Integrated Approach in Science Teaching

Nitu Kaur*
Department of Education, Mizoram University, Aizawl, Mizoram - 796 004, India

Abstract

The need of integration of curriculum is a frequently felt need over the times but has never been able to take up due attention by the curriculum planners while planning the curriculum on account of the vastness of approach, its difficult operational modalities and opposing view by groups who advocate the supremacy of academic excellence through specializations in specific subjects over integration of subjects. Many a times the timing of introducing integration is questioned by the traditionalist academicians who argue that integration sometimes do more harm than good. Obviously, it is a superficial argument by them as they know curriculum integration is not an easy process but requires an extra edge with the curriculum practitioners.

It is never too late to introduce integration, sooner the better. The best thing about integration is that it can begin at any level of education. Its' proper planning, implementation and execution can never go wrong provided the intent of the knowledge provider remains honest, pious and focused.

When it comes to science education the application of integration is an inevitable need. A learner begins to enjoy science learning whenever he/she visualizes the connecting links between the concepts and feels the very integral nature of science in its totality.

The present article is an attempt to justify the need of integration in curriculum, especially in the discipline of science. There can be many parallel existing competitive arguments which can establish the need of introducing integration into curriculum to deliver the knowledge to the learners in its most complete form and in a more psychological way. Knowledge knows no boundaries; taking this basal thought the author want to highlight the benefits one gets out of integrated approach of learning over fragmented approach of learning. Also an attempt has been made to plan a lesson of biology in an integrated approach.

Key Words: Integrated Approach, Science Teaching

INTRODUCTION

Who trains the mind that we have to acquire knowledge in the realm of compartmentalized chambers of disciplines and that disciplines differ from one another in their very nature. There can be rather another way to look into and across disciplines using the lens of integration. The whole is always greater than its parts. Knowledge when compartmentalized becomes incomplete and non-utilitarian. The Primary Programs Framework on Teaching and Learning by Alberta Education, Canada in 2007, states that "*Though organized into separate subject, course or program areas there are many connections across the curriculum. … Integrating across content areas, and providing ways for students to make connections, enhances student learning" (Program of Studies: Elementary Schools, p.1)*. This suggests that children learn better when valid connections are laid out across the entire curriculum. It promotes meaningful learning especially in the initial stages of education spanning through kindergarten to lower primary stages. The scope of integration is in fact beyond the scope of classifications of stages of education as the lower primary, upper primary, secondary, higher secondary and tertiary. On the contrary integration is a flexible, learner-centred, holistic, purposeful, interwoven, connected, correlated, linked approach of teaching wherein according to particular theme or problem curriculum planning can be done. This integration is very much possible in any of the stages of learning. So far the trend is to integrate the topics and themes of curricula in primary stages and a new trend these days is researching on the scope of integration in middle schools. Similarly learning module according to the scope and feasibility of topics of integration can be developed at high school and post high school levels. But as the length, width and depth of subject contents tend to increase towards the higher side of educational ladder integration becomes challenging and difficult but certain topics always can be integrated with proper planning. One note of caution is that we cannot apply integration approach in between every concept across different disciplines. It has to be never applied forcefully. According to a Primary Programs Framework on Teaching and Learning by Alberta Education, Canada in 2007, Curriculum integration can be defined as follows,

"Curriculum integration can be described as an approach to teaching and learning that is based on both philosophy and practicality. It can generally be defined as a curriculum approach that purposefully draws together knowledge, skills, attitudes and values from within or across subject areas to develop a more powerful understanding of key ideas. Curriculum integration occurs when components of the curriculum are connected and related in meaningful ways by both the students and teachers."

Vars (1991) states that the notion of curriculum integration is not new; ever since the dawn of twentieth century it has been advocated by great philosophers like Dewey and Kilpatrick. The very idea of integration is very revolutionary as it demands a great deal of change in the traditional educational setup and change comes with friction. But from time to time there had been several researches related to this area which suggest an adoption of integrated curricular approach in schools to solve a number of problems emerging in the field of education. Despite of a wide availability of literature in this challenging field there are instances when the very idea of integration is misunderstood. On the one end the idea is gaining popularity on the account of providing better alternatives to teaching learning outcomes and on the other end many confusions, uncertainty and concern over what exactly is meant by integration continues to prevail.The integration as an idea needs to be elaborated and understood in many forms of aligned approaches like theme based approach, problem solving approach, application based learning, real-life based projects, industry work force demand based training modules etc. Interdisciplinary and multidisciplinary approach also speaks of integration of concepts across the boundaries of traditional disciplines. In fact integration comes out to be a solution of many relevant problems confronting today's world.

Integration demands a prior analysis of existing situations, better referred as situational analysis in the work of Nicholls & Nicholls (1980) before any kind of curriculum planning. The scope and feasibility of any kind of integration and its application in that particular situation needs to be researched, overlooking which can give rise to serious complication in integration. According to Jenkins &Shipman (1978) worldwide curriculum studies boils down to describing, explaining and justifying curriculum practices. They clearly indicated that curriculum studies are important to update and innovate the curricular practices rather than merely updating the knowledge component only. Integration as an innovative practice is very promising for disciplines which have been suffering the disadvantages of illicit fragmentation into subjects.

