ICASE

PROFILES

Professional Reflection Oriented Focus on Inquiry-based Learning and Education through Science

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The PROFILES Guide book

Section B - Operationalising the Professional Development of Teachers

This section is divided into 5 stand-alone sub-sections

Section B Operationalising the Professional Development of Teachers

Sub Part 1

Identifying Teacher Support Needs for PROFILES teaching

The proposed PROFILES innovation is for partners (and later lead teachers) to support teachers and 'teacher partnerships' to implement already existing, exemplary, context-led, yet IBSE focussed, science teaching materials (i.e. PARSEL type modules –see terms).

The support identified for the teachers can be expressed as promoting teacher ability towards ownership of a research based, student relevant, IBSE inspired, science teaching approach to enhance scientific literacy (the PROFILES approach). This is planned to be implemented as a 2-step process.

1.1 Step 1 - gaining self efficacy

The first step, of the PROFILES 2-step process, is designed to develop the self-efficacy of teachers in putting into practice the PROFILES approach and seeing this enhance students' intrinsic motivation towards science learning in school at the secondary level. For this, the project focuses on developing the teacher as:

- learner (in the sense of enhancing the science background of teachers for contemporary interdisciplinary, society-related teaching on a 'need-to-have basis,' this need as identified by the teacher);
- teacher (through enhanced PCK for context–led, inquiry-based, socio-scientific issue-related teaching, based on partner perceived needs);

1.2 Step 2 - seeking teacher ownership

This builds on achievements from step 1 and attempts to consolidate teacher ownership of PROFILES. Step 2 focuses on:

- reflective practitioner (by raising the teacher ownership through encouraging strong teacher reflection and dissemination of their teaching using a variety of techniques, including action research, based on a partner perceived need);
- *leader/disseminator (through teacher networking with other teachers (teacher educators) to guide others in meeting the goal of the project, using the developed training/intervention model and web-based networking strategies, based on a partner perceived need).

Networking/dissemination

** Most of the first and second groups of teachers involved in PROFILES training are not expected to proceed to this aspect. It is not envisaged all teachers will be able, or will agree, to operate this aspect.*

1.3 Step 1: The Professional Development Longitudinal Course + Intervention

The main approach to the professional development of teachers is via a continuous programme in which face-to-face meetings are inter-dispersed with tryout out session (interventions) in the classroom. Besides face-to-face meetings, additional contacts could be initiated via online approaches and by separate teacher, sub-group meetings. At a minimum, this programme is seen as 40 hours of contact, plus a minimal expectation of 16 hours self-study and leading to a certificate expressed in terms of 56 hours (minimum) professional development.

An exemplar outlines of a longitudinal programme is given below. It is devised as 4 x 2-day course, interspersed with guided intervention (please note – other models may be more appropriate in given circumstances).

Session 1 (September)

(day 1) Why PROFILES (what is it about?); Student motivation and the constructivist teaching approach; Meaning of science education and Education through Science; Teaching using PARSEL-type modules; Modules design - module components; Competency (capability) targets; Setting the scene (familiar socio-scientific) to Scientific inquiry learning (a motivational stage 1 leading to a scientific stage 2);

(day 2) Reflection on PARSEL-type module teaching; Scientific literacy and the multidimensional level; Interrelating the 3 stage PROFILES model to design of modules i.e. introduction (scenario), student tasks (Motivation, IBSE Problem solving, Socio-scientific decision making), Teacher guide (PCK, feedback from students - assessment); Teacher notes (underlying science/support materials/support instruments). Selecting/modifying modules for use by teachers in the 1st teacher intervention.

Intervention Trying out module(s).
Recording modifications made and reasons for these.
Reflecting on attitudes (own, students); teaching/learning concerns.

Session 2 (December)

(day 1) Presentations on a module tried-out. Collective reflections by all. Networking. Addressing matters arising re-science (CK); Addressing PCK concerns (e.g. NOS, student ownership/responsibility; formative assessment; stage 1-2 interface; stage 2-3 interface).

