In Science, teaching and learning focuses on the following dimensions. They are assessed and form the basis of semester reports.

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We recommend that students with a relative weakness in one particular area should attempt that section of an examination paper first or early in the examination period.

**Knowledge of Science (KS):** knowledge of key concepts, including facts, formulae, procedures, principles, theories, etc.

A student could have a relative weakness in this area if she fails to learn her work thoroughly. To overcome these weaknesses she should:

- remain attentive throughout the lesson, dismissing all distractive influences
- participate actively in class discussions, trying to make sense of new concepts and trying to relate what is said to what she already knows
- complete all set homework tasks in a reflective and thorough way
- devise and implement a daily consolidation programme where she reviews what she did in the lesson that day with a view to accommodating what she has learnt into her existing knowledge base
- seek timely assistance to clarify conceptual problems as they arise
- catch up on all missed work as soon as possible after the absence
- prepare a complete yet concise summary of the work to be tested, learn it, and ensure that she can recall it accurately
- prepare thoroughly for tests, not just at the last minute but throughout the unit and becoming more intensive as the assessment date draws near

**Conceptual Understanding (CU):** ability to process and apply conceptual knowledge to a range of situations; ability to link concepts to explain phenomena.

A student with a relative weakness in this area should ensure that she has a thorough knowledge of the course’s content. Incomplete or weakly-held knowledge is difficult to apply.

When solving problems, students frequently rely too heavily on the answers given in their textbooks. They get into the habit of only being able to detect errors in their working when their answer does not match the given answer. Of course, this crutch is not available in an examination situation and students should develop strategies to assess the accuracy of their working without relying on given answers. It is obvious that these strategies are also of immense value during the examination.

To overcome weaknesses in this dimension, a student should:
• ensure that she has a thorough knowledge of the course content (see Knowledge of Science above)
• develop ways of checking her answers without relying on those given in texts
• use questions modelled in class or example questions in texts to familiarise herself with the techniques employed
• practise questions to develop her problem-solving strategies
• discuss solutions and problem-solving strategies with other students
• make sure that she reads test questions carefully so that she is sure of what is being asked
• plan her answers carefully before writing a response so that she answers the question fully while focusing on relevant details only
• re-read the stem of the question after completing her answer to critically evaluate her answer in terms of ensuring (a) that she has answered the question asked, (b) that the answer has a logical structure that makes sense, and (c) that the response is legible

**Investigating Science (IS)** ability to safely and effectively use equipment in practical situations; ability to collect both qualitative and quantitative data; ability to analyse data, draw conclusions, and solve problems.

Typical questions of this dimension include:
- formulating hypotheses;
- identifying independent and dependent variables, and other variables that should be controlled;
- reading scales;
- choosing and using appropriate units;
- locating, extracting, and understanding relevant information;
- classifying objects;
- tabulating data;
- graphing and interpreting graphical data;
- using mathematical techniques to process data;
- inferring and predicting;
- identifying trends and describing relationships either quantitatively or qualitatively;
- generating analogies;
- relating cause and effect;
- communicating information in a variety of forms including laboratory reports, oral reports, and research assignments;
- distinguishing fact from fiction, relevant from irrelevant information, and observations from inferences.

Assessment items designed to gauge student performance in this dimension focus, not on the content, but on the processes involved. Hence, it is possible for students to do well on these types of questions even if they are unfamiliar with the content. As marks are awarded for demonstrating processing ability, it is imperative that students show all of their working in clear, logical steps.

To overcome relative weaknesses in this dimension, a student should:

• prepare experiments thoroughly before they are performed so that she knows the aim of the experiment and what to expect
• participate actively in experimental work and not leave the organising and performing to others
• make connections between experimental and theoretical work
• be critical of experimental results and try to make sense of them by analysing them carefully
• follow the report-writing format carefully, attend to details, and learn from past mistakes
• practise answering questions of this type (see above)
• make sure that she reads test questions carefully so that she is sure of what is being asked
• plan her answers carefully before writing a response so that she answers the question fully while focusing on relevant details only
• re-read the stem of the question after completing her answer to critically evaluate her answer in terms of ensuring (a) that she has answered the question asked, (b) that the answer has a logical structure that makes sense, and (c) that the response is legible
Complex Scientific Reasoning (CSR): ability to apply complex reasoning processes to challenging novel or multi-step situations associated with Conceptual Understanding and Investigating Science; ability to gather, evaluate, and critically use primary and secondary data to make informed decisions about the effects of scientific applications on present-day and future societies.