Kysilka (1998) emphasizes on three reasons that prevents teachers from integrating curriculum in which are assessments of students on mere factual knowledge; inadequate planning time available to the teachers; parents' resistance to change in traditionalist pattern of educating their wards and; narrow knowledge base of teachers as part of their discipline training especially at elementary level. Thus in order to make integration easy and accessible for teachers and curriculum planners changes in pedagogical approaches of classroom teaching, assessment parameters for students and most specially change in the mindsets of all the stakeholders in child's education is required. The pedagogical practices needs to be expand both the knowledge base of prospective teachers along with a sound understanding of psyche of a learner; the assessment parameters needs to be flexible and differential for different learners and a welcoming mindset within all about the unitary nature of knowledge has to be realized. Connections, inter-linkages and integration across various branches of knowledge helps more than harm we all think that it does. Rather it complements to a learner's understanding of subject in a better way. Actually integration is harmless.

CONCEPT TEACHING IN SCIENCE

"The very notion of `integration' incorporates the idea of unity between forms of knowledge and the respective disciplines" (Pring, 1973, p.135).When we develop a plan of teaching following a centralized theme across the boundaries of disciplines it indirectly symbolizes the unitary nature of knowledge. The power of this unified knowledge when unleashed has the potential to solve any problem in front of us. Science as a discipline is in the greatest need of this unification, as rightly put by Ralph W. Emerson, an eminent American philosopher, in his words,*"The astronomer discovers that geometry, a pure abstraction of the human mind, is the measure of planetary motion. The chemist finds proportions and intelligible method throughout matter; and science is nothing but finding of analogy, identity, in the most remote parts."*

Science is taught through concepts (Kaur, 2016). Concepts are simply the mental representations of knowledge with a set of attributes that generalize or distinguish them. Science as a discipline is having two fold functionary aspects, firstly, to facilitate the concept attainment process by bridging connecting links and secondly, associating a utilitarian value to the knowledge of the concepts such that it is easily accommodated and assimilated as a valid piece of knowledge.Effective strategies designed to promote efficient and meaningful learning rely upon connecting prior knowledge to new concepts (Okebukola & Jegede, 1988). The true nature of science learning is meaningful learning which is possible only if the new knowledge concepts is rightly linked with the previous knowledge concepts, a constructivist approach of learning where learning is an active process in which the learner is constantly creating and revising his or her internal representation of knowledge when new concepts are linked to familiar concepts existing in the learners' cognitive structure and can be applied to all subject matter.

The NCF (National Curriculum Framework), 2000 addresses science education as 'Science and Technology' education recognizing the relationship of science, technology and society. According to the framework, science is the creative response to the curiosity and capacity to wonder present amongst every human being. Learning of science in schools augments the spirit of enquiry, creativity and objectivity along with aesthetic sensibility. According to NCF, 2005 one important human response to the wonder and awe of nature from the earliest times has been to observe the physical and biological environment carefully, look for any meaningful patterns and relations, make and use new tools to interact with nature, and build conceptual models to understand the world. This human endeavour has led to modern science. in the light of these two latest curriculum frameworks it can be said that very nature of science is based on identifying meaningful patterns making valid connections in nature. It as an unlimited enterprise open to all curious minds who learn that nature can answer all questions, we have to just live and experience it.

Clayton et al. (2010) states that often, by the time they students reach high school they had already concluded that school has little connection to their current lives and even less to offer in preparing them for the future. They emphasized on making the school curriculum a memorable experience of these young minds through making relevant connections between their subjects and life. School has a prime responsibility to mirror the societal contexts into their classroom experiences through multidisciplinary integration of topics both within and across disciplines. Krathwohl (2002) cites the example of a lesson planning through which he explains the 'structure of a cognitive process' as interplay of cognitive process dimension with the knowledge dimension. The revised cognitive dimension has six hierarchical levels namely remember, understand, apply, analyze, evaluate and create. The knowledge dimension is dismantled into four hierarchies namely the factual, conceptual, procedural and meta-cognitive level of knowledge. An inference thus can be drawn that science learning cannot be summated into knowledge of some facts transformed into concepts, but for firm understanding of these concept inter-linkages and connections needs to be established in-between the concepts to understand the concepts right. The procedural and meta-cognitive aspect of knowledge cannot be undertaken in absence of integration of concepts.

According to UNESCO document talking about challenges in basic science educations some vital recommendations has been reiterated that ask us to rethink how to restructure the curriculum in science.

Science lessons are not to be structured according to the ideas in scientists' science, but to be restructured according to the perspective of students' learning and how their ideas might develop to those of standard science. This is the most challenging part for stakeholders at all levels of education.Some of the main recommendations in the document which are emphasizing on the advantages of science curriculum integration are as following:

- Pedagogy for conceptual, procedural and NOS (Nature of Science) learning in science education could be more effective and inclusive when the existing ideas and beliefs that learners bring to a lesson are elicited, addressed, and linked to their classroom experiences;
- Science is taught and learned in contexts in which students can make links between their existing knowledge, the classroom experiences, and the science to be learnt.
- The students are engaged in thinking about the science they are learning during the learning tasks; students' content knowledge, procedural knowledge, and knowledge about the nature and characteristics of scientific practice are developed together, not separately and
- The students are engaged in thinking about their own and others' thinking, thereby developing a meta-cognitive awareness of the basis for their own present thinking and of the development of their thinking as they learn.