(day 2) Reflection on student attitude – motivation ideas (relevance, interest & intrinsic motivation); Stakeholder expectations; STL; promoting general (personal/social) competencies; Selecting/Modifying of further modules; Educational theories (SDT, self-efficacy).

Intervention Trying out module(s).
Recording modifications made.
Recording student feedback.

Session 3 (March)

	(day 1)	Presentations on trying out. Collective reflections by all. Feedback on networking. Reflecting on the role of the scenario – creating scenarios. Sharing scenarios - reflecting on how to teach the scenario (stage 1).
	(day 2)	Reflecting on IBSE teaching - teaching towards open inquiry; Linking scenario to IBSE problem solving; creating stage 2 concept map.
Intervention		Trying out module(s) emphasising scenario and IBSE. Recording teaching (videotape; description with lesson plan re-stage 1/2).

Session 4 (May/June)

	(day 1)	Presentation on trying out. Collective reflections; Feedback on networking; Cultural mirror on teaching (use of video-snippets); Reflecting on stage 3 – SSI and socio-scientific decision making; teaching from stage 2 to stage 3. Formative Assessment strategies.
	(day 2)	Becoming a reflective practitioner - illustrating ownership; training others – the role of teacher as leader (dissemination and networking); Towards teacher ownership (2nd year plans).

1.4 Rationale for step 1

On page 2, step 1 was seen as important for teachers to gain self efficacy with respect to PROFILES ideas. Two professional support components are put forward related to this:

(a) *The teacher as learner.* This is geared to enhancing the science background of the teacher. Today's contemporary science no longer fits into the man-made divisions of Biology, Chemistry and Physics which have dominated science teaching in the past. Teachers of science subjects are called upon to have a wider conceptual science background.

By early identification of PARSEL type modules to be used during intervention phases of the professional development, teacher needs in those areas, where the **teachers indicate** they would wish to gain an enhanced science background, can be identified. These needs can be met in a variety of ways, one of which can be giving teachers the opportunity to attend lectures/videotape presentations, etc. by eminent scientists working in the particular area identified. Through the use of dubbing, sub-titles or straight translation, it can be possible for videotaped presentations to be shared among partners.

(b) *The teacher as teacher, which is geared to enhancing PCK as professional development.*

This focuses on promoting teaching that relates to the underlying philosophy behind the PROFILES approach on which modules are based (see part A, also page 7):

The teaching approach which PROFILES promotes is based on a previously developed (PARSEL) *3-stage model.* This is far removed from a textbook-oriented approach although the modules do not attempt to take the place of the textbook. Stage 1 is initiated by a student relevant, context-based scenario, which is designed to trigger strong student intrinsic motivation in preparing students for the next, needs-driven, stage. The major learning stage (stage 2) provides student-driven, conceptual, personal and social learning, related to inquiry-based scientific problem solving, which meet student needs. The underlying scientific concept map is based on aspects within the society, rather than viewed from a subject (i.e. textbook) focus (and hence represents a major change of teaching approach and areas of emphasis).

The third, final but essential, stage (stage 3) is consolidation of the conceptual science gains by students and also the building of key competencies through the utilisation of the science (transference to new situations) to undertake justified, socio-scientific decision making, which may include attitudinal, personal and societal (economic, environmental, social, political) reflections.

PROFILES is not a project geared to providing the curriculum, nor is it a project proposing the range of teaching methodologies expected of an effective teacher in deriving a suitable classroom climate for student learning. PROFILES, however, does recognise the importance of teacher self- and collective-reflection and hence teacher responsibility for the teaching process so as the enhance student motivation and learning. This leads to further PROFILES foci of learning – teacher ownership (1.5 below).

1.5 Rationale for Step 2: Teacher as reflective practitioner and lead teacher.

PROFILES recognises that is not enough for a teacher to carry out the intervention component of the professional development and illustrate self efficacy in so doing. PROFILES strives to go further and promote actual teacher ownership of the ideas and the manner in which they can be implemented (see section C).

