’ understanding of geometric shapes to what we expect of PhD scholars in mathematics?

Shape is an aspect of visual experience. Contrary to what Piaget thought, a preschooler’s understanding of triangles and circles involves a high degree of abstraction from sensory experience to focus on the shape, factoring away the experience of color, size, material, weight, smell, taste, and so on. But we do not expect preschoolers’ classification of shapes to include the idea that squares are a subcategory of rectangles, let alone their being familiar with the concept of polygons as a super-category of triangles.

As far as we know, textbooks and teachers do not discuss the rational justification for treating squares as a subcategory of rectangles instead of treating them as mutually exclusive categories, Any geometry curriculum based on the idea of Learning Outcomes must ask at what stage in the cognitive development of children they would be ready to understand the rational justification for postulating squares as a subcategory of rectangles, and also, at what stage they would be ready to provide rational justification on the basis of their own inquiry.

It is very likely that pre-teens are not yet ready for rational justification (called proof in mathematics), which therefore is best left to the curriculum for secondary education. We must note that this point is analogous to the one made in Mohanan et al (2024), where the authors make a case for moving evolutionary theory from secondary schools to higher secondary schools on the grounds that secondary school students are not yet ready to grapple with rational arguments in support of or against the theory of biological evolution.

It is also likely that when asked, “What is the rational justification for treating squares as a subcategory of rectangles?” even our mathematics PhD scholars would base their answers on the definition of squares and rectangles, instead of arguing for the categorization that ought to be the basis for definitions.

Turning to another issue in geometry from secondary school to PhD, do our students understand the concept of angles? They learn what is called the Angle Sum Theorem in secondary school. They also learn the idea of a straight angle as the measure of an angle of a point on a straight line. Let us imagine that we provide the following argument to a student (whether secondary school or PhD):

Consider a point D on the straight line-segment AB in a triangle ABC. Angle ADB is a straight angle, which means it is two right angles (180 degrees in terms of protractor measurement). There are infinitely many points in any line segment. Hence there are infinitely many right angles online segment AB. Since a triangle has three-line segments, the sum of angles in a triangle is infinite. This theorem contradicts the theorem that says that the sum of angles in a triangle is two right angles.

Even though they learn what is called proof through contradiction (also called indirect proof or *reductio ad absurdum* proof), mathematics students — whether in secondary school or in a PhD program — are unfamiliar with the idea of logical contradictions, the prohibition of logical contradictions in a body of knowledge, and strategies for eliminating them. Nor are they aware that to escape from the fatal contradiction that results from the above description, they need to ground their concept of angle in the concept of vertex. Our math textbooks are guilty of not helping students understand the concept of angle in terms of the concept of vertex.

3.2.3.2 Proving and Defining

Let us now turn to the relation between defining and proving. Suppose students (whether in secondary school or in a PhD program) are given the following tasks:

Define triangles in such a way that we can prove that straight-angled triangles do not exist. Then provide that proof.

Define triangles in such a say that we can prove that straight-angled triangles do exist. Then provide that proof.

As these examples illustrate, our curricula, from primary school to PhD, are guilty of not helping learners develop the higher order cognitive capacities that NEP 2020 calls for. The kind of conceptual framework of educational goals provided in UGC 2020 or in Revised Bloom's Taxonomy is not adequate for guiding curriculum designers, textbook writers, designers of final examinations, and faculty members in classrooms to move towards higher order cognitive capacities.

Why do we think that Bloom's taxonomy, including the Revised Bloom's Taxonomy, is inadequate? The reason is simple. It is a classification of the data available in the assessment tasks in the USA. It is not grounded in a normative concept of what ought to be of value to students, let alone a consideration of the investigation of the epistemology of academic inquiry: the kinds of capacities, habits, and values that are needed for arriving at, critically evaluating, and rationally justifying knowledge claims in academic knowledge.

For an analysis of the flaws of Blooms Taxonomy for the purposes of OBE, see Annexure 8, "Bloom's Taxonomy vs. Desirable Learning Outcomes," in the NAAC White Paper 2022 *Re-imagining Assessment and Accreditation in Higher Education in India* (https://xavierscollegegoa.ac.in/wp-content/uploads/2023/02/DOC-20230127-WA0035_pdf.pdf)

Given the above state of affairs, it is natural that teachers in schools, colleges, and universities fail to understand:

The concept of UNDERSTANDING.

the concept of RATIONALLY JUSTIFYING/PROVING as an educational goal.

the role of DEFINING, REASONING, and PROVING in UNDERSTANDING; and

the distinction between PROVING and UNDERSTANDING.

The rational justification of a knowledge claim, whether in mathematics, the sciences, or the humanities has a triplet structure of premises, derivation, and conclusion (what we like to call the PDC structure). The distinction between rational justification in mathematics (called proof) and rational justification in the sciences (proof, evidence, and arguments) lies in the nature of the premises and the forms of logic used in the derivation.

3.2.3.3 Axiomatic vs. Empirical Proofs

Central to the edifice of *axiomatic inquiry* in mathematics, as exemplified in Euclid's *Elements*, is the derivation of the logical consequences (theorems) of axioms and definitions, using classical deductive reasoning. This stands in sharp contrast to the edifice of the knowledge system of *empirical inquiry* as exemplified in the sciences, where the premises are observations, and the derivation uses not only classical deductive logic, but also probabilistic and defeasible deductive logic, as well as probabilistic and defeasible inductive logic, and causal logics. As a result, what is judged as a valid proof in science need not be a valid proof in mathematics.

Because of the absence of the above distinction in our curricula for Higher Education, even 'experts' and teacher educators present ways of understanding as instances of proving. To take an example, consider the so-called 'proofs' of the Angle Sum Theorem in the NCERT official video, "Angle Sum Property of Triangle" (https://www.youtube.com/watch?v=BRDAXvQlzt0&t=198s) and the proof of the equation for the area of triangle in the IISER-Pune video, "Why area of the triangle is 1/2 x base x height?" (https://www.youtube.com/watch?v=epbTR6paVbE) These proofs appeal not to axioms and definitions, but to the observation of paper cutouts of triangles (which do not constitute triangles in Euclidean geometry). Even as scientific proofs, their methodology is seriously flawed because they do not pay attention to the requirement of large random samples. What these videos do is help learners understand the theorems, which is not the same as providing proofs, or understanding proofs.

To summarise, what the above discussion of understanding, defining, and proving, and the difference between axiomatic and empirical inquiries, points to is the need to go beyond mere lip service to the idea of OBE, to serious engagement with academic epistemology, to infuse curricula with the capacities for academic inquiry and critical thinking.

3.3 Learning Resources

To solve the problem of not having achieved the desired educational goals in Higher Education, what we need are online courses and learning materials for:

I. students (to be constructed by a small team of researcher-educator-educationists); and

II. a small team of education leaders to carry forward the pursuit of academic cognition.

3.3.1 A Starting Point: A Trans-disciplinary Foundation Course

As an example of (I), consider a first semester foundation course required of all first-year undergraduate students in all subjects. The core learning outcomes of such a course can be formulated as:

A. the trans-disciplinary capacity to engage in Academic Inquiry across disciplines.

B. an understanding of Academic Knowledge and Inquiry that underlies that capacity; and

C. the academic temper that arises from that pursuit.

The term *academic temper* in (C) is a generalization of the 'scientific temper' required by article 51A(h) of the Constitution of India. While scientific temper is restricted to the practice of scientific inquiry, academic temper covers all forms of academic inquiry, including mathematical, philosophical, and historical inquiries.

The outcomes in (A)-(C) above can be fleshed out as follows:

ABILITIES:

The general components of Academic Inquiry include the ability to:

1. identify and formulate questions/problems/hypotheses to investigate.
2. identify and implement methodological strategies to look for answers to questions, and solutions to problems, and to test hypotheses and predictions.
3. identify and rationally justify (i.e., prove) the conclusions arising from (2).
4. use modes of reasoning appropriate to the context and function:
    deductive (classical, probabilistic, and defeasible).
    inductive (sample-to-population: probabilistic and defeasible).
    abductive; speculative-deductive; and
    correlational and causal

5. take one's own as well as other people's assumptions, conclusions, and arguments, and subject them to critical thinking; and

6. communicate all the above with clarity and precision.

The specific tools of inquiry that Academic Inquiry calls for include:

i) systematic and careful observation, making observational reports.
ii) arriving at and establishing observational generalizations and conjectures.
iii) constructing and defending categories and classificatory systems.
iv) defining and clarifying concepts.
v) constructing and defending academic concepts, ideas, and theories.
vi) predicting, explaining, justifying, and debating.

Different subsets of these tools form part of the capacity to construct and evaluate theories in mathematics, the physical-biological-human sciences, and the humanities (including philosophy, and the study of verbal and nonverbal arts, including literary studies).

During the activities that aim at the above, learners would develop:

a) a rudimentary ***understanding*** of the ***core trans-disciplinary concepts of knowledge and inquiry***.
b) the ***habits*** of and ***motivation*** for ***self-directed independent learning*** from documented sources of knowledge available on the Internet.
c) the ***ability*** to engage in the ***critical reading*** of academic texts.
d) the ***ability*** to engage in ***thinking critically about academic claims, arguments, concepts, ideas, and theories***.
e) the ***ability*** to engage in ***academic inquiry***.
f) the ***ability*** to ***communicate*** academic concepts, ideas, and arguments with ***clarity and precision***; and
g) the ***ability*** to see the ***connection*** between bodies of knowledge currently fragmented into discipline groups under labels like mathematics, sciences, social sciences, humanities, and languages, and into disciplines like physics, chemistry, biology, sociology, psychology, and so on, and ***integrate*** them.

UNDERSTANDING:

We see the world around us in terms of the ideas of *ENTITIES*, their *PROPERTIES* (traits and trait values; variables and values…), the *RELATIONS* among them, and the *STATES*, *PROCESSES,* and *EVENTS* they participate in. The concepts of STRUCTURE, CHANGE, and CAUSE are closely tied up with all these ideas.

Structure would involve COMPOSITIONALITY, along with UNITS, and CATEGORIES, as well as DIMENSIONS and LEVELS of structure. CHANGE would involve TIME, SPACE, and the STRUCTURE of *states*, *processes*, and *events*. Examples of *change* include *change of location* (motion), *change of velocity* (acceleration), *change of properties* (e.g., chemical change), *change of structure* (e.g., linguistic, developmental, and evolutionary changes), as well as changes involved in emergence and origin, as well as extinction.

The discussion of CAUSALITY would call for an introduction to *sufficient* and *necessary* causes; causal reasoning in the context of correlational reasoning; and so on, while connecting causality to mechanics on the one hand, and classical, defeasible, and probabilistic modes of reasoning on the other.

3.3.2 A Textbook

An initial draft of a textbook for a course, called *Foundations of Knowledge and Inquiry across Disciplines*, has been prepared, and distributed to the Vice Chancellors of the universities in Kerala.

The revision of this draft is envisaged in terms of the following phases:

Field Trial Phase: using a hybrid mode (part offline and part online)

Final Steady Phase: completely online

During the first field trial in the first phase, the number of registered students would be restricted to 40, and during the second round, to 200. Once the course is fully online, no restrictions would be required on the number of students.

To turn to (II), a course for a small team of education leaders from the faculty would have three strands, where the teams would need to:

First: master what the students are expected to learn in the foundation course for (I). The team must therefore have the openness and potential to learn outside of their subject specializations, including such things as different systems of logic and epistemology.
Second: proceed to a higher level of learning than what the students need to learn. This can be done in terms of supplementary readings and activities.
Third: be initiated to the pedagogical strategies, including online pedagogies, appropriate for the learning outcomes that (I) aims at.