Ware & Mundial (1992) in their World Bank report on educational profiles of secondary school science teachers in developing nations emphasized on radical shifts in pedagogical content and practices in science teaching training programs. They highlighted that the student teacher needs to learn there are connections between disciplines; some scientific ideas are more important than others; science is one way of understanding reality; there are scientific modes of inquiry and habits of mind than just knowing facts and concepts of science and to accomplish this they all need to be acquainted with the pedagogical content knowledge relevant to the disciplines they will teach. Tunnicliffe, S. D. (2012) states very aptly the faultiness of current school science practices highlighting the fact that there is a prevailing dilemma in biology teaching whether to judge them on their real knowledge of biology or measure them by success on a mandated state exam where they learn the 'word' that will get the mark. The problem in the later approach is that learners do not understand the fundamental concept and ideas that the 'word' represents.

Thus it is very clear that science teaching and learning processes especially in school science perspective needs to be redefined in the light of integration which is a heavily demanded aspect of curriculum change. Lake (1994) mentioned in her report that both researches and teachers' own anecdotal records of success have proved that teachers who link subject areas and provide meaningful learning experiences that develop skills and knowledge leads to an understanding of conceptual relationships within their students. Both teacher and there are very excited and positive towards this new approach being rapidly spoken in the field of curriculum studies.

INTEGRATED VS. FRAGMENTED APPROACH OF TEACHING

Robin Forgarty suggested ten ways of integrating curriculum (1991), in her book, *The Mindful School: How to Integrate the Curriculum.* Integration here is referred as a continuum rather than a single way of its explanation. These ten models range over a continuum beginning with fragmented traditional approach of curriculum planning and ending with an advanced, networked approach to curriculum planning. In between them eight ways of integration approaches has been identified which are, connected, nested, sequenced, shared, webbed, threaded, integrated and immersed respectively.

Heidi Hayes Jacobs (1989) also identified five approaches to curriculum integration ranging from a subject and disciplined centered approach to completely integrated approach of curriculum which are named as, parallel disciplines, multidisciplinary, interdisciplinary, integrated day and complete integration.

It is thus concluded the approach of curriculum planning is ranging over a continuum from a very disciplinary fragmented approach to very interdisciplinary integrated approach. The choices in-between the two are often based on the amount of risk the curriculum planners want to take in order to introduce the change from traditional well set approach to challenging approach of incorporating more and more integration. The choice of integration is also the demand emerging from the requirement of curriculum transaction in a more democratic learner-centered setup of teaching- learning process, a shift from traditional teacher centered setup of teaching- learning process.

In order to enable higher order learning in the students integration seems to be a very suitable model to teach science. In facts concepts across the various sub disciplines of science are never isolated from each other rather they are complementary and supplementary in nature. This is the reason why we find a scope of inter disciplinary branches of science at tertiary level of education like integrating mathematics and sciences, history of science integrating history with science, zoogeography integrating animal science with geographical distribution geophysics integrating geology with physics, biochemistry, biophysics, environmental and forest sciences, earth sciences, health science, forensic science, integrating arts and science, music and mathematics, literature and creative writing with science, science, technology, engineering and mathematics (popular STEM course in USA) and so on. This inter disciplines have greatly emerged out of the different kind of skilled task force requirement in the work force sector. This truly reflects the utilitarian basis of acquired scientific knowledge of the learner. Science Education, especially in context of India is not very pleasing. National Curriculum Committee gave recommendations and guidelines for the new pattern through a policy document titled 'The Curriculum for theTen-Year School - A Framework (1975) which are as following

- all subjects including science and mathematics were to be compulsory for all students up to Class X, as a part of general education,
- at the primary stage, science and social scienceswere to be taught as a single subject:'Environmental Studies',
- an integrated approach was to be followedfor the teaching of science at the upper primarystage as opposed to disciplinary approach thatwas then in vogue, and
- science was to be considered as onecomposite subject at the upper primary andsecondary stages

These recommendations are very much in conformity with a learner- centered approach of teaching facilitating meaningful transfer of knowledge. Despite this provision in Indian setting of education spanning from class I -X wherein real differentiation in curriculum actually begins after high school, there are instances of non-meaningful learning in the disciplines of sciences. Several misconcepts (misconnects) prevail in the minds of the students which are the result of miscommunications, missing links, lack of connectivity amongst the important concepts in the subjects and misinterpretations by the students. There are some guiding philosophies that emphasize heavily on having an integrated science curriculum. It is a strong assumption that nature of science is based on unified holistic knowledge and not distinct zone of sub disciplines; the underlying complementarities of sub-disciplines contribute mutually in grounding concepts into students' learning. Thus this becomes a potential drawback of fragmented curriculum in teaching sub disciplines of science in isolation. It restricts learner's vision and does not facilitate higher order learning.