This dimension involves problem solving and has three main components. The first is internalisation involving those processes which enable knowledge to be acquired from external sources. The second component is internal processing, which allows acquired knowledge to be integrated into existing knowledge structures. The third component, externalisation, allows processed information to be communicated to others. In effect, students are required to gather relevant information, make sense of it and evaluate it in terms of the question asked, and compose a logically-sequenced coherent response.

To achieve competence in this dimension, students will be required to:

- gather information
- predict outcomes
- integrate information and data to make justified and responsible decisions
- adopt and communicate a stance
- identify the scientific concepts relevant to past, present and future scientific issues
- explain the explicit and implicit meanings of information selected from a variety of sources
- evaluate the reliability, authenticity, relevance, accuracy and bias of both the sources of information and the methods used to collect it (e.g., evaluate the quality of scientific writing)
- develop future scenarios based on the analysis of current information
- consider alternatives to information presented

To overcome relative weaknesses in this dimension, a student should:

- relax, anxiety is not conducive to effective problem solving
- take a critical approach to reading
- act to improve her knowledge base by (a) learning her work more thoroughly, and (b) reading more widely
- participate more actively in class discussions in an effort to organise her knowledge more effectively
- identify what the question is asking and apply her scientific and general knowledge to isolate the most relevant concepts
- practise applying scientific processes such as analysing data, rules of evidence, and forming conclusions to a variety of genre
- in response to task goals, create and apply criteria to gauge the strengths, limitations, and value of information, data, and solutions
- practise posing ‘what if’ questions and answering them
- organise assessment tasks into smaller manageable subtasks
- use links between the relevant concepts to plan her answer
- organise her response into a logical sequence before starting to write
- critically examine her response in terms of the question being asked and make modifications as necessary
- at various points during the task, evaluate her response in terms of the criteria or standards assessment table (if provided), identify areas of weakness, and make modifications as necessary
- try extending herself with problem posing and problem formulation during class discussions and with homework tasks; both can strengthen a student’s problem solving ability
- engage in marking the practice responses of their peers

Complex Problem Solving

Some assessment items aim to assess a student’s ability to apply her knowledge to more complex, novel or creative situations or to use more advanced scientific processes. There is no formula for true problem solving. If you know exactly how to get from problem to solution, then the task does not involve problem solving. In negotiating your solution you make your way towards your goal step-by-step, making some false moves but gradually moving closer towards the intended end point. What then are the requirements for effective problem solving?
Domain Specific Knowledge
To become a good problem solver in any subject, you must develop a robust base of domain specific knowledge. How effective you are in organising that knowledge also contributes to successful problem solving. Research has shown that novices attend to surface features of problems whereas experts categorise problems on the basis of the fundamental principles involved.

Algorithms
An algorithm is a procedure, applicable to a particular type of task, which, if followed correctly, is guaranteed to give you an accurate solution. Algorithms are important in science but the process of carrying out an algorithm, even a complicated one, is not problem solving. The process of creating an appropriate algorithm for the set task and generalising it to a specific set of applications is problem solving.

Heuristics
Heuristics are strategies, rules-of-thumb, or procedures that you apply to a problem to help you find a solution. They are selected by you, are not always reliable, and can have variable results. Some examples are: searching for a pattern, drawing a diagram, restating the problem in your own words, simplifying the problem using easier numbers or objects, working backwards, trial and error, writing a mathematical sentence and using algebra to solve, and using a model or an analogy. One of the most important heuristics is the generation of subgoals that enable you to form manageable problem solving plans. Because of the possibility of false moves, you need to monitor your progress continually and switch heuristics if necessary. IDEAL is a common problem solving heuristic.

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<td>Define and represent the problem</td>
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<td>Explore possible solution strategies</td>
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<td>Act on the strategies</td>
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<td>Look back and evaluate</td>
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Managing It All
An extensive knowledge base of domain specific information, algorithms, and a repertoire of heuristics are not sufficient during problem solving. You must also construct some decision mechanism to select from among the available heuristics, or to develop new ones, as problem situations are encountered. The field of metacognition concerns thinking about one's own cognition. Metacognition theory holds that such thought can monitor, direct, and control one's cognitive processes. Effective problem solving requires you to reflect during problem solving activities in a systematic and constructive way.