3.3.3 Further Recommendations for Courses

The Foundation Program as outlined in the previous sections is trans-disciplinary in the sense that the learning outcomes that the courses aim at cutting across disciplinary boundaries, existing at a meta-level of academic knowledge and inquiry. Nevertheless, these attributes are relevant for discipline-specific courses as well. A student majoring in physics, for instance, would find it valuable to acquire the capacity for rigorous reasoning for diverse functions, as well as an understanding of what is unique about reasoning in science, as distinct from reasoning in mathematics, law, and philosophy. Likewise, a course on critical reading across academic disciplines can be followed by courses in critical reading in mathematics, in physics, in biology, in psychology, in economics, in history, in philosophy, in literary studies, and so on. We therefore recommend that such discipline-specific courses be introduced in individual departments as part of the subject major, focusing on academic cognition in that discipline.

With that in mind, we recommend a configuration of trans-disciplinary and discipline-specific foundation courses along the following lines:

A. Foundations

1. Knowledge and Inquiry across Disciplines
2. Research across Disciplines (For grad students)
3. Critical Reading, Argumentative Writing, and Expository Writing

B. Modes of Inquiry:

1. Axiomatic Inquiry
2. Empirical Inquiry
3. Observational Inquiry
4. Theoretical Inquiry
5. Conceptual Inquiry
6. Historical Inquiry
7. Ethical Inquiry
8. Aesthetic Inquiry

C. Systems of Knowledge

1. Introduction to Knowledge Systems
2. Introduction to the History and Philosophy of Science
3. Introduction to Citizenry, Governance, and Law
4. Introduction to Health, Illness and Healing
5. Learning, Teaching, and Educating

D. Being Human

1. Values, Goals, and Pursuit of Goals
2. Citizenry: Roles, Rights, and Responsibilities
3. Appreciating Natural and Manmade Beauty

3.3.4 Learning Resources

As pointed out at the beginning of Section 3, online courses on foundations would require extensive creation of learning materials for both students and faculty, with focus on the educational goals specified above. We have already mentioned a starting point for this enterprise, namely, a draft of the textbook, *Foundations of Knowledge, and Inquiry across Disciplines*, meant for Year 1 undergraduate students.

A larger nucleus of such materials — downloadable textbooks and other resources, videos, webinar recordings, and so on — is available at the ThinQ website (http://www.thinq.education). These materials target a range of learners, from secondary school to graduate school. Here is a short list culled from those resources.

For online courses, whether purely online or blended, we recommend the following pedagogies:

- Use of printable pdf files, supplemented with audios and videos where possible.
- Activities in which learners interact with a bot.
- Where feasible, activities in which learners interact with a human mentor, through emails, discussion forums, and social media.
- Peer learning, the channels for which include.

- off-line interaction (in-person face-to-face)
- online interaction (through emails, discussion forums, and social media)

3.3.5 Assessing Student Learning

3.3.5.1 Designing Assessment Tasks

The format of computer graded multiple choice questions (MCQs) can be used either for formative purposes or for summative purposes. The purpose of ***formative assessment*** is diagnostic: to find out if learners have been learning what the curriculum or course aims at; and if they fall short of the expectations, to provide further assistance. In this form of assessment, it is important to provide feedback to the learners, but not assign marks or grades to their performance: it is ***assessment FOR learning***.

The purpose of ***summative assessment*** is to evaluate the performance of the students such that they can be assigned appropriate marks or grades that are used for certification: useful for future employers or for admission to higher level programs. ***This is assessment OF learning***.

Both forms of assessment presuppose a clear understanding of the outcomes of learning that the program or course aims at. To illustrate, let us imagine that one of the learning outcomes in a course in geometry is that of an understanding of category-subcategory relations among polygons. Let us assume that the learning resources and classroom teaching of this course elaborate the category-subcategory relations in mathematical objects such as rectangles, squares, parallelograms, and triangles. A student who has undergone such a course will be able to pick out the 'correct' statements among the ones below:

a) A rectangle is a square whose adjacent sides are not equal.
b) A square is a rectangle with all sides equal.
c) The relation between a square and a rectangle is the same as the relation between a rectangle and a parallelogram
d) All isosceles triangles are equilateral triangles.
e) All equilateral triangles are isosceles triangles.

If class discussions have already gone through the subcategorization relations among the relevant geometric objects, the skill of picking out the 'correct' statements in the above examples would not count as a higher order cognitive capacity. However, rather than picking out 'correct' statements out of a set, if learners are required to defend their choice of a classificatory system, postulating the relevant subcategory relations, we are entering the realm of higher order cognition. It requires a type of reasoning that we may call Extended Syllogistic Reasoning (ESR).

Classical Syllogistic Reasoning (CSR) is based on the relation between categories and their members. As illustration, consider this example of deductive reasoning, attributed to Aristotle:

All humans are mortal.	(Premise 1)
Socrates is a human.	(Premise 2)
Therefore, Socrates is mortal.	(Conclusion)

The first sentence expresses a statement about the relation between the category of humans and the attribute of mortality. The second sentence expresses a statement about a category-member relation. The third statement expresses a conclusion derived from these two premises.

The rule of inference that sanctions the derivation of the conclusion from the two premises is that of ***logical inheritance of attributes***:

The attributes of a category are inherited by its subcategories and its members.

ESR goes beyond category-member relations to extended category relations. Consider the following example:

Vertebrates are a subcategory of animals.	(premise 1)
Mammals are a subcategory of vertebrates.	(premise 2)
Primates are a subcategory of mammals.	(premise 3)
Humans are a subcategory of primates.	(premise 4)
Animals are mortal.	(premise 5)
Socrates is a human.	(premise 6)
Therefore, Socrates is mortal.	(conclusion)

To derive the conclusion from the premises, in addition to the rule of inference above, we also need a statement on the ***transitivity of the sub-category relation***:

If x is a subcategory of y, and y is a subcategory of z, then x is a subcategory of z.

What we have illustrated above is the need to specify the educational objectives (item B in section 2.2) with the kind of specificity needed in a curriculum that aims at higher order cognition. The descriptors of educational objectives here include:

Demonstrating:

~ an ***understanding*** of category-subcategory relations between polygons, generalized as category-subcategory relations in academic knowledge.

~ the ***ability to postulate*** category-subcategory relations between different types of polygons, generalized as the capacity to postulate category-subcategory relations.

~ the ***capacity to deduce predictions*** from a set of postulates (and definitions).

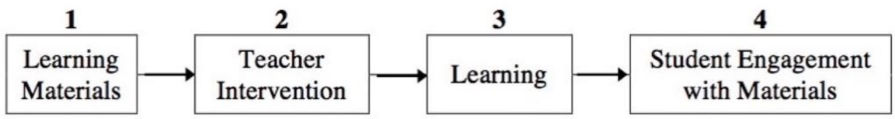
~ the ***capacity to choose between alternatives*** (e.g., in classificatory systems) based on the predictions they yield.

~ a ***degree of mastery*** of ESR.

As can be seen, these (and other) learning objectives in a curriculum that aims at academic cognition go way beyond the descriptors of learning objectives in Revised Bloom's taxonomy.

3.3.6 Pedagogies

A pedagogy that would be effective and worthwhile for the courses mentioned Section 3 is that of the ***flipped classroom***. In most courses in schools and colleges, teachers are mediators between the learners and the learning materials such as textbooks and worksheets. Teachers draw upon the textbooks to help students understand the concepts, and the exercises in the worksheets for practice. After a class session, learners turn to the materials to consolidate what they have learned:



Flipped classrooms invert (flip) this sequence, to enable independent learning. Learners engage with the materials directly and learn from them without the teacher's help.

What, then, is the role of the learning facilitators/mentors in this model of education?

They provide value-added help that begins *after* students have engaged directly with the materials. The teacher would respond to clarificatory and exploratory questions from students, and provide further guidance by asking questions, setting more exercises, and getting students more engaged. In this mode, the time that students and teachers spend together in the class would be used for such activities.

3.3.7 Concluding Remarks

In this article, we have made a case for a trans-disciplinary perspective in the design of a common foundation program for all subjects in undergraduate education, steering clear of the fragmentation involved in the UGC approach of separate foundations for:

a) the Social Sciences,
b) the Sciences,
c) Commerce and Management, and
d) Languages.

The alternative perspective led us to require that, in foundation programs that subscribe to Outcome Based Education, we must specify trans-disciplinary learning outcomes, thereby going beyond the kinds of learning outcomes specified in Revised Bloom's taxonomy and provide students with integrated learning. We also pointed to the value of distinguishing between Learning Outcomes that exist in the mind of the learner (the educational goals) and Learning outcomes observable as the behavioural correlates of those outcomes (the educational objectives). The specification of educational objectives as performance indicators, as in Bloom's Taxonomy, would be meaningless unless we have a clear understanding of what they are expected to 'measure', namely, the outcomes of learning in the mind of the learner.

This alternative approach to the design of a foundation program took us through a careful unpacking of the educational goals, educational objectives, learning resources, pedagogies, and assessment tasks in a sufficiently fine-grained manner, to ultimately make a real difference in student learning.

Resources

1. Book-length pieces

a. *Introduction to Research*
(https://www.thinq.education/itr)

b. *A Theory of Motion*
(https://www.thinq.education/post/a-theory-of-motion)

c.*Constructing Theories: A Case Study in Geometry with an extension to Biology*
(https://www.thinq.education/post/constructing-theories-a-case-study-in-geometry-with-an-extension-to-biology)

2. Shorter pieces

a. *"Introduction to Theory Construction in Biology"*
(https://d35e0249-4596-4e96-bf6036a9ce553fd1.usrfiles.com/ugd/65e23a_2dccb51db1404e578148194379effd1b.pdf)

b. *"Constructing, Measuring, and Calculating"* (https://www.thinq.education/post/constructing-measuring-and-calculating)

c. *"Understanding, Calculating, and Predicting"*
(https://www.thinq.education/post/understanding-calculating-and-predicting)

d. *Mathematising Language Sciences and Life Sciences*
(https://www.thinq.education/post/mathematising-theories-in-language-sciences-and-life-sciences)

e. *"How to Read Non-fiction"*
(https://www.thinq.education/post/how-to-read-non-fiction)

f. *"Statistical Thinking in the Kitchen"*

(https://thinq-website.s3.ap-southeast-1.amazonaws.com/other/articles/3+Statistical+Thinking+in+Kitchen-Diced+Potatoes-2009+copy.pdf)

3. Videos

a. *"Questioning Authority"* (https://www.youtube.com/watch?v=cIALHpLUGUs&t=445s)

b. *"Potential Scientific Theories or Pseudosciences?"* (https://www.youtube.com/watch?v=pxK5PrS_EeM&t=1180s)

c. *"Enhancing Academic Intelligence: An Interview"* (https://www.thinq.education/post/enhancing-academic-intelligence-interview)

d. *"Emergence: A Trans-disciplinary Concept"* (https://www.youtube.com/watch?v=voK-s5OYY-U&t=402s)

e. *"Thinking like a Theoretical Linguist"* (https://www.youtube.com/watch?v=NwcAw5duaYE).

