

SECTION 2

OPERATIONALISING SCIENTIFIC AND TECHNOLOGICAL LITERACY (STL) FOR ALL

2.1 Introduction

This section analyses the current teaching and learning practices, and examines the roles of science educators and teacher trainers in interacting with teachers, students, communities, as well as other concerned agencies, including non-governmental organisations (NGOs). It also discusses manner in which science educators and teacher trainers can enable teachers to gain the skills needed to perform these roles in an effective manner and identify teaching and learning strategies that are relevant for guiding students to increase their scientific and technological literacy. Most of the points made have always been relevant to teacher training and science teaching. They are not new. But they are important and STL teaching and learning will not happen without them. The section is intended to re-awaken the science educator, teacher trainer, and hence teachers and other people concerned with science education to the teaching and learning strategies that will need to be reflected in any STL material.

2.2 Problems in Current Instructional Practices

Research suggests that teacher trainers tell teachers how to teach but give little attention to interacting with teaching actually taking place in the classroom. There is usually little room for action research in any pre-service or in-service teacher education programme.

Further, Research suggests that traditional science teaching and learning usually involve a limited set of instructional strategies, which are used to teach a curriculum with overloaded facts. This in turn tends to lead the students into becoming passive learners. Research also indicates that many students at the primary, middle, and secondary school levels:

- do not understand fundamental science concepts
- do not relate science concepts to real phenomena
- memorise science terms without understanding
- memorise problem-solving steps

Common problems that have been identified with traditional science teaching are as follows:

- Poor involvement of students
- Barriers to change
- Teachers teach science contents, not students
- Poor classroom climate
- Lack of favourable social cultural factors

2.2.1 Poor involvement of students

Research has shown the importance of student involvement in science and technology education. According to Goodlad (1983), in the present context of science education, students are expected to do little more than memorise content knowledge or record observations.

2.2.2 Barriers to change

There are several barriers to change. Anderson et. al. (1992) draws attention to 10 barriers that science educators and teacher trainers have failed to remove when trying encourage changes to the manner in which a teacher teaches. These are:

- (i) Reformers do not all agree on the type of reform and the strategies for reform [intention not clear]
- (ii) Many teachers cannot use strategies proposed by new models of instruction [teaching deficiency]
- (iii) Many teachers hold beliefs and priorities that are incompatible with envisioned changes [philosophical incompatibility]
- (iv) Community members, administrators, and policy makers hold beliefs and priorities that interfere with change [management concerns]
- (v) Students have expectations about learning that interfere with their ability to be full participants in new models of learning [poor teacher-student relationship]
- (vi) New instructional, curricular and assessment materials are needed to support the changes in the learning environment [lack of resource materials]
- (vii) Learning outcomes and expectations for all students are missing [intentions poorly conceived]
- (viii) Systemic thinking about reform is often missing [poor implementation guidelines]
- (ix) Cultural differences and their implications for how this change is handled are not considered [poor implementation guidelines]
- (x) Mixed signals are given to teachers and students via mismatches among learning outcomes, assessment and curriculum [intentions poorly managed].



Activity 2-1: Barriers to Change

You, as a course/workshop leader get participants to discuss the following question in groups.

“What constraints do you perceive as the most important barriers to change?”

Discuss the issue and suggest alternative ways of overcoming the constraints.

2.2.3 Teachers Teach Science Contents, not Students

So far, approaches to incorporate the tremendous changes in modern technology have been for curriculum developers to design new curricula and teaching-learning materials, which includes topics such as biotechnology, plastics, electronics, laser, etc. This merely modernises the content, but does it cater to the needs of ordinary citizens? The ordinary school child will continue to be subjected to issues like pollution danger and health hazards in his/her everyday life. For instance, the term ‘chemical’ refers to something poisonous and definitely not to be found in the home. The average person continues to be ignorant to the fact that foodstuffs and the multitude of painkillers and other pharmaceuticals used at home are actually chemicals and even the petrol used in cars, or paints and other decorations of the home are chemicals.

Perhaps more than in any other subject area, science teachers perceive their task as teaching the subject matter (Aikenhead 1997). They see their task as imparting knowledge and understanding of the principles that underlie this knowledge (Romberg 1985). The feeling is so strong that 'completing the syllabus', as exemplified in the curriculum, is a common target for science teachers. Experimental investigations are given a low priority, especially if the external examination places little weight in this area. Assisting students to develop skills of problem solving is not taken seriously, unless this simply means tackling a variety of numerical problems. Time is certainly not set aside for students to (i) plan an investigation and then (ii) to carry out the plan, or to make decisions where the answer is not clear cut and a multitude of factors can influence the decision, such as economic, social, environmental, political, or ethical considerations.

It would seem that teachers continue to give greater attention to the content knowledge of the subject for a variety of reasons. One important factor is that textbooks, for the most part, tend to ignore non-conceptual areas. If the textbook includes applications within the society, it tends to be 'cases' quoted after a study of the science concepts (rather than an attempt to start from society's way of utilising science).

The textbook emphasis and approach are, of course, heavily influenced by the manner in which the curriculum is put together. For convenience, the curriculum is almost invariably put together based on science fundamentals, and science concepts are grouped together for scientific convenience. The curriculum rarely groups learning based on the way society makes use of science e.g. for solving issues/concerns in the kitchen, the bathroom, the local environment, industry and employment.

Teachers have not been able to initiate student-centred activities and therefore, students have not been able to grasp the content knowledge. Student activities that have the potential to increase content knowledge are avoided e.g. library searches, location of secondary information sources, because these could not be controlled easily by the teacher. As a consequence, science becomes impersonal and increasingly irrelevant; and in the hands of uninterested teachers, just a memory exercise. Utilising various teaching-learning strategies, such as brainstorming, role playing, small group discussions, and creative activities such as developing posters, composing letters to officials, raising environmental awareness and participating in debates, could be helpful.

2.2.4 Poor Classroom Climate

The classroom climate is governed by two crucial factors:

- the atmosphere, including changes in atmosphere, created by the teacher (and the students)
- the manner in which students are guided to learn within the classroom (or laboratory)



Activity 2-2: Classroom Climate

Initiate a Debate on the following statements:

“Effective Teaching for scientific and technological literacy is strongly related to achieving the appropriate classroom climate for a given situation.”

Do you agree with this statement? How important is the link between classroom climate and effective student learning?

Reflect on the agreements and disagreements.

In trying to suppress undesired behaviour, many teachers remove or severely limit classroom freedom. By doing so, teachers often inhibit intellectual freedom as well. Such teachers see simple, repetitive tasks as necessary for classroom control and hence generate a classroom climate with little intellectual stimulation and much boredom. Encouraging intellectual freedom to stimulate critical thinking, creativity, and communication, while restricting social freedom to that deemed necessary or desirable, requires that a teacher has a clear image of the desired classroom climate, a rationale to define and defend it, and above all, the professional competence to create it (Penick and Bonnstetter 1993).

Good and Brophy (1991) reported that all too often teachers:

- dominate communication
- overuse factual questions
- do little to motivate
- neglect to emphasise meaning



Activity 2-3: Teacher Behaviour

Initiate a Debate on the following statement.

“The single most problematic teacher behaviour is that of dominating classroom communication by telling (giving information), or by the use of simple factual recall questions.”