PROFILES Guidebook for Partners

Section B Operationalising the Professional Development of Teachers

Sub part 2

Identifying Teacher Needs for a Professional Development Programme

To enhance the effectiveness of the professional development by each partner, PROFILES provides the opportunity to determine teacher strengths and weakness and to focus on, or emphasise, the professional support in identified areas of 'need'. This is achieved by means of an instrument related to areas of professional development relevant to PROFILES.

As the professional support is intended to be specific to each partner, no specific instrument across all partners is considered essential. This means that emphasise on aspects of teacher needs, depth of treatment within the instrument (e.g. how many items to include per questionnaire), the degree of overlap between instruments in any sub-division (if any) and how the instruments used should be interpreted, is solely under the control of each partner. However it is essential that common agreement is reached as to the purpose of the instruments and the degree to which the effectiveness of the instrument is evaluated.

Both WP2 (support for partners) and WP4 (preparations for the professional support and intervention) are developed to assist partners.

2.1 What constitutes the Instrument identifying teacher needs?

The 'instrument is intended to determine the professional support and guidance needs of the teachers embarking on the PROFILES continuous professional development and intervention programme. Aspects to consider are indicated below.

2.2 Areas of development

A list of professional development areas is identified within which are key terms (see the list of key terms). Against each key term is a list of keywords or key expressions associated with that area. These form the focus of the professional support for the teachers. The length, style and emphasis in the training is dependent on the strength of teacher's conceptualisation of the key terms and visualisation of ways of conceptualisation in making use of these PROFILES indicative areas in the classroom.

Outcomes from utilising the instrument are thus extremely important as they are intended to ensure that the professional development of the teachers meets identified needs of the teachers and is thus 'tailor made' for the group of teachers undergoing the professional support at any one time. The instrument sets up the PROFILES professional development of teachers as unique, with the hope that the support achieves a high level of effectiveness (an aspects to be carefully evaluated in PROFILES (WP5)

2.3 The PROFILES teacher expectations

PROFILES sets out to raise the self efficacy of implementation of PROFILES ideas and also the teacher ownership of the PROFILES philosophy in classroom IBSE teaching. The professional support areas have been identified in the PROFILES description of work associated with the teacher as (a) learner, (b) teacher, (c) reflective practitioner, and (d) leader and disseminator. These terms have been amplified in this guidebook.

As indicated, the *teacher as learner* concept is intended to relate to raising background contemporary science, noting the teaching modules associated with PROFILES are of an interdisciplinary nature. It is suggested that teacher wishes in this area are best identified by the teachers themselves and for the most part can be driven by early selection by teachers of modules they would wish to use during the intervention components of the longitudinal professional development. Assuming choice of modules for individual teachers to use is permitted, early identification of the modules will be important (particularly so if translation is required). Further explanation of the type of modules envisaged with PROFILES is given later in the booklet.

The professional development for teachers in this area is likely to be via lectures, or videos by eminent scientists and the topics chosen by the partner interacting with the selected teachers involved in the PROFILES professional development component. As such, this is a direct interaction between the partner and the teachers and no further instrument in this area is envisaged.

The potential professional support areas are thus identified as:

1. PCK - raising the PCK of teachers for PROFILES teaching to meet teacher's self efficacy needs.
2. Reflection - supporting teachers to self-evaluate their own teaching by means of reflective practices as well as determine the student's gains associated with their PROFILES teaching orientation (preparing for step 2).
3. Leadership - playing a leadership role in guiding, supporting and disseminating to, other teacher in the PROFILES way through training courses, seminars, conference presentations, publications and networking (an aspect of step 2).

2.4 Developing the Instrument

The Instrument is envisaged to cover 3 PROFILES areas, identified as relevant for teachers embarking on teaching the PROFILES way. These are the teacher as (2) teacher, (3) reflective practitioner and (4) leader/disseminator. The focus of each of these areas is seen as:

- Developing PCK ?
- Acting as a Reflective practitioner.
- PROFILES leader and disseminator.

Area 2 Developing PCK

Aspects covered include – undertaking IBSE; Context-based learning (CBL); Education through science; Teaching using the 3-stage model; Using constructivism & motivation (interest/relevance); Promoting STL, Student problem solving; SSI decision making, argumentation; Student societal functioning (interactions, guiding others, creating. deciding, solving issues/problems); Student's learning to learn (to be, to do, to know, to interact); Assessment practices.