Annexure 1

Worksheet for Analyze Phase of Foundation Course Design in General Programs

This Worksheet enables a teacher or a group of teachers to design a foundation course. There are three types of institutions in India as per the NAAC, named as Universities, Autonomous, and Affiliated, offering undergraduate general programs. Universities and Autonomous institutions are responsible for all academic processes, including curriculum design and conduct of examinations. Affiliated institutions are not academically autonomous except for internal evaluation that carries 20% to 70% weightage in the final grade. Instructional System Design Model ADDIE provides the framework for the process used here to design foundation courses. The Worksheet presented here is confined to the Analyze phase of the ADDIE model. The following assumptions are made in designing undergraduate foundation courses

- An undergraduate general program is designed to meet a set of Program Outcomes identified by the University/Autonomous institute and Program Specific Outcomes, 2 to 4 in number, the Department/College identifies.
- A foundation course can only meet a subset of these Program Outcomes while the general program aims at meeting all the Program Outcomes and Program Specific Outcomes.
- Institutions offering general programs are interested in continuous improvement of quality of learning by setting up and ensuring the closure of quality loops.
- The course design process mainly focuses on Cognitive domain even though there are other important (affective and psychomotor) domains of learning,

The three fundamental principles of course design are:

- At the end of the course, the students are to acquire stated course outcomes
- Assessment should be in alignment with the stated course outcomes
- Instructional activities are to be designed and conducted to facilitate students to acquire the stated outcomes

Analyze Phase of foundation course design consists of

1. Writing the course context and overview.
2. Writing 5 to 9 Course Outcomes, for a 3 or 4 credit course, which can be measured for attainment, and marking them with relevant POs, Cognitive Level, Knowledge Categories, and the sessions (classroom, tutorial, and laboratory) required.
3. Locating the Course Outcomes in the taxonomy table.

4. Writing a minimum of four representative test items for each course outcome at its cognitive level and mastery level, and sample solutions to these test items that would reflect the instructor's way of integrating course outcomes, and selected POs
5. Preparing course articulation matrix, Course-PO matrix (row).
6. Elaborating Course Outcomes into 15$\pm$5 Competencies of the course, if necessary, to facilitate instructional planning.
7. Preparing the Concept Map of the course using the Course Outcomes. (Optional)
8. Having the output of analysis phase peer-reviewed and make the changes needed

Note:

- *All materials presented in blue/red color are either instructions or assumptions. Background materials and samples are available elsewhere that need to be consulted if in need of clarifications, or this Worksheet is used for the first time.*
- *When the final document is to be presented, all the materials in blue color can be deleted.*
- *All the materials created by the course designers should only be entered in the boxes or tables shown in black color provided. If materials are prepared as word files separately and pasted into the boxes, make sure they are formatted to be Verdana 9, 1.5-line space, and additional 6 points below paragraphs.*

Any interested teacher can freely use these Worksheets to design his/her course. It would be appreciated greatly if they can give any comments and suggestions at njrao@higheredu.org.in on any aspect of this Worksheet.

Course:
Credits:
Course Designers:

S No.	Name	Email ID

Course Context and Overview:

It should include

- Category the course belongs to: Foundation
- The semester in which it is offered, prerequisites, and the courses to which it is a prerequisite
- The broad aim of the course and its relevance to the program
- The importance of the course
- The approach taken and reasons thereof

Sample

Course: Plant Biotechnology 4:0:0

Instructor: J. Deepika deep.friend3@gmail.com

Course Context and Overview

Plant Biotechnology is the core course offered by the University of Madras in the fourth semester for undergraduate Biotechnology students. Upon completion of this course, the students will have a strong background in genetic engineering of plants that will aid them to learn Industrial Biotechnology. The students should have studied biology or botany at the school level to recollect the basic concepts involving the growth of plants.

Plant Biotechnology can bring plants and biotechnology in one pool to evolve new varieties of crops with desired qualities, virus resistance, herbicide, and insect resistance and as bioreactors. The course is designed to give a brief understanding of the plant's growth, genome and factors related to genetic engineering of plants. The learners will be able to study the genetic organization inside plants, plant, growth hormones, various methods of plant tissue culture in vitro and applications in vaccine development. Additionally, gene transfer methods in plants and development of disease resistant crops can be learnt. The broad aim of this course is to make students understand crop yielding techniques. They can execute the same in their final year projects and work in research institutions, biotechnology or agro based companies in future.

The students will be given periodic assessments and parallel practical sessions in this course. Each batch of students will be able to isolate protoplast from young plants and fuse the same with the other variety of protoplast to produce a hybrid with the help of Polyethylene glycol. The course also involves visiting TNAU and biotech parks for better understanding and to know the real time approaches in plant biotechnology. It is necessary for the learners to participate in all the practical sessions to apply the hypothetical concepts.

Course Context and Overview

Program Outcomes (POs)

Program Outcomes are statements on knowledge, skills, and attitudes a graduate of an undergraduate engineering program should have. These are identified by the Institute

PO1. **Problem Solving**: Understand and solve problems of relevance to society to meet the specified needs using the knowledge, skills, and attitudes acquired from humanities/sciences/ mathematics/social sciences.

PO2. **Effective Communication**: Speak, read, write, listen clearly in person and through electronic media in English and attest one Indian language, and make meaning of the world by connecting people, ideas, books, media, and technology.

PO3. **Individual and Teamwork:** Function effectively as an individual and as a member or leader in diverse teams and a wide variety of settings.

PO4. **Ethics**: Understand multiple value systems, including your own, the moral dimensions of your decisions, and accept responsibility for them.

PO5. **Environment and sustainability**: Understand the impact of technology and business practices in societal and environmental contexts and sustainable development.

PO6. **Self-directed and life-long learning**: Demonstrate the ability to engage in independent and life-long learning in the broadest context of socio-technological changes.

PO7. **Design Mindset**: Represent and develop tasks and work processes for desired outcomes.

PO8. **Computational Thinking**: Understand data-based reasoning through the translation of data into abstract concepts using computing technology-based tools.

Course Outcomes (COs) are statements on what the students are expected to be able to do at the end of a course. Course Outcome statement should carefully be written as per the format indicated in the resource document (Outcome Based Education Engineering) on Course Outcomes and Competencies. Course Outcomes should be identified at the relevant higher orders of learning. The number of COs needs to be small, say 5 to 9 for a 3 to 4 credit course. These statements start with an action verb taken from the relevant cognitive level. These statements should be written in a manner that permits the measurement of attainment of these outcomes.

Action Verbs associated with Revised Bloom's cognitive levels

Remember

- Recognize/Identify
- Recall/Retrieve: List, mention, state, draw, label, define, name, describe, prove a theorem tell, show, label, collect, examine, tabulate, quote, who, when, where, etc.

Understand

- Interpret: Translate, paraphrase, represent, describe, express, extend and clarify
- Exemplify: Illustrate and instantiate
- Classify: Categorize and subsume
- Summarize: Generalize and abstract

- Infer: Extrapolate, interpolate, predict, conclude
- Compare: Contrast, match, map, distinguish and differentiate
- Explain: Illustrate, construct a model, confirm, state, write down, associate, and discuss

Apply

- Execute: Determine, calculate, compute, estimate solve, use, draw, and carry out (a procedure in known situation)
- Implementing: Determine, calculate, compute, estimate solve, use draw, and carry out (a procedure in unfamiliar situation)

Analyze

- Differentiate: discriminate, select, focus and distinguish (between accurate and inaccurate, cause and effect, consistent and inconsistent, dominant and subordinate, essential and inessential, facts and conclusions, facts and hypotheses, facts and inferences, facts and opinions, facts and value statements, plausible and implausible, possible and impossible, relevant and irrelevant, summaries and conclusions, supportive and contradictory, valid and invalid, verifiable and unverifiable, warranted and unwarranted)
- Organize: Identify (adequacy, assumptions, attributes, biases, causes, central issues, completeness, concepts, consequences, contradictions, criteria, defects, distortions, effects, elements, errors, exceptions, fallacies, inconsistencies, inferences, limitations, main ideas, nature of evidence, organization, plausibility, problems, procedures, reasoning, relationships, relevance, stereotypes, trends, validity, variables), structure, integrate, find coherence, outline, and parse.
- Attribute: Deconstruct and ascertain (Assumptions, attitudes, biases, conditions, characteristics, motives, organization, points of view, purposes, qualities, relationships)

Evaluate

- Check/test (Accuracy, adequacy, appropriateness, clarity, cohesiveness, completeness, consistency, correctness, credibility, organization, reasonableness, reasoning, relationships, reliability, significance, usefulness, validity, values, worth), detect, monitor, and coordinate.
- Critique/judge (Criteria, standards, and procedures)

Create

- Generate alternatives and hypotheses
- Plan/design
- Produce/construct

Each CO statement should be reviewed using the following check list.

1. Does the CO begin with an action verb (e.g., state, define, explain, calculate, determine, identify, select, design)?
2. Is the CO stated in terms of student performance (rather than teacher performance or subject matter to be covered)?
3. Is CO stated as a learning product (rather than in terms of the learning process)?
4. Is the CO stated at the proper level of generality and independent of other COs (i.e., is it clear, concise, and readily definable)?

5. Is the CO attainable (do they consider students' background, prerequisite competences, facilities, time available, and so on)?

Tag each CO statement with POs it addresses, Cognitive Level, Knowledge Categories, and approximate classroom sessions, tutorial hours and laboratory/field trip hours of instruction.

Writing course outcomes for a course is central to course design. Mastery level the instructor expects his/her learners to attain should be apparent from the CO statements. It takes several iterations before they are finalized.

Sample Course Outcomes

	Course Outcome	**POs**	**CL**	**KC**	**Class (Hrs.)**
CO1	Understand the plant nuclear, mitochondrial, chloroplast genome and gene families	PO5	U	C	5
CO2	Understand the roles of hormones (Auxin, Gibberelin, Cytokinin, abscisic acid and Ethylene) in phytomorphogenesis and their regulation of gene expression	PO6	U	C	10
CO3	Understand the plant tissue culture by micropropagation, organogenesis, somatic embryogenesis, haploid plants, and protoplasts fusion	PO5	U	P	10
CO4	Understand the production of synthetic seeds and secondary metabolites	PO6	U	P	5
CO5	Understand the gene transfer techniques by Ti plasmid from *Agrobacterium tumefaciens* and viral vectors	PO6	U	C, P	10
CO6	Understand the crop improvement by genetic introduction of herbicide resistance, insect resistance and viral resistance genes in plants	PO1	U	P	10
CO7	Understand the plant seed storage proteins and development of vaccines using plants	PO6	U	C, P	5
CO8	Understand the transgenic plants, its applications, and ecological impacts	PO4	U	C	5
Total Number of Hours					60

Course Outcomes: At the end of the course the student should be able to

	Course Outcome	POs	CL	KC	Class Sessions (Hrs.)	Tut. (Hrs.)	Lab / (Hrs.)
Total Number of Hours							

Note: Delete or add rows as needed

Taxonomy Table and Course Outcomes in Taxonomy Table:

Taxonomy Table is a table of cognitive processes (columns) and categories of knowledge (rows). It is a 6 x 4 matrix with 24 cells for courses in Humanities, Social Sciences, Mathematics and Engineering Sciences. Each cell represents a specific combination of a cognitive process and a knowledge category. The course outcomes can be in these cells. A good course design also requires that the instructional activities and assessment associated with a course outcome should also be planned to be in the same cell as that of the course outcome.

Locate Course Outcomes in the Taxonomy Table. This process of location may lead to refinement of course outcomes through several iterations. Note that a course outcome can be in more than one cell of taxonomy table. If a course outcome is located at a cognitive level, it is considered that all the lower-level cognitive processes are automatically addressed, and hence should not be in any lower cognitive process. However, it can be in cells associated with distinct categories of knowledge if the course outcome statement justifies it.