Whole class discussion should follow after the debate. The arguments could be presented for other participants to reflect upon.



Activity 2-4: Do Teachers Create a Proper Atmosphere for STL?

Arrange for participants to answer the following question, individually or in groups.

“Do you think there is the danger in using an STL classroom approach that teachers think they are creating an appropriate classroom atmosphere for student-centred learning, when in fact, an outsider would view it very differently?”

Answers should be defended, and argued with other members of the workshop.

2.2.5 Lack of Favourable Socio-Cultural Factors

Here are five predictors of socio-cultural influences in the teaching and learning of science in Nigeria of which STL teachers should take note (Jegade and Okebukola 1992).

(i) Authoritarianism

It is difficult to create an appropriate climate for STL teaching where the science teacher is a ‘learner’ because science teachers are usually seen as the ‘elder’ who ‘knows all’ in relation to scientific and technological literacy. The teacher’s views are not to be challenged. In such an environment, whole class teaching and the enhancement of scientific and technological literacy could be very incompatible.

(ii) Goal Structure

The co-operative setting of Africa means the goal structure of individuals is directed to the same objective and there exists a high interdependence among the goal attainment of individuals. This aspect, if carefully nurtured, should be a valuable asset in developing a classroom climate for societal objectives.

(iii) Traditional Worldview

Challenges to the traditional beliefs and superstitions place students in positions of conflict with society, as they are expected to believe the traditional beliefs without question. Case studies and role playing activities may be important classroom strategies to help students in this situation.

(iv) Societal Expectations

Success of an individual within a community is interpreted by the way he/she interacts within a communal society. The behaviour of that individual is governed by the society. Without changing the society, attempts to change the individual become difficult and the classroom climate can become one of non-co-operation.

(v) Sacredness of Science

The learning of science is seen as incompatible to the thoughts of someone from a non-western society. Learning science is something special, requiring magical or weird explanations. It does not relate to societal concerns. A positive classroom climate could well be an essential factor in challenging this belief.

2.3 The Needs for Operationalising STL

Science educators and teacher trainers must be very conversant with the following and ensure teacher needs are met:

- The goals of science education
- Appropriate teaching skills for STL
- Creating a suitable learning environment for STL teaching
- Recognising teaching domains needed for change
- The Role of textbooks in STL teaching

2.3.1 The Goals of Science Education

Science educators and teacher trainers should be aware that Seven major goals have been identified which teachers wish students to attain, have been identified (Penick and Bonnstetter 1993). These are:

- (i) Having a positive attitude towards science
- (ii) Using knowledge learned to identify and solve problems
- (iii) Developing creativity
- (iv) Communicating science effectively
- (v) Feeling that knowledge acquired is useful and applicable
- (vi) Taking actions based on evidences and knowledge
- (vii) Knowing how to learn science

To a large extent, science educators and teacher trainers need to recognise that the above goals are independent of the curriculum content, the textbook and the examination. But they are very dependent on the manner in which teachers see their professional role.



Activity 2-5: Goals of Science Education

Allow participants to Discuss the seven goals in small groups and present your arguments.

Those in agreement will present strategies on how the goals could be achieved. Those who are in disagreement will also present reasons why they do not agree to the goals. Posters or OHTs could be prepared for sharing with other members of the workshop.

Teachers, identified as teaching towards the 7 goals expressed above, are recognisable in that they tend to:

- Create new approaches to instruction
- Consistently tell students their goals
- Let students know that they, as teachers, are striving towards helping students attain these goals

These teachers have a well-developed, research-based rationale for teaching science and technology, which guides their classroom actions and their curriculum sequencing.

2.3.2 Teaching Skills and STL Teacher

Research also informs that, for too long, the perceived role of a teacher has been to behave like a **manager** - assigning lessons, starting and ending lessons, explaining rules and procedures, judging students, and maintaining order and control (Romberg 1985).

The many variables involved in teaching students who have different characteristics and curriculum demands, and react differently to examination pressures, to school policies, to relationships with colleagues and to parental wishes, can easily distract the teacher from the main scientific and technological literacy goals of teaching, and from adopting good teaching behaviour. Developing teacher skills to undertake A self-analysis of the classroom situation is important to evaluate their own teaching skills and their relevance to the classroom (**Please refer to Resource 2A: Teacher Self-Analysis, pg. 40**).



Activity 2-6: Purpose of Teaching Science

Arrange for participants to Discuss the following statement:

“There is a real danger that teachers do not give enough attention to the purpose of teaching science and to making sure their teaching approaches are effective”.

Prepare a report for presentation and further discussions.

We have seen that enabling student to make personal interactions (personalisation), encourage student participation, allow students freedom and encouragement to make decisions, stimulate student investigations, and a willingness to help others, are very important STL teaching attributes.



Activity 2-7: Individualised Classroom Environment Questionnaire

Allow the participants to Discuss in small groups to answer the following:

“Would you agree that the following questionnaire designed for students at the lower secondary school level, is able to ascertain Personalisation (first item in each block of 5); Participation (2nd item); Independence (3rd item); Investigation (4th item), and Differentiation (5th item)?”

Evaluate the questionnaire and provide reasons for your responses.

(Please refer to Resource 2B : Individualised Classroom Environment Questionnaire, pg. 41).

2.3.3 STL teaching and learning environment

Teachers do make a difference. But do teacher trainers? Some important considerations a science educator, teacher trainer or a teacher needs to take into account in achieving the type of classroom climate conducive to STL promotional put forward by Penick and Bonnsetter (1992). All are crucial for STL. They include:

- (i) A stimulating teacher and a stimulating environment
- (ii) Interacting with students
- (iii) Feelings of high achievement expectation
- (iv) Promotes active inquiry by example
- (v) Expect students to question facts, the teachers, and the knowledge itself
- (vi) Stress scientific and technological literacy and the application of knowledge
- (vii) Do not view the classroom walls as a boundary
- (viii) Are flexible in their time, schedule, and curriculumm
- (ix) Put in far more than the minimal time



Activity 2-8: A Teacher Can Create a Stimulating Environment

Allow participants to Brainstorm the following statement in pairs or in small groups.

“A teacher can create a stimulating environment”.

An illustration regarding classroom atmosphere needed for STL teaching should be provided. This could be in the form of simulations, games, etc.

Other factors in this respect could also be listed.

(Please refer to Resource 2C: A Teacher Can Create a Stimulating Environment, pg. 43)

In order to create the classroom climate, the role of the science educator, teacher trainer or the teacher is crucial. Many of the characteristics of scientific and technological literacy require considerable intellectual freedom if they are to be achieved. Such intellectual freedom does not imply social freedom but focuses, instead, on:

- providing opportunities for raising issues and questions
- trying out solutions
- communicating with others

Intellectual freedom requires a safe environment where the student feels comfortable suggesting possibilities, asking questions without fear of humiliation and of initiating actions to test personal ideas. An intellectually safe classroom also provides multiple opportunities to interact with others. This is the same classroom climate advocated by most current leading educational thinkers, even when they speak of the arts, social sciences, or the humanities.



Activity 2-9: Cultural Challenges to STL Teaching

Allow participants to Discuss the following question in groups. Illustrations can be provided based on their experiences in their classroom.

“Do you perceive any cultural challenges for STL teaching of which you should be aware? What are these challenges?”

Ask them to Note down their responses, discuss with their neighbour and argue on the points raised.