Area 3 Reflective Practitioner
Aspects covered can include – creating challenges (within the ZPD); utilising formative assessment operations; building portfolios, creating self-teaching videotapes, carrying out action research activities, identifying student gains (not only as knowledge, skills, attitudes, values, but importantly the utilisation of these in new, unknown situations).

Area 4 Acting as leader/disseminator
Making others aware – developing/undertaking effective & persuasive professional development with other teachers; developing networking & discussion groups, giving presentations (seminars, workshops, conferences), supporting pre-service training; creating reflective videotapes, developing exemplary materials, creating feedback instruments, undertaking action research case studies, writing (theory to practice; exemplary practice) articles.

2.5 Detailing the potential Professional Support Areas

A. PCK
This is the major component of the professional development as it gets to the very heart of PROFILES. It is expected to occupy the major thrust of the professional development and it is these ideas which the teachers put into practice during the interventions (where these occur between training sessions). PROFILES teaching goes beyond simple IBSE definitions, or even teaching suggestions. PROFILES puts the IBSE teaching into a philosophical framework which builds on the PARSEL acceptance of the importance of popularity (interest) and relevance in the teaching of science (and hence intrinsic motivation) and that the purpose of teaching science is expressed in terms of enhancing scientific literacy.

Components of PCK which are seen as particularly relating to PROFILES are:

A. Meaning of the Nature of Science in the classroom setting.
B. The Nature of Science Education (Education through Science/STL-multi-dimensional level).
C. IBSE (inquiry-based science education) in its various orientations and going beyond the learning of process skills.
D. Using/modifying PARSEL type teaching modules, the diversity of learning outcomes and operationalising the 3 stage model.
E. Assessment strategies (especially formative assessment).
F. Theoretical ideas associated with PROFILES teaching (social constructivism, motivation).

And

Constructivism as opposed to Behaviourism.
Social constructivism in association with a Vygotskian zone of proximal development and the teacher as facilitator.
Motivation based on self-determination theory (with a focus on intrinsic motivation – Deci and Ryan).
Activity Theory in interrelating, need, motive and action (inter-relating the system)
Maslow's self-actualisation need (stressing the self actualisation and associated self determination targets to enhance the pace of meaningful learning).
Enhanced teacher beliefs, based on ideas related to the work of Ajzen (the key to success).
Bandura's self-efficacy (towards the 'happy' teacher).

A Professional Support Instrument identifying Teacher 'Needs', geared to the development of Teacher Self Efficacy in utilising PROFILES teaching modules is given below

Dear colleague!

We need your help to organise a suitable continuous professional development (CPD) programme. In order to organise the programme in the best possible way we need to know:

1) your confidence in certain skills;
2) your needs and expectations for the topics dealt with in the programme.

For that reason we ask you to fill in both columns (confidence and emphasis for the professional development programme) for the 50 item questionnaire by putting an 'x' in the appropriate columns.

			Confidence					**Emphasis for CPD**			
			V-very well	W-well	S-satisfactorily	D-do not know		1-definitely not	2-rather not	3- necessary	4- very necessary
	Nature of Science										
1.	Explain to students that science cannot provide complete answers to all questions.										
2.	Explain to students the gap between school science and actual scientific research.										
3.	Explain to students the difference between science and pseudo-science.										
4.	Explain to students how scientists work.										
5.	Explain to students the difference between models and real processes.										
6.	Ensure students can distinguish between a law and a theory.										
	Scientific and Technological Literacy STL										
7.	Give a useful interpretation to the expression "scientific and technological literacy".										
8.	I use a social orientation (dimension) to problems (situations) in science teaching.										
9.	Guide students to use the acquired knowledge and skills in new situations (contexts).										
10.	Guide students to think creatively and justify the socio-scientific problems (issues).										
11.	Promote students thinking as well as practical and predictive skills.										
	Goals of Education/Science Education										
12.	Realize the general objectives of education within subject (science) teaching.										
13.	Specify the competencies that are suited to science teaching, based on the context of science.										