Revised Bloom (RB) Taxonomy Table for courses in Humanities, Social Sciences, Mathematics and Engineering Sciences.

Sample Biotechnology Taxonomy Table of the Plant Biotechnology course

Cognitive Processes	**Knowledge Categories**			
	Factual	**Conceptual**	**Procedural**	**Metacognitive**
Remember				
Understand		CO4, CO7, CO8	CO1, CO2, CO3, CO4, CO5, CO6, CO7	
Apply				
Analyze				
Evaluate				

Create				

Cognitive Processes	**Knowledge Categories**			
	Factual	**Conceptual**	**Procedural**	**Metacognitive**
Remember				
Understand				
Apply				
Analyze				
Evaluate				
Create				

Sample Assessment Test Items for Course Outcomes

Good learning requires addressing higher cognitive levels. It is the assessment that determines the quality of learning. Test Items or Assessment Items, or Items, are used as measures of students' attainment of the course outcomes. They can be either written test items (such as quizzes and problem) or performance test items (such as discussions, simulations, laboratory exercises, reports, field surveys, presentations, mini projects, etc.). A Test Item/Assessment Item is a unit that consists of a question, hints, sample answer, etc. Initially it will be tagged by the cognitive level and relevant categories of knowledge.

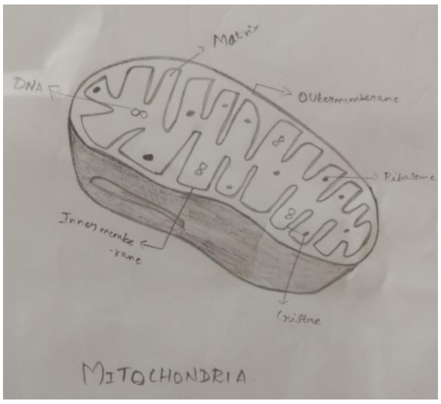
The test items are created in two stages.

1. Create four sample test items for each Course Outcome. These sample test items should be in complete alignment (same cognitive level) with the Course Outcomes.
2. Create the Item Bank as required by the Assessment Plan.

Writing good Course Outcomes is the first key element in designing and conducting a course. The scope of each CO and the level to which the students should master the content is best communicated through sample Test Items (TIs)/problems (a minimum of four) for every CO. Alignment means the Test Items are at the same cognitive level as that represented by the action verb of the CO statement. Sample Test Items should be in complete alignment with COs. Writing good sample Test Items can also lead to the improvement of CO statements. The difficulty levels of sample Test Items should be carefully chosen based on the perception of the cognitive abilities of students.

All the associated knowledge elements should also be addressed through the sample Test Items. In designing the Test Items care should be taken to address the associated POs and PSOs as well. Sample answers for all the Test Items should be presented to communicate how the teacher expects the response from the students.

Sample Test Items

	Course Outcome	POs	CL	KC
CO1	Understand the plant nuclear, mitochondrial, chloroplast genome and gene families	PO5	U	C
TI1	Describe Genome (2)			
Ans.	In the fields of molecular biology and genetics, a genome is all the genetic information of an organism. It consists of nucleotide sequences of DNA (or RNA in RNA viruses). The nuclear genome includes protein-coding genes and non-coding genes, other functional regions of the genome such as regulatory sequences, and often a substantial fraction of 'junk' DNA with no evident function			
TI2	Explain the genetic organization of Mitochondrial genome in plants (5)			
Ans.	 **Genes for stable RNAs**: 26S rRNA; 18S rRNA; 5S rRNA; tRNAs possibly 30 **Protein-coding genes**: NADH dehydrogenase(subunit 1); ATP synthase: subunit A (*atpA*), subunit 6 (*atp6*), subunit 9 (*atp9*); Ubiquinol cytochrome *C* reductase: Cytochrome *B* (CoB); Cytochrome *C* oxidase: subunit I (*cox*I), subunit II (*cox*II), subunit III (*cox*III); Ribosomal proteins: Small subunit **Chloroplast genes**: 3 genes for 16S rRNA; For tRNA; For the large subunit of RuBisCo			
TI3	Discuss Chloroplast genome (5)			
Ans.	The chloroplast genome behaves like bacterial DNA, circular in nature.			

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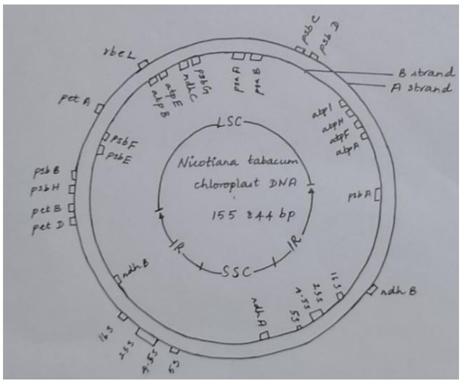
PLASTOME OR CHLOROPLAST DNA (cpDNA)

The presence of DNA in chloroplasts was first demonstrated by Ris and Plaut in 1962. They observed fibrils in electron micrographs of chloroplasts, which could be removed by treatment with deoxyribonuclease. The photosynthetic cells of higher plants contain on an average 50 chloroplasts, each with 10–20 copies of the plastome. The chloroplast genes are repeated approximately 500–1000 times. More recently, multiple copies of the plastid genome have been visualized by light microscopy, using DNA-binding fluorescent dyes. In very young leaves, chloroplast may contain 200 or more copies of the plastome.

In higher plants, chloroplast DNA (cpDNA) exists as a double-stranded circular molecule. Unlike nuclear DNA, it does not contain 5-methyl cytosine and is not complexed with histones. The GC content varies from 36–40% in different species. Purified chloroplast DNA is estimated to have a molecular weight of 120–150 kb. The DNA is replicated in a semiconservative fashion. Initially the DNA forms a theta structure that spreads outward to form daughter replicons. Later, DNA synthesis switches over to a rolling circle mechanism resulting in multiple copies of the genome.



</td></tr>
<tr><td>TI4</td><td colspan="4">Explain gene families in plants (10)</td></tr>
<tr><td>Ans.</td><td colspan="4">

Gene families are a set of genes that are present in common in most plants. For example, Phytochrome genes subsets are available in all plants.

A gene family is formed through the duplication and mutation of the same ancestor. Additionally, family members are defined as containing the same domains. For instance, WRKY genes, which all contain the W-R-K-Y domain, are important components of plant defense response-related signal transduction.

There are 6 phytochrome genes designated as PHYA, PHYB1, PHYB2, PHYE, and PHYF

In angiosperms there are 4 sub families of phytochromes. PHYF is an ortholog of PHYC

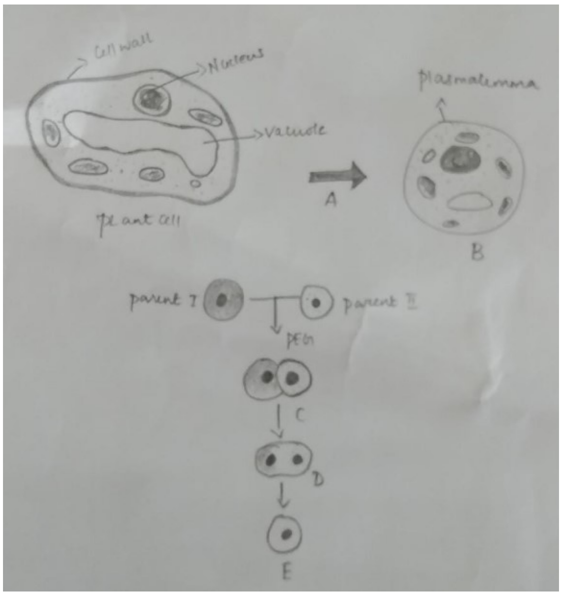
The subfamilies originated because of evolution. The C-terminal region of angiosperm PHY contains 800–1105 codons. The central region of a domain essential for phytochrome signal transduction (codons 652–712) is also evolving due to evolution.

Phytochrome gene family

</td></tr>
<tr><td></td><td>Course Outcome</td><td>POs</td><td>CL</td><td>KC</td></tr>
<tr><td>CO2</td><td>Understand the roles of hormones (Auxin, Gibberelin, Cytokinin, abscisic acid and Ethylene) in phytomorphogenesis & their regulation of gene expression</td><td>PO6</td><td>U</td><td>C</td></tr>
<tr><td>TI1</td><td colspan="4">Describe the role of abscisic acid (2)</td></tr>
<tr><td>Ans.</td><td colspan="4">Abscisic acid (ABA) is a plant hormone. ABA functions in many plants' developmental processes, including seed and bud dormancy, the control of organ size and stomatal closure. It is especially important for plants in the response to environmental stresses, including drought, soil salinity, cold tolerance, freezing tolerance, heat stress and heavy metal ion tolerance.</td></tr>
<tr><td>TI2</td><td colspan="4">Explain the role of cytokinins (2)</td></tr>
<tr><td>Ans.</td><td colspan="4">Cytokinins promote cell division and increase cell expansion during the proliferation and expansion stages of leaf cell development, respectively. During leaf senescence, cytokinins reduce sugar accumulation, increase chlorophyll synthesis, and prolong the leaf photosynthetic period</td></tr>
<tr><td>TI3</td><td colspan="4">Discuss the role of ethylene in fruit ripening (10)</td></tr>
</table>

Ans.	The ethylene in a plant growth regulator that acts as a trace level of entire plant life by regulating and stimulating the opening of flowers, fruit ripening and shedding of leaves. This plant hormone is essentially produced in all parts of grown plants including roots, stems, tubers, leaves, flowers, fruits, and seeds. As a developmental process, fruit ripening is coordinated by a complex network of endogenous and exogenous cues. Indeed, the making of a fruit is a genetically regulated process unique to plants involving three distinct stages: fruit set, development, and ripening. Fruit development is characterized by a series of developmental transitions tightly coordinated by a network of interacting genes and signaling pathways. Among these, ripening has received the greatest attention from both geneticists and breeders. Ethylene is a gas and is known as the "fruit-ripening hormone." Every fruit has a certain level of ethylene production throughout its lifecycle. However, in some fruits, ethylene levels shoot up when the fruit starts ripening. Based on their response to ethylene during maturation, fruits can be classified into two major groups. The first group is called the climacteric fruits, in which ripening is accompanied by a burst of ethylene. These fruits can also respond to external ethylene by increasing their ripening rate. These include fleshy fruits, such as tomato, avocado, apple, melon peach, kiwi, and banana. The second group is called the non-climacteric fruits, in which ethylene production does not increase during ripening. However, these fruits can still ripen if they are exposed to an external ethylene source, such as a ripening climacteric fruit. These include strawberries, grapes, and citrus fruits. For climacteric fruit, exposure to an initial, small concentration of ethylene causes the fruit to produce greater quantities of ethylene until a peak concentration is achieved. This increase in ethylene concentration triggers an increase in the fruit's metabolism and causes the changes to the fruit that occur during ripening. Ripening of climacteric fruits can, therefore, be slowed down by reducing the amount of ethylene the fruits make or by blocking ethylene's actions The effect of ethylene on ripening is dependent on many factors. The fruits need to be mature enough to be able to respond effectively to ethylene. In highly sensitive species, like cantaloupes or bananas, ripening is immediately stimulated by ethylene, but the more immature the fruit, the greater the concentration of ethylene required to cause ripening. In the less sensitive species, like tomatoes or apples, ethylene treatment reduces the time before ripening occurs. Some fruits, such as avocados, do not ripen while attached to the tree and gradually increase their sensitivity to ethylene with time after harvest			
TI4	Summarize the role of auxins (2)			
Ans.	Auxin promotes cell growth and elongation of the plant. Auxins also play a role in cell division and differentiation, in fruit development, in the formation of roots from cuttings, in the inhibition of lateral branching (apical dominance), and in leaf fall (abscission).			
	Course Outcome	**POs**	**CL**	**KC**
CO3	Understand the plant tissue culture by micropropagation, organogenesis, somatic embryogenesis, haploid plants, and protoplasts fusion	PO5	U	P
TI1	Explain micro propagation (10)			
Ans.	Sample Answer Micropropagation or tissue culture is the practice of rapidly multiplying plant stock material to produce many progeny plants, using modern plant tissue culture methods. Steps of micropropagation can be divided into four stages:) Selection of mother plant) Multiplication) Rooting and acclimatizing) Transfer new plant to soil There are many methods of plant micro propagation Meristem culture In Meristem culture, the meristem and a few subtending leaf primordia are placed into a			