2.3.4 Recognising Teaching Domains Needed for Change

Science educators and teacher trainers need to recognise that The views of what is appropriate science for all learners have been broadened. Instilling in teachers an appropriate view is intended to form a basis for determining goals, curriculum strands, instruction and assessment for science and technology education.

Yager and McCormack (1989) have identified 5 domains that are important in science teaching:

- (i) Concept Domain
- (ii) Process Domain
- (iii) Creativity Domain
- (iv) Attitudinal Domain
- (v) Application and Connection Domains

(Please refer to Resource 2D: Domains in the Teaching of Science, pg. 45)



Activity 2-10: Sequencing of Lessons

Guide participants to Discuss the following question in small groups, and prepare to present their views.

“What domains of learning would you suggest are needed to broaden the view of appropriate science for all and enable teachers to reflect on how to sequence their lesson plans.”

“Would you wish to argue for a sixth domain on social values?”

(Please refer to Resource 2E: Review of the Curriculum Sequence, pg. 47)

2.3.5 The Role of Textbooks in STL Teaching

A major support for teachers, even during the present time, has been the textbook. Teachers have relied on textbooks all along. Research has shown that the textbook dictates the direction and pace of the lesson. But scientific and technological literacy is a problem if textbooks concentrate on factual knowledge and conceptual understanding and pay little more than lip service to the wider goals of science and technology education. Unfortunately most current textbooks, and even student workbooks, are weak in meeting objectives such as developing problem solving, decision making and communication skills. Textbooks are often geared to the assessment emphasis of examinations and based on an examination syllabus, sequenced on scientific fundamentals. This promotes conceptual goals but textbooks are not guiding for attitudinal gains.



Activity 2-11: Textbooks for Science Teaching

Ask participants to Discuss the following question in groups.

“As teachers, how much do you make use of the textbook for teaching. Do you perceive any problems in placing too much emphasis on the textbook as an ‘approach to teaching’?”

Responses should be recorded and shared with other members of the workshop.

It is logical to expect that the textbook covers ALL the objectives that are included in the curriculum guide and to expect the emphases to be similar. There is a very strong match between content designated in the curriculum guide and the textbook. However, there can be, unfortunately, a large mismatch when it comes to skills of problem solving, decision making and the various forms of communication skills. This is a concern that needs much more research.

Where teachers have confidence in their teaching and are highly motivated, it is probable such teachers make little direct use of the textbook. Students are encouraged to use the textbook as a resource to support their learning. The mismatch indicated in the previous paragraph is not a problem, as the textbook is used in a reference mode. But the textbook can also be used in a teaching mode. Teachers who are not confident, or who are poorly motivated, are likely to depend heavily on the textbook for their day to day teaching. This is where the problem arises. This is a problem that science educators and teacher trainers should ensure is not faced by teachers.

2.4 STL Approaches/Strategies

Creating the right environment for the promotion of STL would need effective classroom approaches/strategies. In guiding teachers to consider the implementation of the curriculum, science educators and teacher trainers should be aware that one decision that has to be made by the teacher is the manner in which the content and the science concepts are approached. Is it the science discipline, the needs of society, or other factors such as the environment that sets the direction?

Science educators and teacher trainers will recognise that usually, the curriculum developers set the direction, but that in developing teaching materials, teachers also need to face the issue of how best to approach the learning.



Activity 2-12: Approaches for STL Teaching and Learning

Participants should be asked to Identify or suggest approaches which they will utilise in their classrooms for effective STL teaching and learning.

It is important to give reasons for the preferences identified, and if necessary, to describe what is meant by the approach. Recording the discussion and sharing with members of the workshop would be a very useful learning exercise.

(Please refer to Resource 2F: STL approaches, pg. 48 for further explanation).



Activity 2-13: Strategies for Teaching and Learning

Guide participants to Work individually, in pairs or in groups, and suggest or identify effective strategies for STL teaching and learning. The list could be shared between the pairs or in the class discussion. (Please refer to Resource 2G: Other useful strategies for STL teaching and learning, pg. 50)

What do you and participants expect students to do in STL classrooms?

Educational activities take place not only in schools, in a formal setting, but also in non-formal programmes, and in in-formal settings. Some of the examples of non-formal programmes are

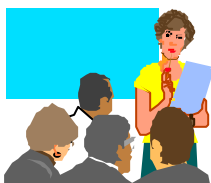
activities of hobby clubs, science fairs, short-term training and workshops. Learning also takes place in in-formal settings, such as visit to shops, TV programmes, and listening to radio programmes.

In the present context of high technological advancement, a large variety of sources for information are available. Therefore, STL teaching and learning by a particular approach or source would be too limiting. Students should always be prepared to learn new information and ways. STL approaches should prepare students to use all possible means - formal, non-formal and in-formal. Formal learning could be more rigour-based, objective and capable of being evaluated. Non-formal approaches could be related to day-to-day needs or interest-based educational activities. In-formal teaching and learning should be focused to prepare students to use all available opportunities for STL learning.

One specific example is the activities of the China Association for Science and Technology (CAST). The organisation works closely with the Ministry of Education in China to promote the creative capabilities and scientific thinking among Chinese primary and secondary students. They sponsor the National Invention and Creation Contest and Science Symposium for Young People every other year (a non-formal approach), which attracts more than 10 million students. The root of this non-formal activity can be traced not only from the school science classes and after-school science clubs (formal education), but also from the training programmes organised by Children's Palaces and Science Museums (non-formal education). The instructors of these activities are not only science teachers in schools, but also many volunteer scientists and engineers.

2.4.1 The Role of Teachers

Science educators and teacher trainers in preparing teachers to talk to students, expect teachers to anticipate the questions and responses of their students. Yet, educators and trainers need to recognise that this is the beginning of a good conversation, not the end. In a true adult conversation, one person's response becomes the others' stimulus, leading to interplay of ideas, thoughts, and even more questions. To create this type of dialogue, a teacher needs to follow up on a student's response by asking for clarification or by using the response in another question. For instance, if a student says that the greenhouse effect can be a problem in tropical countries, it is logical to ask, "What do you mean by 'the greenhouse effect'?" or using the response itself, the teacher could ask, "What type of problems?" In either instance, the response continues the dialogue, allowing the teacher to deal deeper into the student's understanding. Knowing this, the teacher is in a better position to structure the learning environment for maximal student success. The cycle is much like adult conversation where one person's response leads to a response from the other, causing a continuing conversation which may turn in various ways, but will hold the interest of both parties.



Activity 2-14: Teacher Behaviour in STL Teaching and

Ask participants to Discuss the different approaches STL teachers would use. The following question could guide the discussion:

“Are you able to put forward other teacher behaviours that are not only essential in STL teaching, but are used by good teachers in any type of teaching?”

(Please refer to Resource 2H: Teacher Behaviour Essential in STL Teaching and Learning, pg.51)

2.4.2 The Role of Students

In traditional classrooms, the textbook, the teacher, or professional scientists define what students should know. Typically they are expected to read, listen, and repeat the desired information - this being called learning. However, this description of learning for scientific and technological literacy does not seem adequate. All individuals learn continuously, but rarely do students learn as teachers have in mind. Individuals construct personal meaning out of the events, ideas and objects around them.



