PEDAGOGY OF PHYSICAL SCIENCE

Methods of Teaching Physical Science

By

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Introduction

Science teacher can use a variety of methods and techniques for daily teaching. The methods of teaching can be defined as the manner in which teacher impart knowledge and skills while teaching and students acquire this knowledge and skill in the process of learning. Thus it involves both teaching and learning. There are many different teaching methods for Physical Science, and it really depends on the age group of the learners and their level of understanding. Some methods include incorporating hands-on activities, group projects, role-play, field trips, and visual aids. While choosing the method, the teacher should look into certain criteria. Teacher should access its advantages and disadvantages in relation to others, correlate it with the objectives of education and the specific conditions in which learning is to take place.

Criteria for selecting Teaching Method

When selecting a teaching method, it is important to consider the age group of the students, the desired learning outcome, the time and resources available, and the learning environment. Different methods may be more suitable for different topics and objectives. It is important to consider the students' preferences and abilities as well. Some students may prefer a more hands-on approach to learning, while others may be more comfortable with passive instruction. Ultimately, the best teaching method should be one that is engaging and effective for the particular group of students and the specific topic.

The criteria for selection of teaching methods are manifold. However the most important factors are:

1. Human factor

3. Subject area

2. Objectives of teaching

4. Time and material factor

The human factors influencing the selection of teaching methods are the teacher and the students. The knowledge, teaching experience and personality of the teacher are the factors of primary importance. The teacher should have a clear and significant message to convey and a personality acceptable to the students for establishing effective communication links. If these conditions are fulfilled, a well chosen and properly used method is likely to stimulate the process of learning; otherwise the method may be a failure and become an end in itself. The methods of teaching adopted should take into account the intellectual level of the students, the age and practical experience of the students.

The objectives are defined in terms of changes to be effected in knowledge, skills and attitudes. Methods will have to be selected with regard to their ability to impart new knowledge, influence attitudes and develop practical skills.

Each subject area has its own specific features. For example in physical chemistry, extensive use of mathematics is made. It could be taught through a combination of lectures and numerical exercises during which the concepts could be mastered. The teacher should therefore know when to use which method and how. It should be noted that it is often possible to choose from several methods. Thus, a particular topic could be taught in different ways using different methods by different teachers.

Decision on the choice of teaching methods depends on time, financial resources and other factors. Preparation time varies for the different teaching methods. The teaching facilities may be a limiting factor in some schools in small townships. Factors such as the number of classrooms available, accessibility of audio-visual aids, laboratory facilities should be anticipated and the methods selected should conform to the specific needs.

Lecture Method

Of several methods of teaching, the lecture method has so far been the most widely used at the secondary and senior secondary levels. Its effectiveness depends mainly upon the communication skills of the teacher.

The lecture method owes its popularity because of its simplicity and flexibility. It enables a teacher to teach even large classes and over larger content during a given period in comparison to other methods. Through the lecture method a teacher is able to provide an overview of the course unit or topic alongwith background knowledge essential for understanding. Besides, the teacher can provide a large number of facts and clarify terms, concepts, principles, theories, etc.

In lecture method, the teacher talks most of the time. Acquiring mastery of skill components of the lecture can help improve the teacher's performance. One of the most important skills in this context is modulation of voice. This skill has several dimensions viz., speed, pitch, volume, intonation, etc., of the voice. Speed refers to the rate of vibrations of voice cords during speech. Volume refers to the degree of loudness of the speech.Intonation refers to the rise and fall of voice in speech caused by variation in pitch. While lecturing, the teacher should describe concepts, principles, theories, etc., with the help of examples. Effective illustration with examples can make lectures more communicative and meaningful.

The lecture method of teaching is a great way to share information and ideas with students in an organized, efficient manner. It allows the instructor to provide an overview of the subject and to explain key concepts in detail. It is also a great way to engage students in discussion and critical thinking. To ensure that the lecture is effective, be sure to provide a clear

structure for the lecture, use visuals and other materials to enhance the points, and maintain a friendly, engaging atmosphere.