	suitable growing media where they are induced to form new meristem. These meristems are then divided and further grown and multiplied. To produce plantlets the meristems are taken off from their proliferation medium and put on a regeneration medium. When an elongated rooted plantlet is produced after some weeks, it can be transferred to the soil. A disease-free plant can be produced by this method. Experimental results also suggest that this technique can be successfully utilized for rapid multiplication of various plant species, e.g. Coconut, strawberry, sugarcane. Callus culture A callus is a mass of undifferentiated parenchymatous cells. When a living plant tissue is placed in an artificial growing medium with other conditions favorable, a callus is formed. The growth of callus varies with the homogenous levels of auxin and cytokinin and can be manipulated by endogenous supply of these growth regulators in the culture medium. The callus growth and its organogenesis or embryogenesis can be referred to into three different stages. Stage I: Rapid production of callus after placing the explants in culture medium Stage II: The callus is transferred to other medium containing growth regulators for the induction of adventitious organs. Stage III: The new plantlet is then exposed gradually to the environmental condition. Embryo culture In embryo culture, the embryo is excised and placed into a culture medium with proper nutrient in aseptic condition. To obtain a quick and optimum growth into plantlets, it is transferred to soil. It is particularly important to produce interspecific and intergeneric hybrids and to overcome the embryo. Protoplast culture In protoplast culture, the plant cell can be isolated with the help of wall degrading enzymes and growth in a suitable culture medium in a controlled condition for regeneration of plantlets. Under suitable conditions the protoplast develops a cell wall followed by an increase in cell division and differentiation and grows into a new plant. The protoplast is first cultured in liquid medium at 25 to 28 C with a light intensity of 100 to 500 lux or in dark and after undergoing substantial cell division, they are transferred into solid medium congenial or morphogenesis in many horticultural crops respond well to protoplast culture.
TI2	Discuss the protoplasts isolation
Ans.	Protoplast is defined as naked plant cells or plant cells without a cell wall. It consists of plasmalemma containing all the other cellular content or components in it. In tissue culture labs it’s used to regenerate a whole plant providing suitable artificial medium and environmental conditions. This process is known as protoplast culture. Protoplast culture involves the following culture events: Leaves of the specific plant are taken and sterilized. The epidermis layer of the leaf is peeled, and the leaf is cut into small segments. The leaf segments are put into an enzyme mixture for protoplasts' release. Then, the enzyme solution is collected and suspended in a washing tube, which is centrifuged. The obtained pellets are resuspended in a sucrose washing medium and centrifuged again. The protoplasts are separated at the top of the tube in the form of a band. The protoplast bands are suspended in a culture medium. The protoplasts are isolated and induced for wall formation. After the wall formation, the cells enter the division phase, forming a clump of a few tissues followed by callus formation. Shoots are differentiated in callus and then plantlets are regenerated leading to the forming of a whole plant.
TI3	Explain somatic hybridization (5)

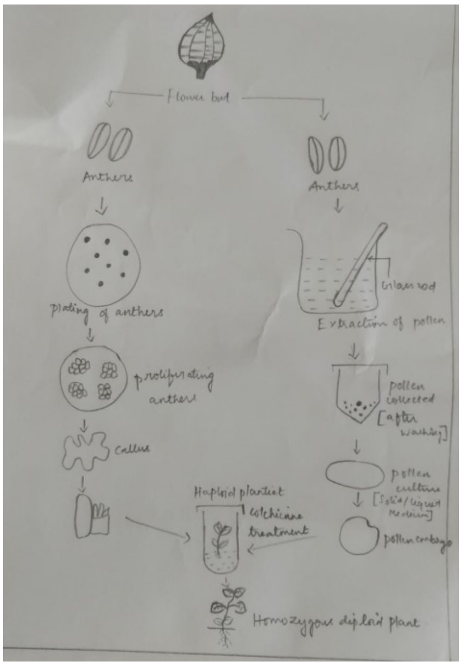
Ans.	Somatic hybridization is a novel technique that allows the fusion of two different plants to obtain a new hybrid plant with characteristics from both plants. The somatic hybridization involves three aspects. The three aspects are: (A) Fusion of Protoplasts (B) Selection of Hybrid Cells and (C) Identification of Hybrid Plants. 
TI4	Discuss the steps involved in production of haploid plants (10)
Ans.	Haploid production is achieved by two methods. 1. Androgenesis: Haploid production occurs through anther or pollen culture, and they are referred to as androgenic haploids. 2. Gynogenesis: Ovary or ovule culture that results in the production of haploids, known as gynogenic haploids. Androgenesis: In androgenesis, the male gametophyte (microspore or immature pollen) produces haploid plant. The basic principle is to stop the development of pollen cell into a gamete (sex cell) and force it to develop into a haploid plant. There are two approaches in androgenesis— another culture and pollen (microspore) culture. Young plants, grown under optimal conditions of light, temperature, and humidity, are suitable for androgenesis. Anther Culture: The selected flower buds of young plants are surface-sterilized, and anthers removed along with their filaments. The anthers are excised under aseptic conditions and crushed in 1% acetocarmine to test the stage of pollen development. If they are at the correct stage, each anther is gently separated (from the filament) and the intact anthers are inoculated on a nutrient medium. Injured anthers should not be used in cultures as they result in the callusing of anther wall tissue.

The anther cultures are maintained in alternating periods of light (12-18 hr.) and darkness (6-12 hrs.) at 28°C. As the anthers proliferate, they produce calluses which later form an embryo and then a haploid plant.

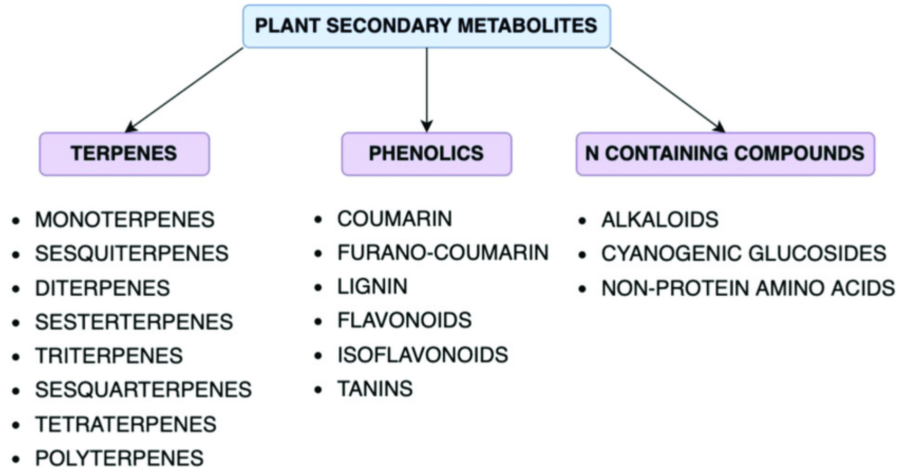
Pollen (Microspore) Culture:

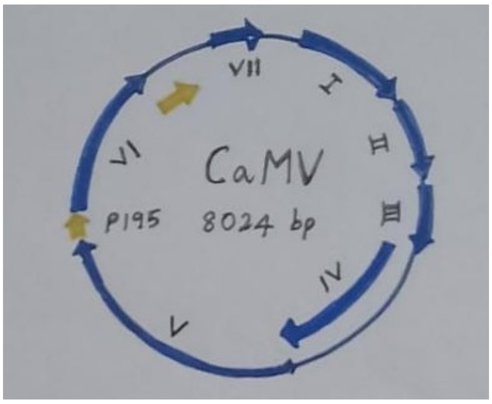
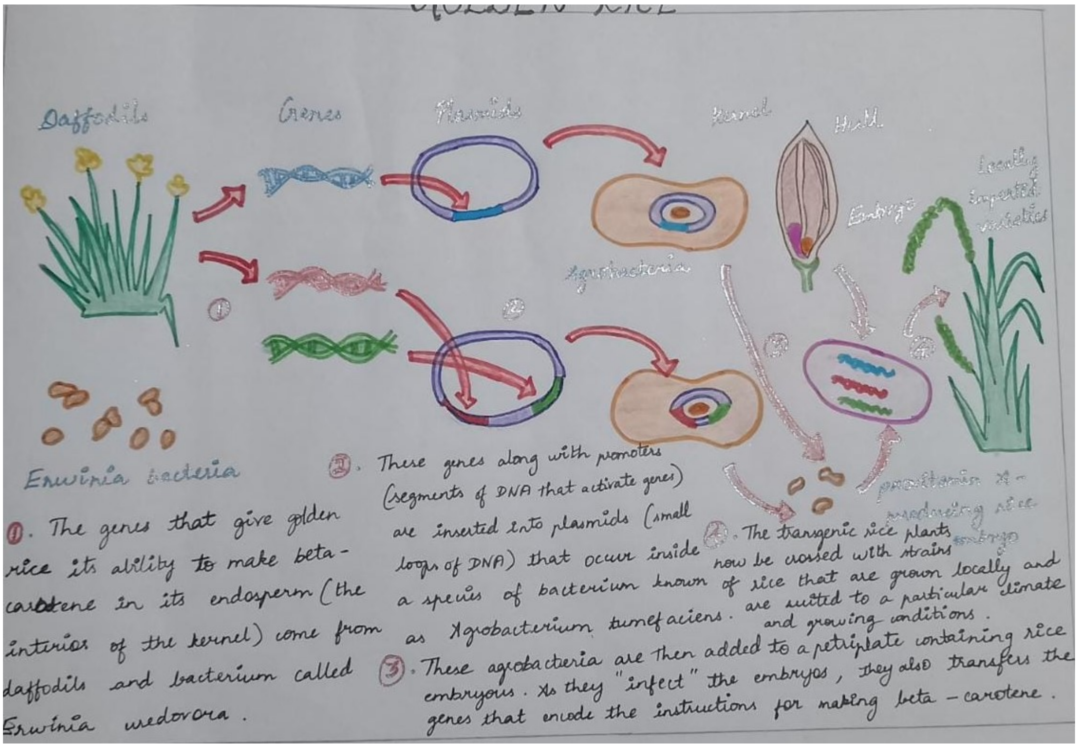
Haploid plants can be produced from immature pollen or microspores (male gametophytic cells). The pollen can be extracted by pressing and squeezing the anthers with a glass rod against the sides of a beaker. The pollen suspension is filtered to remove anther tissue debris.

Viable and large pollen (smaller pollen do not regenerate) are concentrated by filtration, washed, and collected. These pollens are cultured on a solid or liquid medium. The callus/embryo formed is transferred to a suitable medium to finally produce a haploid plant and then a diploid plant (on colchicine treatment).