Activity 2-15: Student Involvement in STL Learning

Ask participants to Discuss in small groups the different ways of involving students in order to achieve STL learning.

Guide participants to Present their your views to other members of the workshop.

(Please refer to Resource 2 I: Students' Role in STL Learning, pg. 55)

2.4.3 Role of Community Resources

While discussing classroom approaches towards STL, science educators and teacher trainers one should also look for community resources that can be used to enhance and develop STL. For instance, local enterprises can provide learners, especially those in rural areas, more opportunities to be connected with technology tools and with the people who use those tools. In the process, they can also come to understand more about the impact of technology on social development. Spreading of modern agricultural technology, especially the eco-agriculture farms, are good examples for learners to understand the ecology theory in their science study. The temples in Thailand have played very important roles in science popularisation. The community groups in many developing countries, like Nepal, are very active and effective in providing technical support and information to farmers. Yet the resources available in these community organisations are normally not easily accessible to “educational institutions”. The potential educational functions of such regional organisations need to be identified and encouraged to become available as educational resources by persons or organisations who have the foresight and out-reaching capability in organising and co-ordinating resources.

In the West District of Beijing, China, the local government agencies set up regular Co-ordination Meetings for community resources to support education. During those meetings, all the governmental and non-governmental institutions located in the community, such as enterprises, research institutes, libraries, and factories, will be asked to make their contributions to work with the local schools to provide a better environment for the young people.



Activity 2-16: STL Activities Using Community Resources

Show examples of STL activities utilising community resources. A bulletin board display could be set up, or exhibition utilising local resources.

Discuss with participants preparatory and post activities as a group.

2.5 The Need for STL Supplementary Teaching Materials

One resource, which can guide science education towards greater relevancy for the 21st century, is the use of STL supplementary teaching materials. These materials are not extensions of the textbook, but are additional resources for the teacher to call upon as required. As such they are optional materials and can be used as and when the teacher feels it appropriate. If the materials allow students to engage in activities relevant to STL, they enhance the learning situation and hence guide students to achieve the intended educational objectives.



Activity 2-17: STL Supplementary Teaching Materials

Analyse the case below:

The major resources used by teachers and students are undoubtedly the curriculum guide (the syllabus) and the textbook, especially in developing countries. Changes in the curriculum and textbook can help to reflect new tendencies to some degree. The textbook can change to follow this sequence. Also, any moving from academic to thematic titles and by presenting the material through story lines rather than factual text, textbooks can reorient the manner in which the learning material is viewed.

But, course outlines, curriculum guides and most textbooks cause problems in promoting STL. For a start, they are out-of-date, having been produced before the latest advances and before the latest issues or concerns have merged within the society. Neither can they relate to a specific area, a specific school district or to the issues and concerns that reflect immediate school environments. And none can take advantage of 'connections' that may be unique to each person, school, science centre, local industry, or the community.

The textbook is even more limiting by its desire to impart knowledge. By stating the case and providing the necessary background, the textbook heavily inhibits the promotion of problem solving and decision-making skills. And, of course, it has already decided on the communication approach i.e. the written text, perhaps supported by diagrams, tables, or graphs. By placing too much reliance on the centralised curriculum and on curriculum developers, the most meaningful context for relevant learning that can only be exploited by the teacher is being undermined. Teaching becomes stereotyped and in danger of being divorced from meaningful learning.

Suggested questions for discussion:

What issues can be identified from the case above?

As an experienced science educator or teacher trainer, how would you suggest teachers solve the issues?

How would you as a course/workshop leader relate your answers to the learning of STL?

Prepare a report for presentation to participants.



2.6 Summary

In many countries, new approaches will be required to meet the demands of a scientific and technological literacy teaching along the lines suggested. As the section has illustrated, this is no simple matter and it is crucial that science educators and science teachers guide teachers to pay attention to:

- The intention of the curriculum with respect to its place in the educational system as a whole
- The intended approach, the sub-dividing and sequencing of the curriculum so that it relates strongly to the underlying philosophy
- The implementation process to ensure that classroom practices do match the intentions and that teachers are able to sustain these practices in the face of possible constraints

Science educators and teacher trainers need also to pay Attention to the need to involve teachers in the development and implementation processes. Such teachers need to be carefully guided, however, as they need to embrace the new philosophy and be in a position to lead the implementation of the curriculum in the classroom during the essential field trials.



Resource 2A: Teacher Self-Analysis
Yager, 1993

A self-analysis scale can be used to judge the likelihood of a teacher being effective. Of course, it is virtually impossible to be perfect (right hand side of the spectrum) in all thirteen features. That is not even the point. What it does give a general picture of whether a teacher is likely to be considered as one using scientific and technological attributes.

“The scale is based on a Constructivist Learning Model as a part of a reform in science teaching” (Yager 1993). For questions 1-7, a four-point scale is used to indicate whether it is overwhelmingly the teacher who makes the decision, predominantly the teacher but with some student help, largely students guided by the teacher, or very strongly a student decision. Questions 8-13 solicit a definite no, largely a no, largely a yes, or a definite yes.

How would you rate yourself on each of the following questions?

The Self-Analysis Scale:

RATING SCALE

	1	2	3	4	
(for questions 8-13)	----	----	----	----	The Student does Yes
	The Teacher does No				

Questions

1. Who identified the issue/topic?
2. Who is asking the questions in class?
3. Who identifies written and human resources?
4. Who locates written resources?
5. Who contacts human resources?
6. Who plans investigation and other activities?
7. Do students see issues as relevant?
8. Are varied evaluation techniques used?
9. Do students evaluate themselves?
10. Do students apply concepts and skills to new situations?
11. Do students take action following study?
12. Do science concepts/skills emerge because they are needed?
13. Are extensions of learning outside the school in evidence?

Add the scores for each question. We hope you managed to obtain a high score, well above 30.

But it is worth remembering – How far do answers to the above self-analysis reflect actual practice, rather than practice the teacher hopes to achieve? Sharp contrasts exist between what research and theory have established about effective learning of science, and the actual teaching practices observed in the vast majority of elementary, middle, and senior high schools (Boyer 1983; Goodlad 1984; Mullis & Jenkins 1988; National Assessment of Educational Progress 1979; Stake & Easley 1978; Weiss 1978).



Resource 2B: Individualised Classroom Environment Questionnaire (ICEQ)

Adapted from Thorpe, Burden and Fraser, 1994

Scale	Scale description
Personalisation	Emphases on opportunities for individual students to interact with the teacher and concern for the personal welfare and social growth of the individual
Participation	Extent to which students are encouraged to participate rather than be passive listeners
Independence	Extent to which students are allowed to make decisions and have control over their own learning and behaviour through problem solving and investigations
Investigation	Emphases on the skills and processes of inquiry and their use in problem solving and investigations
Differentiation	Emphases on the selective treatment of students on the basis of ability, learning styles, interests and rates of working

Individualised Classroom Environment Questionnaire

REMEMBER: You are rating what actually happens in the classroom.

KEY a = ALMOST NEVER; b= SELDOM; c = SOMETIMES;
d = often; e= VERY OFTEN

Indicate a, b, c, d and e, before the statements.