There are some speculations about integrated curriculum that it can emerges out to be a solution for application based and problem based learning.

CONCLUSION

It is felt by the author that science education at any level, spanning from primary, secondary and tertiary level can be made more meaningful through valid integration of themes and concepts wherever possible. Many a time science learning becomes a difficult task to be accomplished by the learner who is taught through fragmented approach. It is said a little learning sometimes lead to misconcepts and a complete knowledge is the only rescue for getting rid of these misconcepts. Fragmented approach is having a narrow approach for learning and it does not ensure psychologically sound learning whereas integrated approach provides a larger canvas for the learner's discourse and interaction with strong inter-linkages in between interdisciplinary themes and concepts. There can be many parallel existing competitive arguments which can establish the need of introducing integration into curriculum to deliver the knowledge to the learners in its most complete form and in a more psychological way. Knowledge knows no boundaries; taking this basal thought the author want to highlight the benefits one gets out of integrated approach of learning over fragmented approach of learning.

Following is an attempt to make an integrated lesson plan for a biology topic which can be integrated with physics and chemistry topics at secondary level of education.

A BIOLOGY LESSON PLAN BASED ON INTEGRATED APPROACH

Lesson plan

School: Govt. High School, Aizawl
Date: 4.7.2017
Class: IX D
Period: 1st
Subject: Science
Topic: Photosynthesis
Teaching approach: Integrated
Method: Inductive-deductive
Time: 1 hour

General Objectives:

After undergoing the lesson students will be able to

- acquaint with scientific concepts, principles and laws
- acquire the scientific knowledge
- inculcate interest towards science
- develop observational and imaginative power
- develop process skills within them
- develop an appreciation towards physical world
- develop scientific literacy and scientific attitudes
- instil scientific outlook within them
- develop critical thinking
- apply the scientific knowledge in life situations
- develop the capacity to solve problems
- involve in creative activities

Specific Objectives:

Cognitive domain:

- Students will be able to define the process of photosynthesis etymologically
- Students will be able to know about the process of photosynthesis as bio chemical life process
- Students will be able to understand the underlying energy transformation mechanism involved in the photosynthesis process
- Students will be able to describe the relationship between photosynthesis and respiration as two fundamental life processes.
- Students will be able to distinguish between plant and animal on the basis of their ability to perform photosynthesis
- Students will be able to figure out the reduction and oxidation reaction in the photochemical process

- Students will be able to describe the event of harvesting solar energy by green plants
- Students will be able to infer the physico-chemical nature of photosynthesis

Affective domain:

- Students will be able to realize the significance of green plants in supporting life on planet earth

Process skills

- Students will be able to classify cell as plant and animal cell based on their ability of performing photosynthesis
- Students will be able to predict the causes for failure of life sustenance in the absence of green plants

Previous knowledge: Students have knowledge about energy forms, cell as structural and functional unit of life and plant parts

Strategies used: Questioning

Teaching aids used: Chalk, diagram, picture, chalk board, different parts of plant viz. flower, leaves, roots and stem

Key Concepts to be covered:

1. Photosynthesis
2. Energy transformation process,
3. Oxidation and reduction reaction
4. Relationship between photosynthesis and respiration
5. Chemical expression of photosynthesis

Phase of Teaching: Introduction of the Topic

Teacher asks: Name some forms of energy in our surrounding.

Students' expected response: Heat, light, electric, potential etc

Teacher asks: Can you name the ultimate source of energy on our planet?

Students' expected response: Sun

Teacher explains: Yes, exactly sun is the ultimate source of energy. The energy of sun in form of solar energy is received as a radiation which is making life possible on our planet. Solar energy is responsible for the production of all energies required for life to dwell on our planet.

Teacher asks: Well, is it possible to trap solar energy for our own usage?

Students' expected response: Yes, through solar panels, solar cookers etc.

Teacher explains: Very good. Just the way a solar panel is able to trap the sunlight, a very natural process is happening in the living forms every day where huge amount of solar energy is harvested. Today we are going to study about these special life forms and the interesting process they perform called as photosynthesis. (*Teacher writes the topic on the board, "Photosynthesis")*

Phase of Teaching: Explanation of the topic

Teacher asks: What are the two words with which the term photosynthesis is made up of?

Students' expected response: Photo and Synthesis

Teacher explains: Yes, very good. The term 'photo' means *light* and the term 'synthesis' means *to make.* So in the process of photosynthesis something is being synthesized in presence of light energy. Those special living forms which are able to perform photosynthesis are the green plants. They are capable of making their own food i.e. organic compound-sugar with the help of abiotic components i.e. inorganic compounds available in their surrounding in the presence of solar energy. Photosynthesis is possible in some photosynthetic bacteria like blue-green algae or cyanobacteria (oxygenic) and anoxygenic bacteria, some protistans like euglena and green algae.

Teacher asks: Sunlight or solar energy is available to all the living organisms on the planet earth, then why do all living organisms are not able to perform photosynthesis?