	Course Outcome	POs	CL	KC
CO4	Understand the production of synthetic seeds and secondary metabolites	PO6	U	P
TI1	Explain the materials used in synthetic seed preparation (2)			
Ans.	Synthetic seeds are artificially encapsulated plant propagation material. This material could be somatic embryos, shoot buds, cell aggregates, or any other tissue that we can use as a seed for propagation. The most popular method of forming hydrated synthetic seeds is using Ca-alginate encapsulation. The procedure followed to produce hydrated synthetic seed involves the mixing of somatic embryos with a 2% (w/v) solution of Na-alginate.			
TI2	Explain the types of synthetic seeds (2)			
Ans.	Two types of artificial seeds (encapsulated somatic embryos) are commonly produced: desiccated and hydrated. Desiccated artificial seeds are achieved from somatic embryos either naked or encapsulated in polyoxyethylene glycol followed by their desiccation.			
TI3	Classify the plant secondary metabolites (5)			
Ans.	Secondary metabolites are compounds that are not required for the growth or reproduction of an organism but are produced to confer a selective advantage to the			

	organism. For example, they may inhibit the growth of organisms with which they compete and, as such, they often inhibit biologically important processes. Plant secondary metabolites can be classified into four major classes: terpenoids, phenolic compounds, alkaloids, and sulphur-containing compounds. 			
TI4	Describe the functions of secondary metabolites (2)			
Ans.	Function of secondary metabolites competitive weapons against other living such as animals, plants, insects, and microorganisms. metal transporting agents. agents for symbiotic relations with other organisms. reproductive agent and. differentiation effectors. agents of communication between organisms.			
	Course Outcome	**POs**	**CL**	**KC**
CO5	Understand the gene transfer techniques by Ti plasmid from *Agrobacterium tumefaciens* and viral vectors	PO6	Un	C, P
TI1	Describe Crown gall tumor (2)			
Ans.	It is an abnormal tumor like growth caused by *Agrobacterium tumefaciens* at the base of the plant. Crown gall appears as rough, abnormal tumors or galls at or below the soil surface on roots, the crown, or trunk. Live galls are not hard but soft and spongy, the centers of older galls decay. Young trees become stunted. Older trees often develop secondary wood rots.			
TI2	Describe T-DNA (2)			
Ans.	The soil bacterium Agrobacterium tumefaciens can transfer a part of its tumor-inducing (Ti) plasmid, the T-DNA, to plant cells. The virulence (vir) genes, also located on the Ti plasmid, encode proteins involved in the transport of T-DNA into the plant cell			
TI3	Compare the applications of Ti plasmid (2)			
Ans.	The ability of Agrobacterium to deliver DNA into plant cells opened new doors for plant genome engineering, allowing the production of genetically modified plants (transgenic plants). Proteins involved in mediating the transfer of T-DNA will first recognize the border sequences of the T-DNA region. Therefore, it is possible for scientists to use T-DNA border sequences to flank any desired sequence of interest - such a product can then be inserted into a plasmid and introduced into Agrobacterium cells. There, the border sequences will be recognized by the transfer apparatus of *A. tumefaciens* and delivered in a standard manner into the target plant cell. Moreover, by leaving behind only the border sequences of the T-DNA, the resulting product will edit the plant genome without causing any tumors in plants. This method has been used to modify several crop			

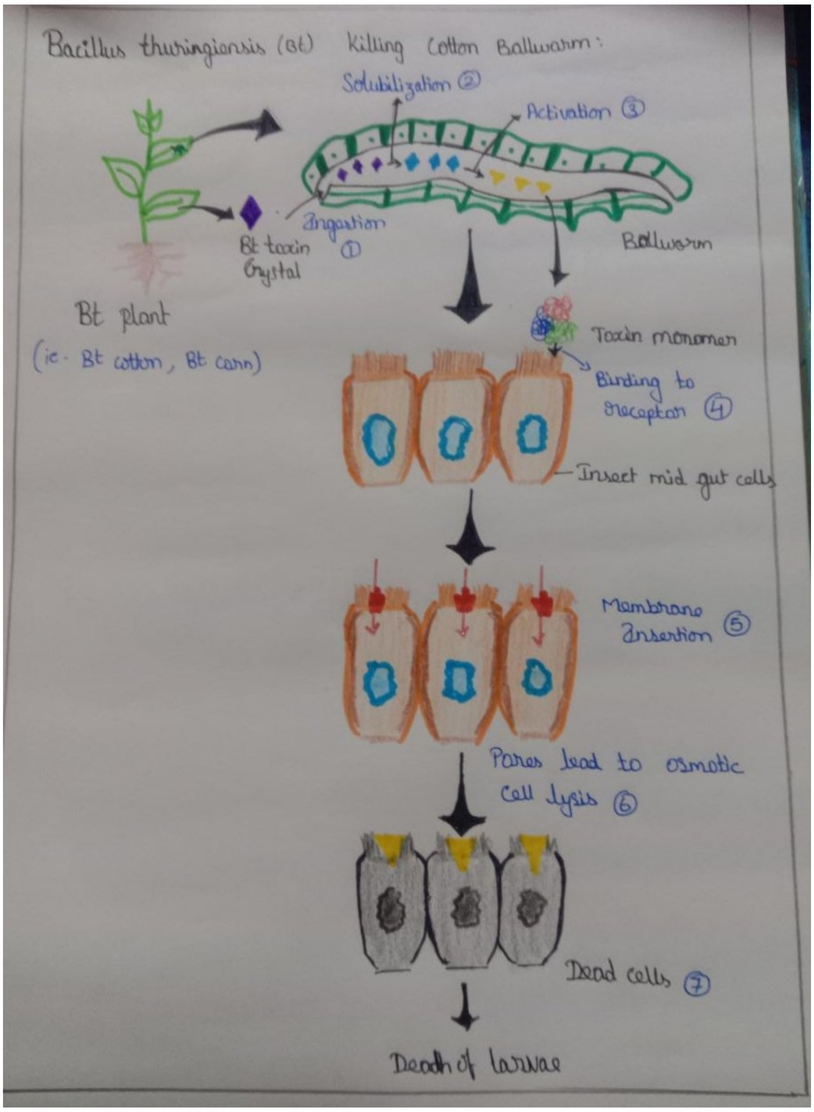
<table>
<tr><td></td><td colspan="4">plants, including rice, barley, and wheat.</td></tr>
<tr><td>TI4</td><td colspan="4">Explain any two plant viral vectors (2)</td></tr>
<tr><td>Ans.</td><td colspan="4">There are four main types of viral vectors (adeno-associated viral, adenoviral, lentiviral, retroviral) each with their own unique characteristics, uses, and limitations. Cauliflower mosaic virus and Gemini virus are the two viral vectors used in genetic modification of plants</td></tr>
<tr><td></td><td>Course Outcome</td><td>POs</td><td>CL</td><td>KC</td></tr>
<tr><td>CO6</td><td>Understand the crop improvement by genetic introduction of herbicide resistance, insect resistance and viral resistance genes in plants</td><td>PO1</td><td>U</td><td>P</td></tr>
<tr><td>TI1</td><td colspan="4">Describe the structure of cauliflower mosaic virus (CaMV) (5)</td></tr>
<tr><td>Ans.</td><td colspan="4">
</td></tr>
<tr><td>TI2</td><td colspan="4">Explain the crop improvement procedure done in golden rice (5)</td></tr>
<tr><td>Ans.</td><td colspan="4">
</td></tr>
<tr><td>TI3</td><td colspan="4">Discuss the production technology of Bt Cotton (10)</td></tr>
<tr><td>Ans.</td><td colspan="4">Bacillus thuringiensis
Bacillus thuringiensis is a gram-positive, spore-forming bacteria which is mainly found in the soil. As stated above, it produces proteins that are toxic to insects. Organic farmers</td></tr>
</table>

use this bacterium in a solution and spray it on the plants to protect them from pests.

The practice of using *Bacillus thuringiensis* began in the year 1996 with small quantities of genes from the bacterium. This facilitated the production of cry proteins in plant cells that helped to kill pests. Pests like European and southwestern corn borer, tobacco and cotton budworm, pink bollworm and Colorado potato beetle largely destroyed the crop yields. *Bacillus thuringiensis* protected the crops against such pests.

Bt Cotton

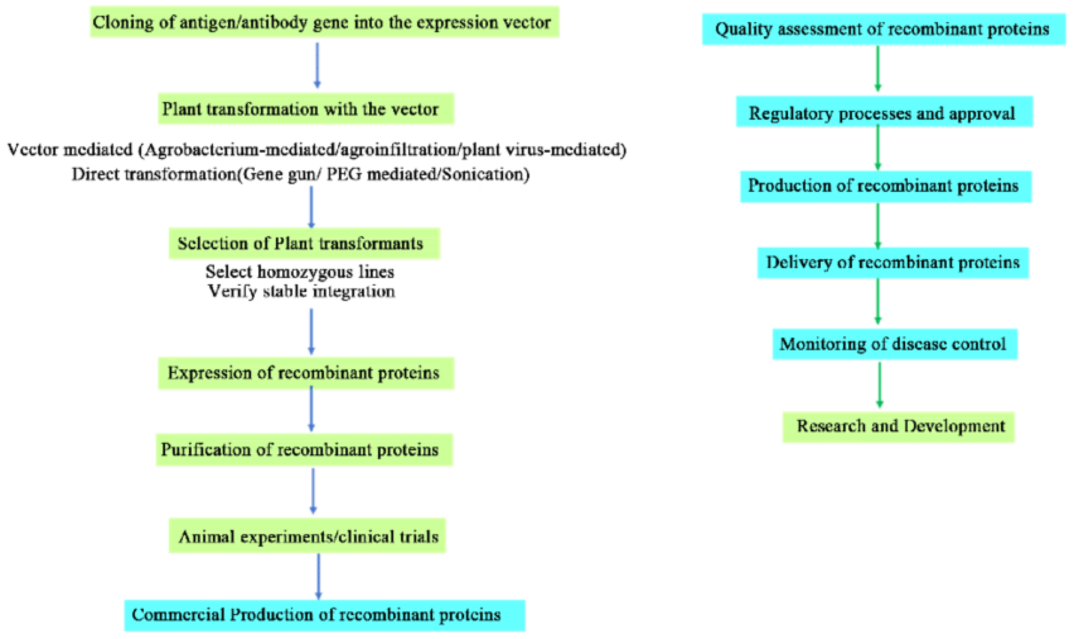
The Bt cotton variety is genetically transformed with the Bt gene to protect the plants from bollworm, a major pest of cotton. The worms present on the leaves of Bt cotton become lethargic and sleepy and thus cause less damage to the plants. When the worms consume the plant, the toxic proteins produced by the crops are ingested, thereby, killing them.



TI4	Explain the importance of satellite RNA in producing viral resistant plants (2)			
Ans.	Satellite RNAs and satellite viruses are extra viral components that can affect either the pathogenicity, the accumulation, or both of their associated viruses while themselves being dependent on the associated viruses as helper viruses for their infection.			
	Course Outcome	**POs**	**CL**	**KC**
CO7	Understand the plant seed storage proteins and development of vaccines using plants	PO6	U	C, P

TI1	Discuss on seed storage proteins (2)
Ans.	Seed storage proteins are proteins that accumulate significantly in the developing seed, whose main function is to act as a storage reserve for nitrogen, carbon, and sulfur. These proteins are rapidly mobilized during seed germination and serve as the major source of reduced nitrogen for the growing seedlings.
TI2	Describe the edible vaccines with examples (2)
Ans.	Edible vaccines are nothing but transgenic plant and animal-based production of or those contain agents that trigger an animal's immune response. In simple, plant or animal-made pharmaceuticals are edible vaccines. Foods under such application include potato, banana, lettuce, corn, soybean, rice, and legumes.
TI3	Explain the steps involved in production of plant vaccines (5)

Ans.