1. The teacher talks with every student
2. Students give their opinions during discussion
3. The teacher decides where students sit
4. Students find out the answers to questions from textbooks rather than from investigations
5. Different students do different work
6. The teacher takes a personal interest in each student
7. The teacher lectures without students asking or answering questions
8. Students choose their partners for group work
9. Students carry out their investigations to test ideas
10. All students in the class do the same work at the same time
11. The teacher is unfriendly to students
12. Students' ideas and suggestions are used during classroom discussion
13. Students are told how to behave in the classroom
14. Students carry out investigations to answer questions coming from class discussions

15. Different students use different books, equipment and materials
16. The teacher helps each student who is having trouble with the work
17. Students ask the teacher questions
18. The teacher decides which students should work together
19. Students explain the meanings of statements, diagrams and graphs
20. Students who work faster than others move on to the next topic
21. The teacher considers students' feelings
22. There is classroom discussion
23. The teacher decides how much movement and talk there should be in the classroom
24. Students carry out investigations to answer questions, which puzzle them
25. The same teaching aid (e.g. blackboard or overhead projector) is used for all students in the class.



Resource 2C: Teacher Creating A Stimulating Environment

Penick and Bonnstetter, 1993

The following 5 aspects show how a teacher can create a stimulating environment.

(i) Caring

Students must see the teacher as a caring helper working with individuals, not a judge dealing with the masses; they need to feel safe, to have success if they are to develop science literacy (Fisher et. al. 1980; Marlave & Filby 1985). The best classroom dialogue is similar to adult conversation. Adults rarely ask each other test questions (What is Avogadro's number?); instead, they ask each other questions to ascertain feelings, ideas, or to gain information not previously held or forgotten. No one likes being tested.

(ii) Friendly

Students do best in a safe and friendly environment, supported by a rich variety of resources, and with many opportunities to initiate, plan, and take action (in the laboratory, library, or elsewhere). As students work in this rich and safe environment, the teacher observes, watching for clues to student understanding or moments where provided information or material might spur the student on, or allow new insights into the problem being investigated. At the same time, this teacher is carefully listening to students and asking open questions with the same goal in mind. In both cases, the teacher is trying to take actions that reveal the teacher's logic, a most critical step in communicating science and teaching students how to solve science and technology problems. This is what good, progressive teachers have always done.

(iii) Importance of effective questioning

To help students, the teacher needs to gain feedback. Questioning can guide the teacher to the depth of the problem or the level of understanding possessed by the students.

A teacher's questions answered simply by "yes" or "no" are rarely suitable for science and technology teaching. They do not require deep thought, often encourage guessing and certainly encourage, if used in a whole class situation, students responding with a 'chorus' answer. They are of little use for STL.

Asking open questions, which you know the student can answer, is easy if you think of questions as a hierarchy. In this hierarchy, the lowest level questions are those relating to what the student has already done. Since they are part of the student's personal history, the student can answer them with ease. Now, with success at answering, the student feel more at ease while the teacher has multiple avenues on which to continue the conversation. Once the student has answered questions such as "What did you do first?" or "How did you do that?" you can ask questions which relate one aspect to another. For instance, "How does that compare to what happened the last time?" or "What did the other groups find?". These questions, like the historical ones, are not usually difficult to answer. And, if they are, these are questions where it is acceptable to not know. (Penick and Bonnstetter 1993).

Other higher order questions may follow these first two types. As students become more comfortable answering questions and comparing, it is possible to begin to ask questions that require

application of ideas or knowledge. For example, “How could you use that idea to reduce the problem of rubbish disposal?” or “Where have you seen that idea in operation?” Application questions are very important in bringing student to understanding basic concepts. As students attempt to apply their knowledge, they often begin to see what they do or do not understand.

Application questions are often followed by speculation such as “What if we burned all our rubbish?” or “What might happen if we each had our own compost pile?” Again, much like the other questions, there is not a single right or wrong answer and students should be encouraged to make up an answer. At the end comes the questions, which the teacher would really like students to be able to answer; questions that focus on explanations. Requests for explanations are among the most difficult of questions and should be reserved for those rare occasions when students are ready for them.

(iv) ***Holding discussions***

Dillon (1981) noted that, to be considered a discussion, students must account for at least 40% of the total talk. Teachers allowing this are likely to be viewed as more patient and will be able to encourage multiple responses. Also, since the teacher does not know the students’ answers in advance, the teacher is in a learning situation (Rogers, 1969), a key factor in classrooms where the learning is exciting.

All too often teachers refer to holding discussions, when in practice it is not. Consider a class of 40 students, in which the lesson lasts for 40 minutes (a reasonable approximation) and in which the teacher takes half a minute to ask the questions to stimulate student ‘discussion’. In each case, a student takes half a minute to respond (again a reasonable approximation). In this scenario, it takes the whole lesson for all students to be involved. (As the teacher is teaching the whole class and communication skill can be considered one of the goals, it is reasonable to expect the teacher to want all students involved). So in this situation, the teacher is overtly involved for 20 minutes, whereas each student is limited to half a minute i.e. half a minute, in 40 minutes of time. A reasonable mathematical approximation is surely to say each student is involved for a negligible amount of time. Hence, in a situation such as this, it is not possible to say they were ‘discussing’! They were passive listeners most of the time. The actual activity is one of teacher talk, student listen. This can hardly be called a discussion. And this type of teaching must not dominate in the STL classroom.

(v) ***Developmental approach***

Elkind (1989) notes most classrooms emphasises a psychometric approach rather than a developmental one. The psychometric approach stresses achievement scores and acquisition of knowledge while the developmental approach seeks critical and creative thinkers. As the effective teacher encourages and wants critical thinking and creativity, the teacher needs to create a classroom climate that organises, stimulates, and makes readily available a wide range of resources and ideas and actions that encourage students to achieve the desired roles and goals.



Resource 2D: Domains in Science Teaching

Yager and McCormack, 1989

Five domains that are Important for Science for All

1. Concept domain

Science aims to categorise the observable universe into manageable units for study, and to describe physical and biological relationships. Ultimately, science aims to provide reasonable explanations for observed relationships. The Concept domain includes: facts, concepts, laws (principles), and existing hypotheses and theories being used by scientists. This entire vast amount of information is usually classified into such manageable topics as – matter, motion, animal behaviour, and plant development.

2. Process domain

Scientists use certain processes (skills). Being familiar with these processes concerning how scientists think and work is an important part of learning science. Some processes of science are – observing and describing, classifying and organising, measuring and charting, communicating, and understanding communication with others, predicting and inferring, hypothesising, hypothesis testing, identifying and controlling variables, interpreting data and constructing instruments, simple devices and physical models.