Students' expected response: They lack chlorophyll or Silence

Teacher explains: We humans cannot produce our own food unlike green plants and photosynthetic bacteria. This is because they possess wonder molecule chlorophyll which helps them to trap solar energy which in turn is used to make sugar and starch as food.

It is because of their ability to synthesize their own food, green plants are also referred as producers of vital energy for life sustenance on earth which later is consumed by the consumers at higher trophic levels in the food pyramids of different ecosystems.

Teacher asks: What do we do in the kitchen?

Students' expected response: We cook food inside the kitchen.

Teacher asks: Okay, then which part of the plant is known as its kitchen?

Students' expected response: Leaves.

Teacher explains: Yes, right. Plants are able to make their own food in the leaves due to the presence of a pigment in the leaves as already mentioned, the chlorophyll.

Pigment is the molecule that absorbs light because of their special structure and is responsible for formation of a particular colour.

Teacher asks: Why do you think that the colour of blood is red?

Students' expected response: Because of red colour pigment present in blood named haemoglobin.

Teacher asks: What pigment is responsible for skin colour?

Students' expected response: Melanin.

Teacher explains: Very good! Haemoglobin gives red colour to blood and melanin is a dark colour pigment responsible for colour of the skin, iris in eye and hair. Similarly, chlorophyll pigment is able to absorb visible radiation of solar light maximally between 400-700 nm and reflect back green light. Hence majority of plant leaves look green.

Teacher asks: Name some plant parts which look green other than leaves. (Asks by showing a sample plant with all parts)

Students' expected response: Green shoots, stem, calyx part of flower.

Teacher explains: yes, exactly. It means photosynthesis is also possible in other green plant although majority of this process takes place through leaves because of their huge number.

Teacher asks: So what are the colours present in plants other than green?

Students' expected response: Red, orange, white, yellow etc.

Teacher explains: Yes, it means different kinds of pigments are present in plants. Plant pigments are stored in special double membrane cellular organelle called plastids. Plastids are present in plant cells only. Some plastids are colourless like leucoplasts, where as other like chromoplasts, chloroplasts are coloured because of possessing colouring pigments. These different plastids are located in different types of plant parts like tubers, seeds, flowers, fruits, leaves etc. Plastids are thus referred as paint box of plants.

Teacher asks: Do you think photosynthesis is possible in roots of plants? (Thought provoking / higher order thinking question)

Students' expected response: No / Silence

Teacher explains: Well roots, flowers do not possess the green pigment chlorophyll which is the photo receptor molecule. In the lack of this molecule there is no possibility of photosynthesis. Although recently studies have reported that mother cells or pro-plastids (present in all types of plant cells) in dividing tissues of roots may develop chloroplasts if they are exposed to sunlight for a lengthy period.

Teacher asks: Now tell me, out of leucoplasts, chromoplasts and chloroplasts where do you think chlorophyll are found?

Students' expected response: Chloroplasts.

Teacher explains: Yes perfect. Chloro means green and plast means a form. Hence, chloroplasts are the green plastids containing chlorophyll molecule and are the sites of photosynthesis, present in all green parts of plants. If we see the transverse section (T.S.) of leaf in a dicot plant we can localize the chloroplast in palisade layer (elongated parenchyma cells with more chloroplast) and spongy parenchyma cells in the mesophyll tissue below epidermal layer. (Explanation showing labelled diagram- Fig. 1).

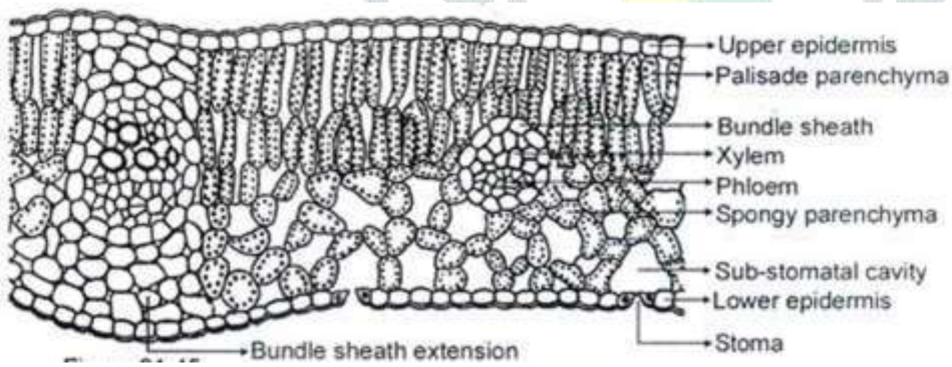

Fig.1

The number of chloroplasts varies from plant to plant, some higher plants have chloroplasts from 20-40 per cell to 1000 per cell.

Now let's understand the structure of chloroplast. If we see the electron micrograph of a section of chloroplast, it reveals the structural arrangement within it which is 5-10 micro meter long. Every chloroplast is a double membrane bound cellular organelle like mitochondria having its own genetic material and cytoplasm. There is a third internal membrane system called thylakoid which are frequently arranged in stacks called grana. These grana are interconnected by branching membraneous tubules called stromal lamellae. The 3 membranes divide chloroplast into 3 distinct internal compartments.