(a) (b)

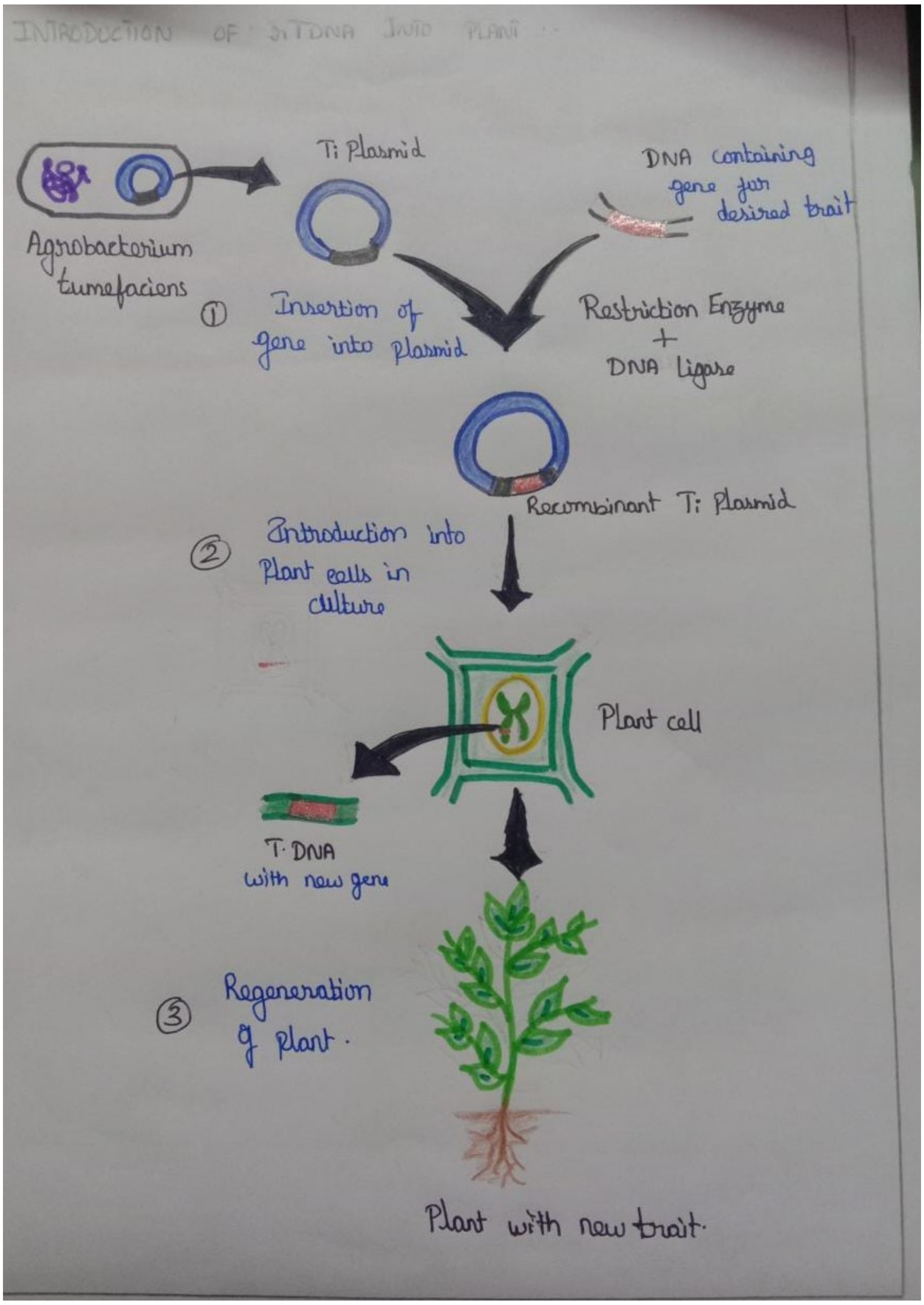
TI4	Compare the advantages and limitations of plant vaccine (10)

Ans.

Advantages	*Disadvantages*
The plants producing the edible vaccines could be grown in the third world countries	Plants are living organisms that changes, so the continuity of the vaccine production might not be guaranteed
Plants are regularly used in pharmaceuticals, and there exist established purification protocols	The edible vaccines could be mistaken for regular fruits and consumed in larger amounts than might be safe
Growing plants is much cheaper than producing vaccines	The dosage of the vaccines might be variable. For example, different sized bananas will contain different amounts of vaccine
Plants can not host most human pathogens, so the vaccines will not pose a danger to humans	If the vaccines were grown in fields or on trees, security would become a big issue
Agricultural products can be transported around the world relatively cheaply	Glycosylation patterns in plants differ from those in humans and could affect the functionality of the vaccines

	Course Outcome	**POs**	**CL**	**KC**
CO8	Understand the transgenic plants, its applications, and ecological impacts	PO4	U	C
TI1	Explain the production technology of transgenic plants (10)			
Ans.	A transgenic plant is a modified organism where genes are transferred from one			

	organism to another through genetic engineering techniques". The purpose of producing a transgenic plant is to obtain a species that has ideal traits, high yield, and quality.



TI2	Discuss the steps involved in producing genetically modified foods (5)
Ans.	Genetic modification of plants involves adding a specific stretch of DNA into the plant's genome, giving it new or different characteristics. This could include changing the way the plant grows or making it resistant to a particular disease. The new DNA becomes part of the GM plant's genome which the seeds produced by these plants will contain.
TI3	Discuss the ethical issues related to the production of GM crops (10)
Ans.	Risks arising from the application of GMOs in agriculture include risks to human health, environment besides ethical concerns. There are concerns, doubts, and fears in the mind of common men about genetic engineering. There are pro and anti-genetic engineering.

There is no doubt that genetic engineering offers great opportunity for solving hunger, food insecurity and malnutrition problems globally. On the other hand, some people think that genetic engineering is unnatural, and people are scared to buy GM foods since they think that genes will be transmitted to them. Moreover, some of the companies do not even label GM foods. Although people in the US eat GM foods in Europe, people are not willing to accept GM foods because of fears of risks and other ethical concerns. However, GMOs need to be tested extensively for toxicity to humans and animals before their release in the market. Sometimes, newer proteins may behave as allergens. GMOs are generally produced involving antibiotic resistance genes which raises the concerns of antibiotic resistance gene transfer on consumption. All these are discussed in the following section.

1. Antibiotic resistance

There have been several issues raised at different platforms on the use of antibiotic resistance markers in selection of recombinant organisms (GMOs).

i. It is generally assumed by people that eating foods with antibiotic resistance markers would reduce the effectiveness of an antibiotic since the antibiotic will be degraded. This issue was raised during the approval for Galgene's FlavrSavr and Ciba Giegy's Bt corn 176.

ii. The transfer of antibiotic resistance marker gene from GMO to intestinal microflora also poses risk of horizontal gene transfer which can lead to antibiotic resistant micro-organisms, although its probability in acidic environment is extremely rare.

In view of the above issues, antibiotic resistance markers are being replaced with auxotropic or food grade markers.

2. Eating exogenous/foreign DNA

There are also apprehensions regarding the ingestion of exogenous DNA while eating transgenic foods. However, there are no scientific reports that DNA from these transgenic crops or foods pose any risk to human health. Generally, foreign DNA is destroyed by the body's defense mechanism. Generally, DNA present in micro-organisms, plants and animals is eaten by human beings all the time and does not pose any problem. Similarly, exogenous DNA is not likely to pose any health problem.

3. Food safety

Consumers are sometimes wary of the safety of GM foods due to problems such as allergens, pesticide residues, microbiological contaminants, and bovine spongiform encephalopathy (mad cow disease). There is also a common notion that GM crops are unsafe for other organisms that feed on them e.g. Bt toxin may kill Monarch butterfly larvae. However, there is no scientific evidence to support this.

4. Environmental concerns

GMOs are novel products which, when released, may cause ecosystems to get polluted unintentionally and may also result from out-crossing with wild populations. GMOs may get released in the environment and pose several risks such as transgene instability, transfer to weeds, persistence of transgene in the environment, loss of biodiversity, changes in soil ecology, generation of new live viruses etc. NGOs have also raised the concern that growing genetically engineered crops will be harmful for the environment e.g. if herbicide resistance genes from canola flow into weedy relatives will make them resistant to herbicides. There are no scientific studies to support this. Moreover, the risks to birds, insects and other non-target species that come into contact with or consume GM plants is not known. Hence, the extent of post-release monitoring of GMOs is required to protect ecosystems.

5 Risk of toxicity

GMOs need to be evaluated for toxicity rigorously in animal models before their release for human consumption. Sometimes, the companies hide controversial data in this

	regard for getting clearance from regulatory authorities. 6. Risk of allergies The proteins from GMO may become allergens and hence need to be tested for allergenicity. Since GM foods are not labeled, a person could suffer a potentially fatal allergic reaction e.g. an allergenic Brazil nut gene was transferred to a soybean variety, but the resultant modified crop was never released to the public because of this problem. The FDA considers potential allergens to be a very important issue. Developers are required to systematically evaluate this possibility. Special care is taken with genes derived from foods that commonly cause food allergies. For example, about 8% of the people are allergic to foods that contain milk, wheat, some seafood, or nuts. The FDA regulations state that proteins taken from commonly allergenic foods are presumed to be allergens unless demonstrated otherwise. So far, no products on the market contain such allergens. If they do, the FDA requires that they be clearly labeled biotech. 7. Perceived risks and benefits While accepting any new technology like GMO, consumers always weigh the perceived benefits of accepting it against the perceived risks. The scientific evidence is required to prove their benefits. 8. Accountability Consumers should be involved in local, national, and international debates and in policy guidance. There are very few fora available to the public to discuss the wide range of issues related to GMOs. Consumers comprising everyone in the world (and including future generations) also have a stake in the process. Consumers' choices to buy non-GM or GM foods cannot be ignored. They are not forced to buy food that they don't want. Keeping this in mind, some of the leading GM crop producers are reconsidering their production decisions and the agrifood industry is rapidly restructuring. 9. Loss of biodiversity There is a concern among people that extensive use of GM crops / foods will lead to loss of our biodiversity. GM crops could compete or breed with wild species threatening biodiversity. We need to retain our traditional foods. 10. Soil fertility It has been demonstrated scientifically that GM crops transfer their genes to soil fungi and bacteria. The affected fungi and bacteria then behave in abnormal ways and diminish their function in breaking down organic material, which makes nutrients available to plants. The soil becomes progressively less fertile. After a few seasons of planting GM crops, the soil will not be able to host any other conventional crop. If farmers wish to switch back to conventional crops, it could take a whole season to rehabilitate the soil. Hence, the economic consequences are unfavorable besides the added cost of nutrients and fertilizers which are necessary to regenerate the soil.
TI4	Describe the applications of transgenic plants (2)
Ans.	The six applications are: (1) Resistance to Biotic Stresses (2) Resistance to Abiotic Stresses (3) Improvement of Crop Yield and Quality (4) Transgenic Plants with Improved Nutrition (5) Commercial Transgenic Crop Plants and (6) Transgenic Plants as Bioreactors.