3. Creativity domain

Most science programmes see science as something to be done to students to help them learn a given body of information. Little formal attention has been given in science programmes to development of students' imagination and creative thinking. Some of the specific human abilities important in this domain are:

- Visualising – producing mental images, combining objects and ideas in new ways, offering explanations for objects and events encountered
- Questioning
- Producing alternate or unusual uses for objects
- Solving problems and puzzles
- Designing devices and machines
- Producing unusual ideas
- Devising tests for explanations

4. Attitudinal domain

Human feelings, values, and decision-making skills need to be addressed. This domain includes:

- Developing positive attitudes toward science in general, science in school, and science teachers
- Developing positive attitudes toward oneself (an 'I can do it attitude')
- Exploring human emotions
- Developing sensitivity to, and respect for, the feelings of other people

- Expressing personal feelings in a constructive way
- Making decisions about personal values
- Making decisions about social and environmental issues

5. Applications and connections domain

It seems inappropriate to divorce “pure” or academic science from technology. Students need to become sensitised to those experiences they encounter which reflect ideas they have learned in school science. Some dimensions of this domain include:

- Seeing instances of scientific concepts in everyday life experiences
- Applying learned science concepts and skills to everyday technological problems
- Understanding scientific and technological principles involved in household technological devices
- Using scientific processes in solving problems that occur in everyday life
- Understanding and evaluating mass media reports of scientific developments
- Making decisions related to personal health, nutrition, and life style based on knowledge of scientific concepts rather than on ‘hear-say’ or emotions
- Integrating science with other subjects



Resource 2E: A Review of the Curriculum Sequence

Yager and McCormack, 1989

An example of **STL Curriculum Sequence** – *Our world and the inside story of matter*

Exploring differences between solids, liquids and gases
Our need to understand the effects of putting solids in water
Why we need to know about molecules?
Can solids, liquids and gases move through one another?
Our lives and giving molecules energy
The advantage of knowing what affects the evaporation of liquids?
Heaviness and lightness: why the inside story is important
Luckily for us, molecules can push?
Molecules and air pressure – affecting more than the weather

Comments on the context, teaching approach and the emphases in this curriculum modification.

The content above is not intended to be prescriptive. It merely tries to illustrate a different approach. The emphases is no longer on content only, but enhancing a range of skills through involving students in a variety of activities. It is much more geared to enabling students to strive for multi-dimensional STL.



Resource 2F: STL Approaches

Holbrook J.B., 1998

The decisions facing the teacher in achieving STL is whether the content should progress through:

1. Fundamental (science concepts) led Approach

In a fundamentals-first approach (Approach 1), the emphasis is usually on a systematic study at the microscopic level. In initial chemistry courses, protons, neutrons, and electrons leading to atomic structure and bonding. Based on this, formulae and equations can be written and processes such as electrolysis and rusting can be explained. It is all very logical, very systematic, but it means there is much to study for little relationship (at least for much of the initial part of the course) with the world around us. This does not lead to STL teaching.

2. Societal (or issues) led Approach

The alternative approach (Approach 2) recognises the technology in society around us. It recognises the concerns of society, the skills required to deal with scientific issues in society, and the depth of understanding needed to gain some comprehension for problem solving. It begins with societal technology and in particular the concerns we have related to areas such as resources, health, food, the environment, energy problems, the need for industry and how we can communicate. This alternative approach uses more societal headings and approaches the science concepts through issues and concerns within society. It sees the society as the context for learning and the issues within society as the rationale for learning a particular aspect of science. The science is included on a 'need to know' basis which means that the depth of treatment of the science is dependent on the societal issues being studied, rather than by the scientists' view of conceptual compartmentalisation. Whilst the linking together of various topics in this way may not be scientifically logical, the curriculum can still be inherently logical from **the students' point of view**.

3. Environmental Education Emphases

Another approach is to consider an interdisciplinary area. This is really a variation of approach 2, where the environment is recognised as interdisciplinary and hence the teaching is not bound by conceptual ideas in any scientific discipline. It emphasises that environmental education is too important to leave to the well intentioned, but scientifically ill-informed. While the products of science and technology have caused many life-threatening environmental problems on this planet, these problems will only be solved by men and women who understand the nature – and limitations – of science and technology.

4. Thematic Emphases

In a constructivist idea, learning is contextual. New knowledge is highly dependent on its context and knowledge has different meanings in different contexts. School science and technology knowledge often has little meaning for students because it is presented in the abstract, independent of meaningful context. Concrete experiences such as those acquired in laboratory activities can provide some of this context. The overall framework of the discipline being studied and its major themes are other aspects of context. (Anderson, 1992).

In this approach the issues are not so much the primary focus as thematic areas, such as water, air or a balanced diet. This approach suffers from the fact that it can be conceived as Approach 1 or Approach 2 depending on the way the themes are developed. It is thus unclear whether a thematic approach will also be geared to STL teaching.



***Resource 2G: Other Useful Strategies for STL
Learning***

UNESCO-SEAMEO RECSAM. 1999

Some strategies that are useful for STL teaching and learning are:

1. Individual work by students

Applicable to the development of individual problem solving or decision-making strategies and to all forms of written communication.

2. Brainstorming

Students are to present their ideas related to the topic under discussion. All ideas are collected and recorded, irrespective of their worth or correctness and without comment. This activity is designed to stimulate thinking and to call on students' background knowledge (and may be their misconceptions).

(A common approach is for the teacher to write student suggestions on the blackboard)

3. Role Playing

Students (or a group of students) undertake to play a specific role within a group debate or enactment of a scene. The student undertaking the role, tries to act according to the role assigned, putting forward points of view in line with the expected belief. The role playing exercises lend itself to decision making, whereby decisions can be made by a judge, a panel, or by a referendum of many people, based on the value placed on the various aspects within the scenario indicated.

4. Public Inquiry

This is similar to a role playing exercise wherein students create a courtroom and allow individual students to play the role of various figures in the enactment of a public inquiry. The bulk of the class acts as the jury and vote on the final decision. The teacher plays the role of the judge advising the 'Jury' as necessary.

5. Debate

A panel is set up (often of 3 speakers) that speak for the motion that is to be debated and are opposed by a similar number of speakers. Starting with the speaker for the motion and followed by a speaker from the opposition. The panel takes turn to present the points as forcefully as possible without duplicating a previous speaker, yet carefully refuting points put forward by the other side. The audience (or a panel) decides the winning team.



Resource 2H: Teacher Behaviour Essential in STL Teaching and Learning

Penick and Bonstetter, 1989

Here are some possibilities you may have mentioned.

1. Wait Time or Pausing

The time a teacher waits or a pause is also a key behaviour, essential for science and technology teaching. It is the time a teacher waits for a student response after asking a question. Without wait time, students quickly learn that the teacher does not really want a response. Plus, with a short wait time, only the brightest and quickest students respond (Rowe, 1986). Wait time, pausing after a student has responded, also leads to much more cross-talk, where students are challenging each other, offering additional ideas, and truly getting involved in the discussion. It appears that if teachers could learn to ask good questions and then wait, classroom teaching of all subjects and students' literacy in science and technology would be predicted to improve dramatically.

Research indicates that students respond more often, with more explanation, and with more self-confidence when the teacher makes effective use of wait-time or the pause. This is aided when the teacher:

- Asks questions clearly the first time, without dragging it out, undertaking rephrasing, or talking after the question
- Makes the pause overt. The teacher just asks the question, look at the student who is to respond, and waits patiently. Every time the teacher speaks, or looks away, the 'wait-time clock' starts all over again.

While pausing often feels very awkward, even embarrassing for the teacher, it ensures that students respond in desired ways. Once students come to recognise and expect wait-time, they will respond even better. In addition, as the teacher waits, this develops habits of good listening, and students also, become better listeners, with the result that their conversational partners are given more time without interruption. Wait-time is probably among the most influential of all teacher behaviours, leading to more active and involved students plus teachers who understand and teach them better.