Demonstration Method

Demonstrating is a traditional method in teaching science that can raise interest and encourage pupils to think about a topic. While demonstrating, the teacher can focus the pupils' attention on the relevant facts and introduce scientific principles and concepts. Through discussion and actively making observations and inferences, rather than looking passively at what is happening in the demonstration, the pupils gain experience of the scientific way of thinking.

The main objectives of demonstration are to show how some thing is performed, happens or works. While presenting a demonstration, either lecturing or inquiry or both can be used. While lecturing the interest and attention of the students have to be maintained by telling them, what to look for, what is likely to happen, and why things happened as they did. Through inquiry the skill of inquiry among students should be promoted by asking questions such as: "What do you observe?", "What will happen if a lighted match stick is inserted in a jar containing oxygen?", "Why do you think so?", etc.

The role of the teacher in demonstration method of teaching is to plan, organize and execute the demonstration properly so that the students understand the concepts clearly. The quality of demonstration depends on the amount and quality of preparation made by the teacher.

The role of the students in demonstration is to observe, listen and follow the demonstration. Demonstration requires the use of the sense of hearing and seeing. It leaves vivid and lasting impression on the students' minds. In addition, the students are required to answer different types of questions: lower and higher order and replicate the performance. For showing standard performance, the students need practice under feedback conditions. The appropriate outcome of practice, however, is improvement rather than perfection.

In the context of teaching, the demonstration method is used for various purposes. First, it is used for enhancing understanding of concepts, principles, theories, etc. Second, it is used for development of intellectual skills like observation, questioning, explaining, hypothesising, inferring, etc. Third, it can be used for the development of psychomotor skills like playing a musical instrument, drawing maps, diagrams, figures, tables, graphs, dissection of animals, etc. It is also used for developing skills of fixing up and operating of audio-visual devices, such as an overhead projector, a slide projector, a film projector, etc. In teaching sciences, demonstration develops appropriate skills for conducting experiments independently.

It involves teaching by doing which makes it easier to learn concepts, principles, complex techniques and skill-intellectual as well as psychomotor; lays foundation for independent practice by the student; and involves considerable preparation on the part of the teacher before presentation.

Lecture cum Demonstration Method

The lecture cum demonstration method is a great way to teach and learn new concepts. It involves lecturing or talking about a topic and then demonstrating or showing how to do something related to the topic. This method can be used in any subject and allows the instructor to provide a more comprehensive overview of the topic. It also helps the student understand how the concepts work in practice, which is often the most difficult part of learning. Demonstrations can also help to break up long lectures and keep the student interested and engaged.

The Lecture Demonstration Method includes the merits of the lecture as well as demonstration method. It attempts to filter out the disadvantages of both. The teacher performs the experiment in the class with the active participation of the students. Thus the students observe the experiment, help in taking down readings as well as assist in setting up the apparatus etc. The teacher helps the students draw inferences.

This method serves the following two purposes: To provide means of making certain parts of subject matter clear by objectifying it and to be economical, both time-wise and finance-wise, as possible. Steps needed to conduct a Lecture-cum- Demonstration lesson are:

Planning and preparation: Great care should be taken by the teacher while planning and preparing his demonstration. He should keep the following points while preparing his lesson - subject matter, questions to be asked, apparatus required for the experiment. The teacher should thoroughly go through the pages of the textbook, relevant to the lesson. After this he should prepare his lesson plan in which he should essentially include the principles to be explained, a lot of experiments to be demonstrated and type of questions to be asked form the students. These questions should be arranged in a systematic order to be followed in the class. Before actually demonstrating the experiment to a class, the experiment should hearse under the condition prevailing in the classroom.

Introduction of the lesson: The lesson should start with proper motivation of the students. It is always considered more useful to introduce the lesson in a problematic way which would make the student's realise the importance of the topic. The usual way through which the teacher can introduce the lesson is by giving some personal experience or incident of a simple young and interesting experiment. A good experiment carefully demonstrated is likely to leave an everlasting impression on the mind of the students and would set the students talking about it in the school.

Presentation: The method of presenting the subject matter is very important. A good teacher should present his lesson in an interesting manner and not in a boring manner. To make the lesson interesting the teacher may not be very rigid too and remain within the prescribed course; rather he or she should make the lesson as broad-based as possible. For widening the lesson the teacher may think of various useful applications taught by him. Constant questions and answer should form a part of every demonstration lesson.