	Course Outcome	**POs**	**CL**	**KC**
CO1				

TI1				
Ans.				
TI2				
Ans.				
TI3				
Ans.				
TI4				
Ans.				
	Course Outcome	**POs**	**CL**	**KC**
CO2				
TI1				
Ans.				
TI2				
Ans.				
TI3				
Ans.				
TI4				
Ans.				
	Course Outcome	**POs**	**CL**	**KC**
CO3				
TI1				
Ans.				
TI2				
Ans.				
TI3				
Ans.				
TI4				
Ans.				
	Course Outcome	**POs**	**CL**	**KC**
CO4				
TI1				
Ans.				
TI2				
Ans.				
TI3				
Ans.				
TI4				
Ans.				

	Course Outcome	POs	CL	KC
CO5				
TI1				
Ans.				
TI2				
Ans.				
TI3				
Ans.				
TI4				
Ans.				
	Course Outcome	**POs**	**CL**	**KC**
CO6				
TI1				
Ans.				
TI2				
Ans.				
TI3				
Ans.				
TI4				
Ans.				
	Course Outcome	**POs**	**CL**	**KC**
CO7				
TI1				
Ans.				
TI2				
Ans.				
TI3				
Ans.				
TI4				
Ans.				
	Course Outcome	**POs**	**CL**	**KC**
CO8				
TI1				
Ans.				
TI2				
Ans.				
TI3				
Ans.				

TI4	
Ans.	

Note: Add/Delete rows as needed

Course – PO Matrix (Course Articulation Matrix)

It is necessary to determine the level (mapping strength) at which a particular PO/PSO is addressed by the course. A simple method is to relate the level of PO/PSO with the number of hours devoted to the Course Outcomes which address the given PO/PSO.

- If ≥40% (out of 28 for a 2 credit courses, 40 for a 3-credit course and 54 for 4 credit course) of classroom activity measured in terms of designed classroom sessions addressing a particular PO/PSO, it is considered that PO/PSO is addressed at Level 3
- If 25 to 40% (out of 28 for a 2 credit courses, 40 for a 3-credit course and 54 for 4 credit course) of classroom activity measured in terms of designed classroom sessions addressing a particular PO/PSO, that PO/PSO is addressed at Level 2
- If 5 to 25% (out of 28 for a 2 credit courses, 40 for a 3-credit course and 54 for 4 credit course) of classroom activity measured in terms of designed classroom sessions addressing a particular PO/PSO, that PO/PSO is addressed at Level 1
- If < 5% (out of 28 for a 2 credit courses, 40 for a 3-credit course and 54 for 4 credit course) of classroom activity measured in terms of designed classroom sessions addressing a particular PO/PSO, that PO/PSO is considered not-addressed

Sample mapping strength of POs of the course Plant Biotechnology

10 of 60 (16%) classroom sessions are devoted to PO1 Course Level PO1 strength is 1

5 of 60 (8%) classroom sessions are devoted to PO4 Course Level PO4 strength is 1

15 of 60 (25%) classroom sessions are devoted to PO5 Course Level PO5 strength is 2

30 of 60 (50%) classroom sessions are devoted to PO6 Course Level PO6 strength is 3

. The POs and their levels a course addresses are captured in a C-PO matrix for the course as in

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8
	1	0	0	1	2	3	0	0

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12

Competencies

Though competency is another term for Course Outcome, here we use competencies to elaborate the Course Outcomes. The 7±2 COs are elaborated into 15±5 competencies. This elaboration helps the instructor to plan her instruction. Each competency constitutes an instruction unit of 1-5 hours of classroom interaction. Instruction is proposed to be planned in the Development Phase as per Merrill's First Principles of Learning (Problem, Activation, Demonstration, Application, and Integration). Elaboration of a course outcome into multiple competencies results in multiple Demonstrations and Applications. The competencies can be labeled as, say, C2.1 with C as Competency, the next digit representing the CO, and the following digit representing the competency number under that CO. Therefore C2.1 represents Competency 1 under Course Outcome 2.

The same care that is taken in writing course outcome statements should also be taken in writing a Competency statement and as per the format indicated in the resource document on outcomes.

Sample Competencies

	Competency	PO	Class Hrs.
CO1	Understand the plant nuclear, mitochondrial, chloroplast genome and gene families	PO5	5
CO2	Understand the roles of hormones (Auxin, Gibberelin, Cytokinin, Abscisic acid and Ethylene) in phytomorphogenesis and their regulation of gene expression	PO6	10
C1	Understand the roles of Auxin and Gibberelin in phytomorphogenesis and their regulation of gene expression		4
C2	Understand the roles of Cytokinin in phytomorphogenesis and its regulation of gene expression		2
C3	Understand the roles of Abscisic acid and Ethylene in phytomorphogenesis and their regulation of gene expression		4
CO3	Understand the plant tissue culture by micropropagation, organogenesis, somatic embryogenesis, haploid plants, and protoplasts fusion	PO5	10
C1	Understand the plant tissue culture by micropropagation and organogenesis		4
C2	Understand the plant tissue culture by somatic embryogenesis and haploid plants		4
C3	Understand the plant tissue culture by protoplasts fusion		2
CO4	Understand the production of synthetic seeds and secondary metabolites	PO6/PSO1	5
CO5	Understand the gene transfer techniques by Ti plasmid from *Agrobacterium tumefaciens* and viral vectors	PO6	10
C1	Understand the gene transfer techniques by Ti plasmid from *Agrobacterium*		5

	tumefaciens		
C2	Understand the gene transfer techniques by viral vectors		5
CO6	Understand the crop improvement by genetic introduction of herbicide resistance, insect resistance and viral resistance genes in plants	PO1	10
C1	Understand the crop improvement by genetic introduction of herbicide resistance gene in plants		3
C2	Understand the crop improvement by genetic introduction of insect resistance gene in plants		3
C3	Understand the crop improvement by genetic introduction of viral resistance gene in plants		4
CO7	Understand the plant seed storage proteins and development of vaccines using plants	PO6	5
CO8	Understand the transgenic plants, its applications, and ecological impacts	PO4	5

	Competency	PO/PSO addressed	Class Sessions (approx.)	Tutorial (Hrs.)	Lab Sessions (Hrs.)
CO1					
C1.1					
C1.2					
C1.3					
CO2					
C2.1					
C2.2					
C2.3					
CO3					
C3.1					
C3.2					
C3.3					
CO4					
C4.1					
C4.2					

C4.3					
CO5					
C5.1					
C5.2					
C5.3					
CO6					
C6.1					
C6.2					
C6.3					
CO7					
C7.1					
C7.2					
C7.3					

Note: Add and delete rows as needed

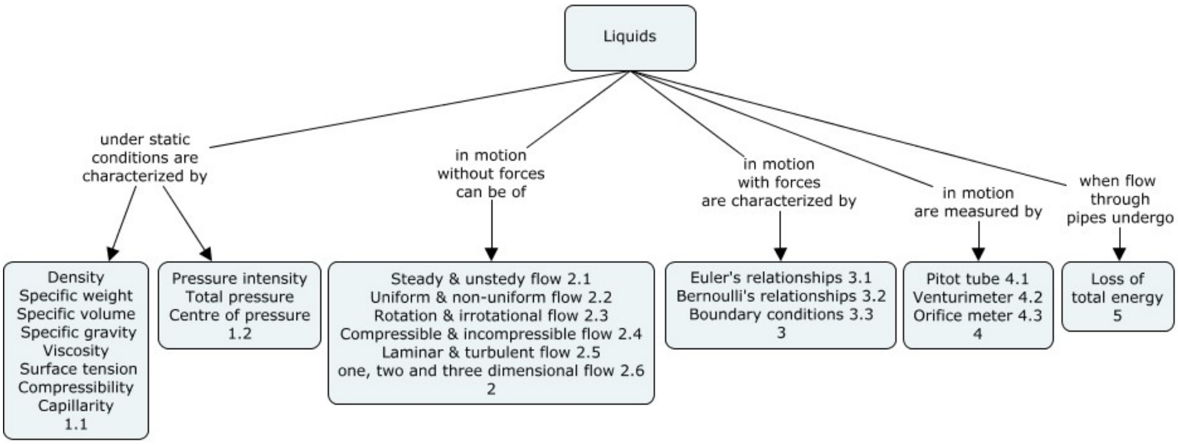
Concept Map (optional)

Concept Map is a graphical tool for organizing and representing conceptual knowledge (http://cmap.ihmc.us/). It includes Concepts, Relationship between concepts indicated by a connecting line linking two concepts and Linking phrases specifying the relationship between the two concepts. Concepts are represented in a hierarchical fashion with the most inclusive, most general concepts at the top of the map and the more specific, less general concepts arranged hierarchically below. The hierarchical structure for a particular domain of knowledge also depends on the context in which that knowledge is being applied or considered.

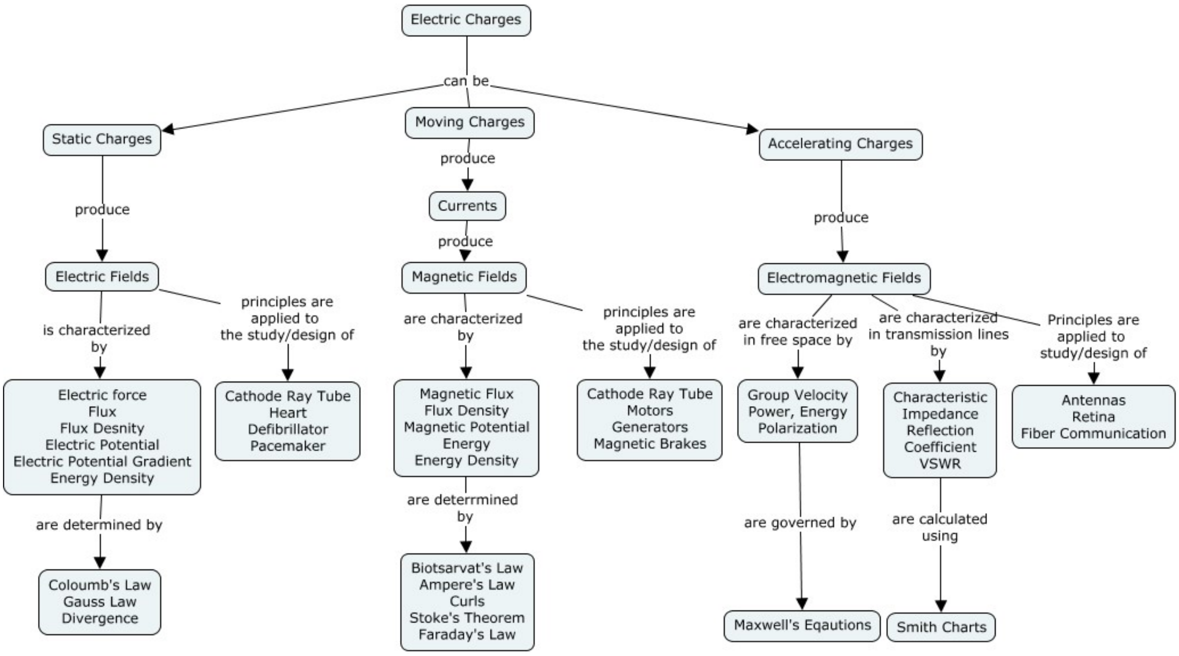
Cmap, an open-source tool, is amazingly easy to use. It has many editing features that enable you to create a good hierarchically organized Cmap. The Cmap can be drawn based on the content given to you and/or your view of the course. Faculty creating Cmaps of their courses found it a very enjoyable and enriching activity. If the concept map becomes unwieldy to include all the learning units, break the concept map into multiple concept maps

Sample Concept Maps

Course: Fluid Mechanics



Course: Electromagnetic Theory



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