2. Effective communication

Teachers and students not only communicate orally, facial expressions and the use of gestures with the hands, or with the whole body, can indicate willingness or reluctance to participate. This monograph is not the place to go into details on the use of facial expressions, but it is worth noting that a smiling tends to convey happiness and a relaxing atmosphere. Students like a teacher with a smiling face. On the other hand a facial expression showing determination, guides the students to concentrate. And few students like it when the teacher's expression conveys anger or disappointment, because the atmosphere prevailing in the classroom is not pleasant.

An effective teacher will make use of these attributes a great deal. A stiff, rigid and expressionless teacher can do little to stimulate the classroom atmosphere and hence control learning. The expression of the teacher can be particularly effective when one student is struggling to respond to a teacher question (facial expression can encourage) and teacher tries to maintain the concentration of the rest of the class (frowning on any undesirable behaviour).

But how do students see the facial expressions of the teacher? Clearly the closer the teacher moves to the students, the easier this becomes. Also the physical presence of the teacher near students gives a sense of encouragement, or being involved and thus helps students to participate more fully in the lesson.

3. *Teacher positioning*

Effective teachers do not stand behind the teacher's bench to talk to the whole class. Such teachers are too far away from the students. Effective teachers come closer to the students. If it becomes necessary for teachers to use the chalkboard, they move to the board for that specific purpose. Then as teachers do not spend more than a few moments writing (this is necessary if they want the whole class to pay attention), they are free to move closer to the students again.

The effective teacher moves as close to the students as possible and tries to find ways of being close to every student, some of the time. Or, alternatively, the effective teacher will move the students so that they are all equally as close to the teacher as possible (all students, not just the lucky few – the ideal arrangement is probably a semi-circle of seated students).

4. *Feeling of high achievement expectations*

Good teachers expect change. Change may be in learning, or attitude, or it may be resolution of a real problem. Teachers have different expectations for students as they recognise that students have varying potentials and interests. The effective teacher expects all students to achieve personal excellence through quality performance, but recognises this will be at different levels depending on the ability of the student. Evidence of high expectations is shown by their continual push to do more, gain more involvement, and see the resolution. They are never contented with a status quo. Teachers with high expectations also see their roles as more than a teacher of a group of students. They see their role in a larger perspective in the community, and as a model of active inquiry.

Encouraging each student to participate in critical thinking and to learn is not easy in a whole class situation, unless individual work is demanded. A whole group, teacher-centred situation tends to encourage only 'good' students to respond. Whole class teaching has serious limitations for STL.

5. *Promotes active inquiry by example*

An inquiring teacher reads and explores widely, bringing this reading, action, and new knowledge visibly into the classroom. Students know this teacher is open to wonder, new ideas, and is innovative. Exemplary teachers bring inquiry alive by presenting themselves as students, eager and willing to learn new ideas, skills, and actions. By bringing new ideas to the class, by questioning and being open-minded, these teachers are clearly models to be followed. They also model the thoughtful and rational approach to problem identification and resolution by being interested, seeking information, asking for evidence, and by taking action themselves. In essence, they are making their thinking, feelings, and approach to learning highly visible.

6. *Expect students to question facts, question the teachers, and question the knowledge itself*

When teachers make their approach visible, students more easily see that science and technology involves a degree of skepticism. Not an assumption of being wrong, such a belief is a quest for evidence to support a fact, idea, or position. Teachers and students who have questions, seek answers, and who can provide evidence, may well become active citizens with the same attributes.

All too often students, in poor classroom climate conditions, have absolute belief in the correctness of the textbook and in the uniqueness of scientific solutions as expressed in the textbook. A discussion of the meaning of pure water may serve as an illustration. Depending on the situation, this can mean distilled water, de-ionised water, or simply water that does not contain sufficient bacteria to be harmful to man. Yet the textbook will, in all probability, only mention one of these.

7. *Stress scientific and technological literacy and the application of knowledge*

Teachers stress scientific and technological literacy by demanding a rational and independent approach to science and technology and its impact on society. Students are expected to seek, to question, to explain, and to apply their knowledge. Teachers are not content with students just knowing words or skills, they insist that words be used to justify, defend, or clarify larger concepts or actions. For many students, they must apply their knowledge before it truly becomes a part of them.

For many traditional teachers applying knowledge may be restricted to answering questions at the end of the chapter, but effective teachers are never contented with this alone. Calculating vectors in a pulley system does not have as much potential and is not, for most students, as problematic as making up a block and tackle. The same is true with societal applications where students, seeking justification for a new community water treatment plant, view their learning as vastly different from reading a standard text on the subject. In both instances, they can see their knowledge as it is being used, often outside the classroom.

8. *Do not view the classroom walls as a boundary*

Any learning that is real must, by definition, continue into the rest of the students' lives and world. Obviously, effective teachers see that both their students and their ideas have many opportunities to go beyond the classroom, via field trips, visits to resource persons and facilities, and using outside materials such as books, papers, and ideas. At the same time, teachers invite community experts in, offering new insights and perspective on existing problems and often raising new ones. Teachers also encourage going beyond by stressing issues and ideas from outside the school.

9. *Flexible in their time, schedule and curriculum*

An effective teacher takes advantage of opportunities, changing as occasions present themselves. A student learn but not always as the teacher anticipates or on the same schedule, but the stimulation, excitement, and involvement lead to many new avenues of motivation and learning – for the teachers as well as the student.

10. *Put in far more than the minimal time*

Scheduling, co-ordinating, developing materials and planning all require time. Exemplary teachers worry about time, but focus that worry on the finding of more time to devote to their classes and ideas. They complain that days are not long enough and as a result, such teachers devote time after school and on weekends, striving to make their teaching all it can be. For this, of course, the morale of the teachers needs to be high. Rarely are there any material rewards – the reward is simply the gains of their students as they strive for greater and greater degrees of scientific and technological literacy.

A common, negative cry from weaker teachers is that they do not have time to do extra tasks in the classroom. It is important that we finish the syllabus. It is crucial that STL teachers know better than to make such a statement. STL teachers know that the teacher finishing the syllabus has no meaning. It is not for the teacher to finish the syllabus, but for the students to acquire the knowledge and skills inherent in the curriculum.

STL teachers know that students learn better in an interesting, friendly atmosphere where there is also an element of challenge. It is the skill of the teacher to create such a situation. And once achieved, it is a powerful learning situation. Students learn how to learn. Students take responsibility for their learning.

11. Interacting with students

Teachers interact with students whenever it appears this would help students move towards the classroom goals. They begin the interaction cautiously. For instance, the teacher may watch students from a distance, observing what they are doing. Now, when the teacher approaches, rather than “What are you doing?” they already know that answer and can ask a more meaningful question. It is worth remembering that, if an individual or group were busy with a task in an adult setting, one would hesitate to interrupt. And, if this were necessary, one would begin with a polite amenity such as, “Excuse me”. Yet, with students, teachers often barge in, asking questions as if only they matter. Often the end result is students who resent the teacher’s intrusions and pay little attention to them. It is also worth bearing in mind that in a ‘hands-on’ curriculum, teacher interruptions take away activity time.

Although interactions at the student’s level are important, they can lead to awkward situations. If teachers approach quickly, sit down, either to watch or interact, but unfortunately, the students do not want to interact, or for some reason consider it an inopportune moment, teachers have an embarrassing moment getting up and leaving. Much better would be for teachers to move toward the individual or group and, just like in an adult social setting, wait for the student or group to recognise their presence. Usually, at this point, it is obvious whether it is appropriate to ask a question. As teachers begin their conversation, they will soon know if this will be a minimal interchange or whether it is likely to turn into a real conversation. Rather than awkward or intrusive, the interaction between teacher and students becomes more natural and its value increased by the reduction of distance and the intimacy of the conversation.