Performance of experiment: A good observer has been described as a person who has learnt the use of the senses of touch, sight, and smell in an intelligent way. Through this method students will observe what happens in a experiment and to state it carefully. The following steps are generally accepted as valuable in conducting science experiment - Write the problem to be solved in simple words, Make a list of activities that has to be used to solve the problem, Gather material for conducting the experiment, Work out a format of steps in the order of procedure so that everyone knows what is to be done, Try the experiment in class, Record the findings, Assist students to make generalizations.

Black Board Summary: A summary of important results and principles should be written in the blackboard. Blackboard should be frequently used to draw sketches and diagrams. The entire procedure should be displayed to the students after the demonstration. Students are asked to take the complete notes of theblackboard summary including the sketches and diagrams drawn.

Project Method

Project method is a approach to education which uses John Dewey's educational philosophy which is student centric. According to an expert, a project is a problematic act which is carried out to completion in its natural and immediate settings. Another expert is of the view that a project is a whole hearted activity which is done with a specific purpose in a social environment.

Types of Project Work

Project work may be of different kinds. In school context, it may broadly be classified as laboratory work, field work, and library work.

Laboratory work: Laboratory work aims at developing certain skills in the student through activities conducted in controlled conditions. Such project work is carried out in science and science-related subjects. The students are required to undertake mini research projects, for example, carrying out small laboratory experiments, like preparation of Oxygen, dissection of a frog, etc. Laboratory work involves skills of manipulation, organisation, experimentation and interpretation. Through lab work, students get real-life experiences, of course, in controlled conditions. The students get the opportunity to apply theoretical knowledge into practice.

Field work: Unlike laboratory work, field work is conducted in real-life conditions, and not under controlled conditions. The students are expected to go to the real-life situations where they observe a phenomenon, collect the relevant data, process and analyse the data and arrive at conclusions. Field work is appropriate for both the physical and the social science subjects. Students may be motivated to take up field work to gain firsthand knowledge of the subject.

Library work: Sometimes students may be asked to undertake project work related to library studies. Such a project has potential to promote individualised learning. Library projects may be conducted in two ways:

i) After introducing the topic and providing necessary information to the students in the class, teacher can tell them about the relevant books which contain the topic selected for the project work. Students should go through those books and develop a report on their work.

ii) Another way of conducting library projects is first to ask the students to read the relevant books on the topic and then ask them to come with small reports on the basis of which discussions can be held with them.

Role of a Student in Project Work

The student has to play an important role in project work. The main responsibility of carrying out the project work lies with the student. There are three major stages the student has to work through while carrying out project work.

Planning stage: At the planning stage, the student should have a clear idea of the objectives and the criteria of the project. If there is any ambiguity, he should seek help. He should carry out a task analysis of the project. He should arrange the tasks in a sequence and fix a target date to complete the project.

ii) Implementation stage: At the implementation the student should carry out the following tasks at this stage: Collect all necessary information, Decide about suitable methods of enquiry, Use resources such as equipment, materials, available expertise, etc., effectively, Cooperate with other students in case of group project and Carry out the processes involved in the project, namely, analysis, synthesis, application, decision making, problem solving, etc. Stick to time schedule prescribed for the project. Secure help and guidance from the teacher throughout the implementation stage.

iii) **Reporting/presentation stage:** The student is expected to carry out the following tasks at the reporting stage: Interpret information and use materials properly, Draw appropriate conclusions, Compile an effective project report. Present the report, product, procedure, decision or solution effectively.

Heuristic Method

Heuristic methods are problem-solving techniques that use trial and error and experience-based learning to search for solutions. Heuristic methods are used to find approximate solutions to difficult problems that require many computing resources and time to determine the exact answer.

Heuristic is derived from the Greek word HEURISKIN meaning discovery. This method was advocated by Professor Armstrong who felt that by placing a student in the position of a

discoverer he would learn much more than being merely told about things. It is based on the principle of learning by doing. Heuriskin method is basically training in scientific method. Knowledge is a secondary consideration. Students learn to collect data, interpret data and arrive at solutions by rejecting superfluous statements.