			V-very well	W-well	S-satisfactorily	D-do not know		1-definitely not	2-rather not	3- necessary	4- very necessary
14.	Understand the purpose of PARSEL-type materials.										
15.	Specify the learning outcomes in each class, so as to foster development of students' knowledge, skills, attitudes and values.										
	Inquiry-based Science Education										
16.	Distinguish between “structured“, “guided“ and “open inquiry“.										
17.	Guide students to put forward scientific questions and hypothesis for investigation.										
18.	Guide students to plan an experiment.										
19.	Guide student to undertake investigation using pencil and paper.										
	Classroom Learning Environment										
20.	Implement student-centred teaching in the classroom.										
21.	Consider students’ prior knowledge, attitudes and skills.										
22.	Consider students’ wishes and proposals for lesson planning (interact with student ideas).										
23.	Promote students’ communication skills in a variety of ways, both orally and in written formats.										
24.	Guide students to ask questions and discuss the social dimension of scientific problems.										
25.	Promote higher order thinking amongst students (analysis, synthesis and evaluation).										
26.	Promote effective peer-peer learning through student group work.										
27.	Involve students in learning through group work of various types (experimental, discussions, role playing, debates).										
28.	Promote students creative thinking.										
29.	Promote students argumentation skills for socio-scientific decision-making.										
	Student Motivation										
30.	Create motivational challenges for students within their capabilities.										
31.	Guide students to value their science learning as useful for life, lifelong learning and for their career choice.										
32.	Use media texts and video clips.										

			V-very well	W-well	S-satisfactorily	D-do not know		1-definitely not	2-rather not	3- necessary	4- very necessary
33.	Use (extract, draw, use) interesting and suitable examples of the history of science.										
34.	Encourage self-motivation by students in science lessons.										
35.	Determine relevant topics, in the eyes of students.										
	Assessment										
36.	Use a variety of assessment strategies that are designed to measure competencies.										
37.	Undertake a range of formative assessment strategies with one's own students.										
38.	Provide suitable positive feedback to both the "more able" and the "weaker" students.										
39.	Assess students' knowledge and skills according to their portfolios.										
40.	Counting different levels of thinking (different types of questions) in test preparation.										
	Education theories										
41.	Promote student learning which focuses on storage in students' long term memory rather than short term.										
42.	Give meaning to ZPD (zone of proximal development).										
43.	Aware of SDT (self determination theory) to motivate students.										
44.	Distinguish between intrinsic and extrinsic motivation of students.										
45.	Motivate student by valuing learned (material).										
46.	Teach in a constructivist manner so that students are guided to construct meaning of knowledge.										
	Self reflection										
47.	Create self-reflective teaching videotapes.										
48.	Carry out action research to raise effectiveness for my teaching.										
49.	Modify science teaching modules to raise effectiveness for student learning.										
50.	Appreciate the meaning of self-efficacy (being both confident and competent).										

Section B Operationalising the Professional Development of Teachers

Sub part 3

Other Professional Development Components.

Some aspects of the intended professional development of teachers are very specific to PROFILES. These components are proposed as part of the professional development of teachers irrespective of the outcomes of the instrument needs questionnaire

3.1 A 3-Stage Model for Social, Competency-based, Open Inquiry, Science Education

A change of approach

While a general rationale for the teaching of science subjects is that we live in a scientific and technological world, curricula tend to see the link between the science teaching and the outside world as one of applications of scientific principles. The approach is along the lines - teach the conceptual science first and then consider its applications second.

However there are very few cases where the science as situated in the society has been used as a platform for the teaching of conceptual science. This is put forward as a major oversight. The thinking goes like this – if addressing social issues is a way forward to making the teaching of science more attractive, but the conceptual science is taught first, why would students feel this is much different to the concept first, applications second, approach?

The approach is based on Activity Theory which has its roots in the Vygotskian ideas on the zone of proximal development, plus Marzano's ideas on a three component mental system.