Teachers anticipate that, in talking to students, they will obtain a response. Yet, this is the beginning, not the end, of a good conversation. IN a true, adult conversation one person’s response becomes the others stimulus, leading to an interplay of ideas, thoughts, and even more questions. To create this type of dialogue, a teacher will follow up a student response by asking for clarification or by using the response in another question. For instance, if a student says that the greenhouse effect can be a problem in tropical countries, it is logical to ask, “What do you mean my ‘greenhouse effect’” or using the response itself, the teacher could ask, “What type of problems?”. In either instance, the response continues the dialogue, allowing the teacher to delve deeper into the student’s understanding. Knowing this, the teacher is in a better position to structure the learning environment for maximal student success. The cycle is much like adult conversation where one person’s response leads to a response from the other, causing a continuing conversation which may meander in various ways, but holds the interest of both parties.



Resource 2 I: Student's Role in STL Learning

Pennick and Bonstetter, 1993; Krajcik 1993; Mamalinga, 1993; Yager, 1993

Students play various roles in STL Learning. Some of these are:

1. Constructing Meaning

All individuals learn continuously, but rarely do students learn as teachers have in mind. Individuals construct personal meaning out of the events, ideas, and objects around them. Often, these constructed meanings have little congruence with the reality of professionals in the field. In addition, these self-constructed meanings are quite persistent, often surviving formal instruction about the same subject.

Successful learning often means replacing naïve, prior conceptions with more sophisticated and thoughtful ideas. But, since each person develops meanings individually, imprinting the teacher's ideas directly onto the students cannot achieve such learning. Meaningful learning derives from being in an environment where the student experiments, reads, talks, listens, and, above all, thinks.

Constructivism differs from traditional science education in that science and culture are seen as inseparably linked. Constructivists view science in a cultural context and that the cultural matrix of science education embedding science may not be widely shared by students (Cobern 1994). With knowledge of the way a student has constructed personal meaning, the teacher can make clear and rational decisions about how to interact with the cultural environment so the student can confront their own misunderstandings and rebuild an idea, and in the process come closer to the desired meaning.

Moving to Constructivist Practices

Constructivist practices result in students attaining more of the goals typically cited by teachers. Among these are:

- demonstrate mastery of basic concepts (in ways other than repeating or recognising standard definitions)
- use of basic process skills (again, in new situations ability to apply, interpret, and synthesise information)
- enhancement of creativity skills (questioning, proposing, predicting consequences)
- improved attitudes toward science study, school, teachers, and careers

Constructivist practices require teachers to:

- place students in more central positions in the whole instructional programme.
- question more and the questions must be used as the basis, for discussions, investigations, and actions in the classroom/laboratory
- propose solutions and offer explanations
- use the proposals in the classroom to form the basis for seeking and using information and for testing the validity of all the explanations offered

The above suggests a progression of involvement which starts with the student, moves to pairs and/or small groups of students for more questions and eventually consensus, then to the whole class for similar processing, and finally to the professional (scientific) community's views.

This progression is just the opposite of what typically happens in science classrooms.

2. Communicating

If students learn to communicate science effectively, they would be expected to read and write, converse in pairs or in small groups, or interact with the teacher. Sometimes a student could speak to a group or the whole class. Since communication involves comprehension, students could analyse and respond with questions, statements, actions, and feedback. Students would eventually be able to synthesise ideas and communicate with others.

As communication is a social activity, interactions occur. If education is for life and living, then effective and ambitious classrooms would expect students to carry out the activity beyond the classroom walls to where they live. For example, in a small town in Iowa, students began learning about problems with the ozone layer. As they studied, they became concerned with the impact on their own community. Several students contacted the mayor, asking, "What are you doing about the loss of ozone?" Contacting the mayor is usually considered a waste of time by many people, and few adults, much less children, ever go to this length to pursue their questions and issues. This is truly adult action, the kind that leads to knowledge, change, and a feeling of empowerment.

Encouraging interaction, communication, and conversation requires an appropriate and carefully designed classroom climate. In addition, since each goal implies overt action on the part of the student, the teacher must be prepared to encourage, support, and promote desired student initiatives and action. Teachers must recognise the difference between appropriate and inappropriate action on the part of students and themselves (Penick and Bonnstetter 1993).

3. Participation in Group Work

Science and technology students, working together in small groups (2-5 students) is common in schools and almost inevitable when students undertake any form of practical investigation. But there has been some concern that group work encourages students to agree on superficial and obvious features rather than abstract constructions (Mamalinga 1991). However, a Greek study, which requires students to solve problems through group work, showed no evidence that the range of ideas was reduced in the group context, or that the ideas were more superficial. As it happened, abstract ideas were few for both the group context or when students worked as individuals. In addition, it seemed possible to conclude that the group situation was a better learning situation, since wrong ideas seemed to be suppressed.

The manner in which group work functions, is likely to be enhanced strongly by the classroom climate. Teachers' handling of group work is perhaps one of the hardest area of science and technology teaching and it is perhaps a common sight to see groups of students left alone to cope with a worksheet, or other forms of instruction as best as they can. Worksheets cannot give students' feedback or even specific guidance should this be needed. This comes from the teacher's interaction with students as the teacher moves from group to group, or from teacher's intervention after observing groups in action from various advantage points.

The teacher's role is to provide the groups with the initial stimulus and to guide the students in their task. As part of the guidance, the teacher gains feedback from the groups, rather than 'interfering' with specific or isolated instructions (often given to the class as a whole without reference to the progress made within the groups and often without requesting the groups to temporarily stop their activity so that they can concentrate on the teacher's instructions).

Group work is applicable to experimental work in the laboratory and to such actions as: discussions of tasks, making decisions, role-playing exercises, playing games, participating in a debate and preparing for presentation of work to the whole class.

4. Gaining Other Skills

One of the greatest benefits of incorporating STL teaching approaches is the experience students gain in skills such as research, critical thinking, problem-solving, and integrating science concepts with their own experiences. With the need for an ever increasing emphases being placed on higher-level thinking skills, societal situations and issues provide excellent opportunities for students to expand their education beyond the traditional classroom offerings and meet the challenge of higher-level thinking.

In appropriate settings, students can begin to make connections between the coursework in science class and their work in other classes. In researching topics like deforestation, students are able to link their study of the biological issues present with concepts from other classes such as economics, mathematics and social studies. In addition, in effective communication and undertaking calculations or plotting graphs, students can draw upon skills learned in classes such as languages and mathematics (Kracjik 1993). Learning becomes an interdisciplinary affair.

Co-operative learning strategies are employed when students are involved with the following: field experiences, practical laboratory activities, case studies, simulations, role-playing, debates, library searches, brainstorming, panel discussions, individual or group projects, problem-solving, class discussions and presentations, displays, fairs and exhibitions, peer tutoring, designing and constructing equipment, models, and other learning aids, interviewing, audio-video recording, letter writing, surveys and decision-making. All these involve continuous planning and re-evaluation and may go on beyond the normal class time and extend outside the school hours (Yager 1993). Such strategies are crucial for the development of scientific and technological literacy.