Teacher asks: Can you identify the 3 spaces seeing the diagram.(Asks by showing the electron micrograph of a section of chloroplast- Fig 2)

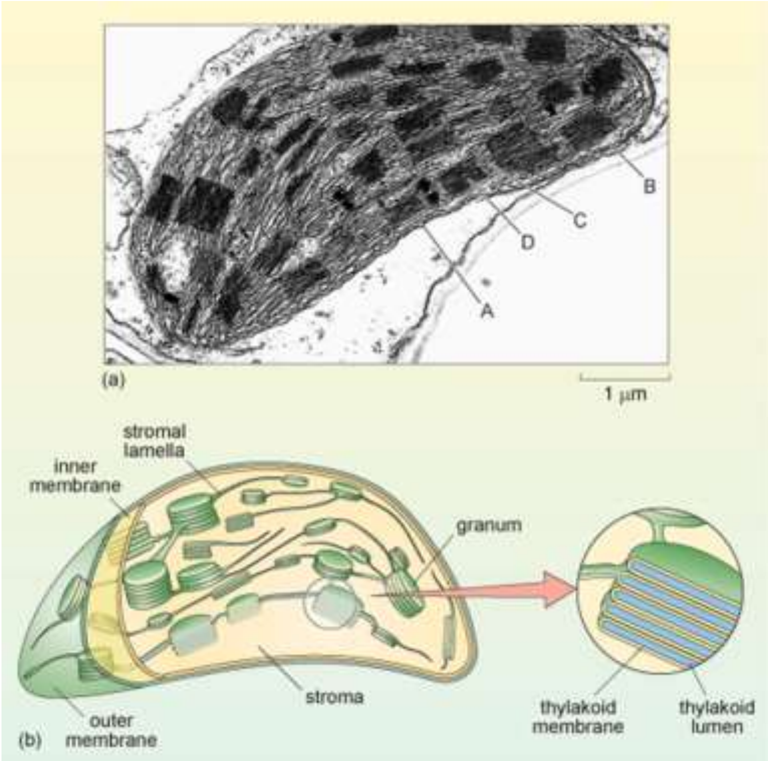

Fig. 2

Students' expected response: 1.The inter-membrane space between the outer and inner membrane. 2. The storma inside membrane but outside thylakoids. 3. The thylokoid lumen.

Teacher explains: Yes, very good! This special internal structural arrangement of chloroplast makes it more complex than mitochondria. Chloroplasts contain chlorophyll pigment within the thylakoid membrane in its lumen. It is the most internal compartment of chloroplast. There are different types of chlorophyll molecule involved in light harvesting process during photosynthesis. Each type of chlorophyll molecule is able to trap light energy of different wavelength from visible to infra red radiation. For e.g. in bacteria there is bacteriochlorophyll. The chlorophyll pigment involved in photosynthetic reaction in green plants and algae are mainly chlorophyll a, chlorophyll b, carotenoids, xanthophylls. The chlorophyll pigments involved in photosynthetic reaction are organized into two discrete Light Harvesting Complexes (LHCs) called Photo System I (PS I) and Photo System II(PS II). In some bacteria only PS I is present. . LHC are made up of 100s of pigment molecules bound to protein. They harvest light energy maximally. They are hence also called antenna complex. PSI has peak absorption at light wavelength of 700 nm and PSII has peak absorption at 680 nm. All the accessory pigments other than chlorophyll a absorb sunlight and transfer it to reaction centre PSI and PSII. Wavelengths beyond 700nm are insufficient to produce energy enough to drive photosynthetic process. This phenomenon is called as red drop effect. This sudden fall in photosynthetic yield in the far red region (greater than 680 nm) compared to red region of the electromagnetic spectrum was experimentally proved by Robert Emerson et al (1958).

Teacher asks: Name the cell organelle which is called the power house of cell.

Students' expected response: Mitochondria.

Teacher explains: Yes, correct. Mitochondria is described as cellular power house as it generates most of the cell's supply of Adenosine triphospate (ATP), the energy currency of cell in form of chemical energy.

Teacher asks: What is name of life process happening 24 x 7?

Students' expected response: Respiration.

Teacher explains: Yes correct. Both photosynthesis and respiration are two most important life processes which are opposite in nature. Respiration at cellular level happens in mitochondria and photosynthesis happens in chloroplasts.

Now let us try to understand the chemical nature of photosynthesis and respiration.

As we already know that phototropic living organisms need to use the inorganic substances available in the surrounding and convert it into organic substance. This process of change of inorganic substance to organic substance involves a chemical change. In every chemical reaction at least 2 reactants combine to produce product which involves change in energy.

Phototrophs fulfil their requirement of two essential reactant substances from their surroundings.

Teacher asks: In case of green plants, what is the immediate source of carbon available in their surroundings?

Students' expected response: Carbon di-oxide from air.

Teacher explains: Yes, exactly. Plants take in carbon di-oxide from air through the special pores stomata present in epidermis of leaves which is one of the reactant involved in photosynthetic reaction. The second reactant for the reaction is water available in the soil. The roots conduct the water through the vascular tissues xylem to the leaves through the mechanism of ascent of sap. The palisade layer of leaves receive both carbon di-oxide and water molecules.