The term "heuristic method" can be used to describe any problem solving or creativity technique that involves creating a basic model as a starting point for further experimentation or refinement. Heuristic methods are trial-and-error approaches.

Objectives of Heuristic Method

The objectives are:

Develop in the student the habit of enquiry and research

Instil in the student the habit of listening, observing, asking and discovering

Make the students more reflective

Lay the foundation for future learning

Inculcate the spirit of scientific inquiry Heuristic method also gives all these opportunities to the student to acquire knowledge which is fully based on the learning by self-experimenting.

The essential conditions for heuristic learning are freedom of action to the student, providing a responsive environment, guidance of the science teacher when required and encouragement to continue learning through heuristic method.

Historical Method

In this method, the topic is introduced in an anecdotal fashion when required, and carried through various stages of evolution. Using historical anecdotes in science may appeal to a large number of students especially at the primary level. Everyone likes to hear a story. A skilful Physical Science teacher can motivate students by narration of the life histories, anecdotes, and situations related to her subject.

The historical treatment of each and every topic at every stage may not prove practicable but an occasional use of this method may sustain the interest of the class. Subjects like Chemistry, Astronomy, Geology etc have an interesting historical background and a historical treatment of these can prove very useful. The study of a particular topic can be made interesting by tracing its evolution. Similarly, while teaching Newton's Laws, petrol and steam engines, radio, radar the teacher can resort to several interesting anecdotes. This method will arouse interest among the students for learning science and may motivate them to read more on the life of scientists and pursue on the same lines.

Biographical Method

The biographical method is a research technique that uses a scientist’s life story or biography as a source of data. This method involves collecting information from the person's past, present, and future, as well as interviews and observations. The biographical method can be useful to gain an understanding of the social, cultural, and economic influences that shape an individual's life, and can be used to understand the nature of a person's relationships with others.

The biographical method involves the study, use and collection of personal-life documents, stories, accounts, and narratives which describe turning point moments in individuals' lives. (Issac Newton the apple falling on his head: Archimedes, bathing in a tub). The subject matter of the biographical method is the life experiences of a person. When written in the first person, it is called an autobiography, life story or life history. When written by another person, observing the life in question, it is called a biography. This method would rely upon the subjective verbal and written expressions of meaning given by the individuals being studied, these expressions being windows into the inner life of the person.

Laboratory Method

Science laboratory work is a unique way of instruction that is an integral part of science teaching. It helps students understand complex abstract ideas and gives students an opportunity to participate in and have an appreciation for the methods of science.

There are a variety of methods used in a laboratory setting, depending on the type of experiment being conducted. Generally speaking, the most common methods include pipetting, titration, centrifugation, chromatography, microscopy, spectroscopy, and electrochemical analysis. Additionally, specialized equipment and techniques, such as high-pressure liquid chromatography and mass spectrometry, may be used to obtain more accurate or precise results. No matter the method, a laboratory should always follow safety protocols to ensure the safety of all personnel involved.

Laboratory work involves students in hands-on activities that help them participate in scientific investigations and to verify for themselves scientific concepts, principles and laws. Most laboratory approaches can be classified into one of the following: 1) Verification and deduction 2) Induction 3) Science-process oriented 4) Technical-skills oriented 5) Exploratory.

1. The verification laboratory is the most common approach used in India. The purpose of this approach is to illustrate concepts, principles, and laws.

2. The inductive laboratory provides students with the opportunity to form concepts, principles and laws through first hand experiences. This approach, followed in projects, allows students to form concepts for themselves and to explore ideas and pursue them.

3. All laboratory work stresses the science process skills of observing, classifying, measuring, inferring, predicting, interpreting data and experimenting.

4. Technical skills oriented laboratory approach would require students to acquire manipulative skills that involve the development of hand-eye coordination (like focussing a telescope, measuring angles, pipetting etc.). Science teachers should master the basic laboratory techniques and manipulative skills associated with their particular subject.

5. Exploratory laboratory activities allow students to explore an idea, concept or principles without structured procedures; students are given freedom to explore and specific learning outcomes are left to the students to determine and achieve.