The Importance of Looking Back
Looking back may be the most important part of problem solving. It is the set of activities that provides the primary opportunity for you to learn from the problem. Five activities essential to promote learning from problem solving are developing and exploring problem contexts, extending problems, extending solutions, extending processes, and developing self-reflection.

Research has shown that there are several reasons why students fail to reach a satisfactory level of proficiency in problem solving tasks.

- They suffer from fears and anxieties, especially fear of failure, that prevents them from thinking clearly in problem solving situations.

- They don’t have sufficient knowledge of the topic. Some problems require special knowledge, and without this knowledge, problem solving becomes very difficult. Novices and experts have differences in both the amount and structure of relevant knowledge. Chess masters have stored lots of patterns of pieces on a chess board from real games - so they have excellent recognition of "real" patterns. Experts have more organized knowledge. Physics experts group problems according to principles (conservation of energy) but novices group problems according to surface descriptions (block on an incline plane).

- They get a mental set, seeing a problem in a particular way instead of other plausible ways. This could be due to a tendency to stick with a familiar context because of inexperience with others.

- They use an incorrect or incomplete representation of the problem. The way you represent the problem in your mind can be crucial in finding a solution. Incorrect or incomplete interpretations will lead to wrong
answers. Sometimes drawing a picture can help you form the correct representation. Novices and experts exhibit differences in problem solving behaviour in the way that they represent problems and their choice of strategies. When problems are well-defined, experts can identify the type of problem more quickly than novices and for ill-defined problems, experts will spend more time defining it before attempting to solve. Both use similar strategies but better problem recognition and representation probably allows experts to work forward more often.

- Particular learning styles may make it harder to learn to solve problems. Some people are primarily visual learners, others aural. Some naturally employ a step-by-step approach to problem solving, dividing the problem into small manageable tasks, while others see it as an all-or-none prospect. Some students cogitate on a problem introspectively while others prefer to sort out their ideas through discourse with others, a technique unavailable to them during formal exams.

- General thinking patterns can inhibit students’ problem-solving ability. Some students are better visualisers than others and can easily “imagine” what is happening or what might ensue. Others are better at organising information and linking concepts.

- Many students have difficulty identifying analogous situations. For successful transfer students have to map objects, their attributes, and the relations between them, all without prompting.

**For example**

*A patient has a cancerous tumour. Beams of radiation will destroy the tumour, but in high doses will also destroy healthy tissue surrounding the tumour. How can we use radiation to safely eradicate the tumour?*

*A fortress surrounded by a moat is connected to land by numerous narrow bridges. An attacking army is unsuccessful when it tries to attack across one bridge only but successfully captures the fortress by sending only a few soldiers across each bridge, converging upon the fortress simultaneously.*

Can you identify the analogous objects, attributes, and relations?

So a student with a relative weakness in this area should note the suggestions for the other dimensions and the following:

- practise answering questions of this type to develop problem-solving strategies
- adopt a more logical, stepwise approach to problem-solving
- obtain practice questions from a variety of sources such as extension material and alternative texts
- read more widely
- be patient and don’t panic or give up
- be more reflective to ensure that responses are not superficial or incomplete
- reflect on attempts made to solve a problem and present all reasoning and working to her teacher. This will help her teacher to diagnose the source of the student’s difficulties. Remember also that marks are awarded for the processes used, not just the answer to the problem.
- continually compare her current state with the goal and choose an action to bring her closer to the goal. This is called means-ends analysis. The criteria sheets accurately define the goal in general terms.
- break the problem down into smaller subgoals
- relax, take a risk, there is no harm in trying
- participate actively in all class discussions. This assists in the transferral of knowledge to novel situations and in the development of problem solving strategies.
- develop algorithmic procedures where possible. These are step-by-step prescription for achieving a goal. An example would be teaching a preschooler to tie a shoelace. Problem solvers follow a logical sequence of simple steps to arrive at a solution.
- leave it for a while and come back to it. This is one way to get around mental set problems. Sometimes students have an insight into a problem after setting it aside for a while and then returning to it - this is incubation. Not working on something for a while may weaken tendencies to keep trying the same approach and thus help break mental set problems.