Now in the presence of sunlight following reaction occurs:

Carbon di-oxide + Water------------------- >Carbohydrate + Oxygen (in presence of sunlight and chlorophyll)

This chemical reaction is not happening in one step; rather it is combination of more than one step. Photosynthesis process comprises of light and dark reactions. The light reaction is light dependent reaction. The dark reaction is light independent reaction, which means it happens both in presence and absence of light. But dark reaction follows the light reaction because it depends on the bi products of light reaction.

In light reaction the synthesis of high energy molecule ATP and NADPH takes place in presence of sunlight.

Teacher asks: What is light particle also known as?

Students' expected response: Photons

Teacher explains: Yes, good. The first stage of light dependent reaction is splitting of water molecule. Since this splitting happens in presence of photons this phenomenon is also referred as photolysis of water. Water acts as valuable electron donor in light reaction by its splitting. Water by its splitting releases electron, hydrogen ion and oxygen. In anoxygenic bacteria hydrogen di-sulphide is available as electron donor; Sulphur is produced as the bi product of this reaction.

The second stage of light dependent reaction is photo-phosphorylation, which is the production of ATP.

After photolysis of water electrons are generated which are transferred to a series of carriers (electron acceptors). This electron transport through PSII, excited at wavelength of 680 nm, is coupled to establishment of proton gradient which drives the chemiosmotic synthesis of ATP. Further the electrons are passed on to PSI. Simultaneously electrons here are also excited when they receive red light at 700 nm. In this process NADPH molecule is also produced.

Thus living organisms have the capacity of extracting energy from oxidible substance and store this in form of high energy bonds as ATPs.

Teacher asks: What are the two important stages of light dependent reaction? (Recapitulatory question)

Students' expected response: Photolysis and Photo-phosphorylation.

Teacher asks: Yes. Then what are the bi products of light dependent reaction?

Students' expected response: Oxygen, ATP and NADPH.

Teacher explains: Good. The oxygen molecule is released out of diffusion from chloroplast. Hence an important point to note is that, the product of oxygen is coming from water molecule and should not be mistaken to be coming from carbon-di-oxide. With the remaining substance i.e. ATP and NADPH the biosynthetic phase begins. This phase is dependent on the product of light reaction but not on light. Hence it is referred as dark reaction. This is the phase of carbon fixation in form of synthesis of plant food, the sugar. As already discussed carbon di-oxide gas act as carbon source in photosynthetic process which get converted into carbohydrates by using ATP and NADPH. This reaction happens in stroma where all the enzymatic machinery for the reaction is available.

If we see the complete balance equation of photosynthesis comprising of both light and dark reaction it can be expressed as

$6CO_2 + 12\ H_2O$-------------- > $C_6\ H_{12}\ O_6 + 6\ H_2O + 6\ O_2$

This reaction is an example of oxidation reduction reaction.

Loss of electron is oxidation and gain of electron is reduction.

$2H_2O$----------------------→ 4 H * + $[O_2]$+ 4e-(light , chlorophyll)

Here H2O is losing electron. This is oxidation reaction.

4[H] + CO_2---------------------- > $(CH_2O) + H_2O$

Here CO_2gets reduced to carbohydrates by gaining of electron. This is reduction reaction.

Cellular respiration is just opposite process of photosynthesis which can be verified chemically.

In cellular respiration glucose (food) is oxidized and Oxygen is reduced.

$C_6H_{12}O_6$+ O_2-----------------------→CO_2+ H_2O+ ATP (Energy)

*Teacher asks:*What is law of conservation of energy?

Students' expected response: Energy is neither created nor lost; it only gets transformed from one form to another.

Teacher asks: When we switch on the bulb which energy gets transformed into light energy?

Students' expected response: Electric energy.

Teacher asks: What happens when one start the engine of a bike?

Students' expected response: The chemical (potential)energy stored in molecules of fuel get converted to mechanical energy.

Teacher explains: Yes, exactly. Similarly in this photo chemical reaction, one form of energy i.e. solar energy is converted to the organic form of chemical energy in form of sugar, a form of carbohydrates with the help of intermediate ATP molecule. This ATP production is light dependent and in turn it does the CO_2 fixation. Thus it can be inferred that photosynthesis process is also physico-chemical process which is based on law of conservation of energy.

Phase of Teaching: Recapitulation of main points

Thus today we learnt about the physico-chemical process of photosynthesis.