Laboratory activities must be well organised and carefully planned. The science teacher should give pre-laboratory instructions which prepares the students for the laboratory exercises and orients them to the objectives to be attained and the procedures to be adopted. Necessary directions should be given for actual laboratory work, highlighting the precautions to be taken. These instructions could be oral, or written either on the blackboard or on instruction cards. Post-laboratory discussions help the students to analyse their findings and draw inferences. Students can work either in groups or individually depending on the facilities available.

Inductive and Deductive Method

Inductive and deductive methods are two methods of reasoning used to arrive at a conclusion. Inductive reasoning is observing a pattern and using that to draw a conclusion. Deductive reasoning is to use the information already have to make a logical conclusion. Both of these methods can be used to come to conclusions, but they require different types of evidence and reasoning.

Inductive approach to problem-solving

The inductive approach to problem-solving provides students with a learning situation in which they can discover a concept or principle. In this approach, generalisations are drawn from particulars, principles from observed phenomena, rules from instances. The steps in this approach are:

Sensing the problem: The students explicitly define the problem.

Analysing the situation: All aspects of the situation are examined. The students collect a lot of relevant information from various sources - books, laboratories, factories, etc.

Organising information: The information collected is organised with the help of the teacher.

Framing possible solutions: Students frame possible solutions using the organised information.

Eliminating: Only plausible solutions are retained and the rest are rejected.

Verification: The solutions are applied to the problem situation and the results checked. The procedure is repeated until a correct solution is obtained.

The inductive approach to problem-solving should be carefully planned, in order to enable the students, especially students with low ability to recognise the relevant cues, provided in the situation. Through the inductive method, student interest and motivation in science, can be appreciably increased, provided the right conditions prevail, which are i) students should have the prerequisite knowledge and skills, and ii) there is not much irrelevant information cluttering the problem situation.

Deductive approach to problem-solving

The most widely used approach in science teaching is the deductive approach. Here the students are given the rule and then shown examples. The steps involved in this approach are:

Understanding the problem: Students understand the concepts involved in problem. They are able to define it clearly.

Collecting information: Students are ready to gather information about these concepts through laboratory activities.

Reviewing: Principles, generalisations are reviewed to find ou which is best applicable to the current problem.

Drawing inferences: Principles, rules or generalizations are applied to the particular case and the inferences drawn that the problem under study falls under this principle, rule or generalisation.

Verification: The principle or rule or generalization is applied to the particular case. If it solves the problem then it is accepted; otherwise the procedure is repeated till a better solution is found.

The deductive approach is an effective way to teach difficult content. With difficult subject matter, all students may not be able to arrive at the rule or principle through the inductive approach. A majority of students may respond better to a deductive approach.

Comparison between inductive and deductive methods

Inductive Method	Deductive Method
One proceeds from specific to general.	One proceeds from general to specific.
It is a psychological method with the student's nature as the nucleus.	The stress here is on acquisition of facts.
It is a scientific method, stimulating reflective thinking	This is not a discovery method.
Reasoning is the keynote in this approach.	The stress is on rote memory.
This is suitable for the primary classes as it provides opportunity for direct and concrete experiences.	It is better suited for high school classes.
Inductive Method is a time- consuming process	It is an economical method in terms of time. It gives essential speed, skill and efficiency to problem-solving.
It encourages active participation of the students in the teaching-learning process.	This method makes the student a rather passive participant.

While comparing these two approaches it can be concluded that inductive method is better as it is a method of discovery whereas deductive method involves application of the deduced results. However, the deductive method is excellent for drilling purposes, for it saves time and labour of both the teacher and the students. Therefore an attempt has been made to combine both these methods in such a way as to derive maximum advantages of both. This method - in combination is called Inducto-deductive method. In this method, the first phase is inductive. The students are made to discover truth or establish a formula with the help of inductive method. The second phase is deductive. Inducto-deductive method thus can help the teacher maintain control over the learning situation by reducing errors and minimising student frustration, which can interfere with learning process.

Scientific Method

The scientific method is a process of inquiry and experimentation used to develop and test scientific theories. It involves making observations, formulating hypotheses, conducting experiments, analyzing data, and drawing conclusions. The scientific method helps us to better understand the natural world and can be used to solve complex problems. It is an integral part of the scientific process and is used in all areas of science.

The following steps should be followed to solve a problem. John Dewey has outlined this method in the following series of steps.