Following are main points for recapitulation:

- The term 'photo' means *light* and the term 'synthesis' means *to make.* So in the process of photosynthesis something is being synthesized in presence of light energy. This process is possible in all green plant cells and some photosynthetic bacteria.
- Chlorophyll pigment is able to absorb visible radiation of solar light maximally between 400-700 nm and reflect back green light. Hence majority of plant leaves look green. This pigment is present in special cellular organelle present in plant cells called chloroplasts.
- Every chloroplast is a double membrane bound cellular organelle like mitochondria having its own genetic material and cytoplasm. There is a third internal membrane system called thylakoid which are frequently arranged in stacks called grana. Chlorophyll pigment is present within the thylakoid membrane in its lumen.
- The chlorophyll pigment involved in photosynthetic reaction in green plants and algae are mainly chlorophyll a, chlorophyll b, carotenoids, xanthophylls. The chlorophyll pigments involved in photosynthetic reaction are organized into two discrete Light Harvesting Complexes (LHCs) called Photo System I (PS I) and Photo System II(PS II).
- The first part of photosynthesis is light dependent reaction (photolysis of water and photo phosphorylation) depending on sunlight and the second part is light independent reaction(carbon-fixation).
- The chemical process of photosynthesis and respiration are opposite in nature.
- Law of conservation of energy is observed in the bio-chemical process of photosynthesis and respiration.

Phase of Teaching: Evaluation of learning

Evaluatory Questions:

1. What is the site of photosynthesis?
2. Which organelle in plant cells are known as the paint boxes of plants?
3. In which type of plant parts we can localize chloroplasts?
4. What are the different types of pigment responsible for photosynthesis in green plants?
5. What are LHCs?
6. Which of the photosynthetic pigments is the main pigment involved in reaction centre?
7. What is red drop effect?
8. How is light reaction different from dark reaction?
9. State how energy conservation law is operated in photosynthesis?
10. In anoxygenic bacteria hydrogen di sulphide is used as electron donor. Write down the photolysis of H_2S gas.
11. Out of the two substrate in photosynthesis reaction i.e. carbon-di-oxide and water, which one is responsible for producing oxygen?

Home task

1. What would happen if all the producers or photo-autotrophs are wiped out from food chain?
2. What would happen to the level of oxygen gas in atmosphere if there are no photo-autotrophs ?
3. Justify that respiration and photosynthesis are opposite biochemical process and find their reversible nature.
4. Photosynthetic bacteria are perhaps the first living forms on earth, existing since 4 billion years. They facilitated in evolutionary process of forming higher forms of living. Can you suggest how?
5. Find out the name of the most abundant enzyme present in the world?

REFERENCES

1. Clayton, M., Hagan, J., Ho, P. S., & Hudis, P. M. (2010). Designing Multidisciplinary Integrated Curriculum Units. *ConnectEd: The California Center for College and Career*.
2. Emerson, R. W. (2014)*Essays*, Irvine, CA: Xist Publishing.
3. Fogarty, R. (1991). Ten ways to integrate curriculum. *Educational leadership*, *49*(2), 61-65.
4. Guide, A. E. (2007). Primary Programs Framework-Curriculum Integration: Making Connections. *Alberta Education, Alberta, Canada*.
5. Jacobs, H. H. (1989). *Interdisciplinary curriculum: Design and implementation*. Association for Supervision and Curriculum Development, 1250 N. Pitt Street, Alexandria, VA 22314.
6. Jenkins, D. & Shipman, M.D.(1978)*Curriculum: an introduction*. London: Open Books Publishing Limited.
7. Kaur, N. (2016).Learning science is all about getting the concepts right, *Mizoram Educational Journal, Vol.2(1), 57-68.*
8. Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice*, *41*(4), 212-218.
9. Kysilka, M. L. (1998). Understanding integrated curriculum. *Curriculum journal*, *9*(2), 197-209.
10. Lake. K.(1994)*Integrated Curriculum*, School Improvement Research Series: Series VIII, Washington , DC.
11. National Council of Educational Research and Training (1975) *The Curriculum for the Ten-Year School*, New Delhi, India: Author
12. National Council of Educational Research and Training (2000). *National Curriculum Framework*, New Delhi, India: Author
13. National Council of Educational Research and Training (2005). *National Curriculum Framework*, New Delhi, India: Author
14. Nicholls, A. & Nicholls, H.(1974)*Developing a curriculum: a practical guide.*London: George Allen and Unwin Ltd.
15. Okebukola, P. A., & Jegede, O. J. (1988). Cognitive preference and learning mode as determinants of meaningful learning through concept mapping. *Science Education*, *72*(4), 489-500.
16. Pring , R. (1973). Curriculum integration. In R. S. Peters (Ed.), *The philosophy of education* (pp. 123– 149). London: Oxford University Press.
17. UNESCO(2009) *Current challenges in basic science education*, Paris, France: Author
18. Tunnicliffe, S. D. (2012) The critical biology education in the early years in In *HSCI2012: proceedings of the 9th International Conference on Hands-on Science* (pp. 1-398). Hands-on Science Network.
19. Vars, G. F. (1991). *Integrated curriculum in historical perspective*. Educational Leadership,49(2), 14–15.
20. Ware, S. A., & Mundial, B. (1992). *The education of secondary science teachers in developing countries* (Vol. 68). World Bank

21. http://www.biologydiscussion.com/leaf/list-of-leaf-found-in-plants-botany/69591 (Fig. 1 T.S. of *Mangifera* Leave)
22. https://www.open.edu/openlearn/ocw/mod/oucontent/view.php?printable=1&id=13785 (Fig. 2 Chloroplast micrographUniversity of Wisconsin Plant Teaching Collection)