1. Identifying and defining the problem

Students come across several situations where they can apply skills and knowledge to a problem that motivates them to participate in exploring. These problems can stem from daily life or from the background literature on some topic, or from the place of work of the student. The student should have an exact idea about the problem and be able to define it in concise terms.

2. Formulating the hypothesis

The student should focus on hypothesizing the relationship between two or more variables or difference between two treatments. A review of literature would give students more content information: various possible causes of the problem may be listed. These possible causes are hypotheses or "educated guesses". Next the students are asked to outline a laboratory procedure to test out their proposed solution.

3. Testing hypothesis by collecting and evaluating data

Students are permitted to enter the laboratory to conduct their tests and note down observations. The teacher's job at this juncture is to ensure that the students work carefully and collect accurate data.

4. Interpreting results

All inferences bearing on the data at hand must be considered tentatively This phase of problem-solving demands an unusual amount of guidance from the teacher. Interpretation of data should be based on proper use of techniques and charts; graphs, tables can be used to record the data. At this stage, students can become careless in their work and it is an opportunity to develop skills in constructing tables and graphs.

5. Drawing conclusions

The students are asked to determine if their results substantiate the expected solution. Conclusions drawn on the basis of data should be accurately reported after proper interpretation. Findings should be reported concisely, and recommendations for further work should be mentioned. The students should be able to make generalisations and apply them to their daily life.

The problem-solving method can be used in most science courses to improve knowledge and understanding of the subject matter as well as to improve inquiry skills. Real life problems that students find interesting and challenging are provided. The teacher should be selective in

identifying the science topics around which problems can be developed so that the method continues to retain the interest of the students. Also, the teacher should ensure that the students have or acquire the prerequisite skills and knowledge to be used in solving the problem. Students should possess or be taught the necessary principles and concepts which might be useful for finding a solution to the problem.

Analytic and Synthetic Method

The analytic and synthetic methods are two different approaches to understanding and studying a subject. The analytic method involves breaking down a subject into its component parts in order to gain a better understanding of its overall makeup. On the other hand, the synthetic method involves combining different elements together in order to construct a new, more complex idea or concept. Both methods can be used to gain a better understanding of a subject, and the best results often come from combining the two approaches.

Analytical Method

The meaning of the word analysis is to "separate things that are together." In this method one starts from what is to be found or proved. Analysis also means, "Breaking up of a given problem, so that it connects with what is already known." In analysis one proceeds from," Unknown to Known." Analysis is thus," unfolding of a problem to find its hidden aspect." The analytic method is when one proceeds from the unknown to the known, from abstract to concrete and from complex to simple.

This method is used under the given conditions:

For proving any theorem.

For construction problems.

To find out solutions of new arithmetical problems.

Synthetic Method

The word synthesis means," to place things together or to join separate parts." In this method we proceed from "known to unknown." It is the process of relating known bits of data to a point where the unknown becomes true. It is the method of formulation, recording and presenting concisely the solution without any trial and errors.

Both the methods of analysis and synthesis by themselves have their advantages and disadvantages. In order to ensure the complete understanding of science in the learners both

the methods must be used together to teach science. By using a combination of these two methods the teacher can ensure that effective teaching learning takes place.

Parameters	**Analytic Method**	**Synthetic Method**
Definition	Breaking up into components	Combining elements to get something new
Direction ofprocess	From unknown to known	Known to unknown
Type of method	Method of discovery and thought	Method of presentation of fact
Time factor	Time consuming	Economic
Learning	Meaningful	Rote
Application	Inductive reasoning	Deductive reasoning
Role of learner	Active	Passive

Conclusion

Methods that the teachers use to support the learning cycle should create interest, generate inquisitiveness, raise questions and elicit responses, facilitate cooperative learning, refer to and include previous learning experiences as they relate to new learning and incorporate alternate assessments.

Teaching methods should allow students to show interest by asking questions, use inquiry to explore or investigate new concepts, form predictions and hypotheses, formulate experiments with alternatives, record ideas and observations, use various resources to seek explanations, make connections between prior knowledge and new concepts and help to self-evaluate. So it is in the hands of teachers to choose suitable method to teach Science topics and have an effective teaching –learning process.

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