Ideas behind the 3 stage model

This model sees the frame of reference to one familiar to the student. Science conceptualisation are not put at the forefront, but it is recognised that for most students science in society is the key focus. The society for them is thus a more appropriate starting point. However, the need (activity theory) is still proposed as relevant to the students within society. Narrowing this down, this can be seen, for science lessons, as a socio-scientific relevant topic with need associated with self actualisation (Mazlow's triangle).

Such a need suggests an issue of concern that affects the individual and, bearing in mind the need of the teacher to teach the students within a class, the issue or concern requires sufficient appeal to a significant number, if not the majority, of the class. The relevant need becomes the issue and the motive for its consideration is to find a way to decide how to tackle the issue or concern. Making the decision becomes an activity within activity theory.

Meeting a relevant need (relevant to the student) is seen as intrinsic motivation (Deci and Ryan, 1996) and is proposed as a more powerful teaching approach than attempts to rely on extrinsic motivation approaches as usually adopted by the teacher (the motivating lesson plan, reflective use of PCK, etc).

But providing a motivational start is obviously not enough. Cognition or meta-cognition are expected to be important components of learning and hence need to occupy the majority of learning time. This follows once the issue or concern has been identified, as students become involved in seeking activities that can play a role in deciding on the issue or concern and students are suitably guided to operate within their ZPD to seek scientific conceptualisation needs and ways to determine this. Acquiring the science needs are associated with solving the scientific component.

The model is this conceived as

Science learning stemming, as a learning area of need, from a motivational, contextualised situation STAGE 1	→	De-contextualisation The conceptual science learned on a need-to-know basis in a science environment STAGE 2	→	Re-contextualisation The science ideas are consolidated and applied to the contextualised socio-scientific situation STAGE 3

3.2 Stage 1: Recognising the area of learning and the associated scientific learning needs

Introduction
Stage 1 is driven by 'student needs' which here is called 'relevance.' An alternative way of looking at this is to relate to students' *intrinsic motivation*. The teaching starts from learning more about aspects, concerns, issues (or whatever) which students identify as relevant for them.

For younger students, this relevant learning may be heavily driven by interest (if it is interesting, it is also relevant). The 'feel good' factor (that is, I like) is the major driving force. The concern, issue etc can be scientific (especially how things work) and the learning is approached in a very 'concrete' (see-able or touchable and not developed in the abstract or by models) manner. This relevant learning is fairly easy to achieve, but it is important not to assume that motivation gained at this level is automatically transferred to learning when conceptual science becomes more abstract at higher levels of learning (junior sec? but definitely senior sec), or its purpose is much less apparent with respect to everyday life.

For older students, the relevance of the learning becomes a big issue. From adolescence, the focus of the students' lives is less around the school as the social centre and more about their functioning in society. The society plays a special role in the learning and especially the acquiring of values. Where school learning reinforces society learning, the relevance is more strongly appreciated and this applies to science learning in school in particular, because of its early emphasis on abstract ideas (theories and laws).

Stage 1 is thus seeking its relevance from aspects, concern, issues within the society which can be related to conceptual science ideas. It is the complete reversal of the traditional teaching approach of science ideas first, application second. It is contextual within the society. It is thus a clear example of context-based learning (CBL). It is contextualised learning and can be initiated by means of a scenario (a situation originating from with the society or simulating the society).

3.3 Teaching stage 1

The teaching within stage 1 is driven by:

- Establishing the relevance of the aspect, issue, concern.
- Determining the scientific competencies missing which are needed for meaningful problem solving and debate/decision making on the relevant area of concern.

The teaching approach therefore needs to focus on:

1. How to identify relevance at least for a sufficiently number of students within the class.
2. Determining students' views on the aspect of relevance in a manner which has educational value.
3. Establishing in the minds of students that by gaining a stronger (conceptual) background they would be better places to appreciate the decisions needed related to the aspect of relevance.
4. Identifying the way forward – that is, the science knowledge and skills needed in order to begin to develop the competencies for the ultimate decision making.

This means teaching starts from the society and the society interests and then leads to the conceptual learning. A concept map, restricted to conceptual learning, is thus incomplete for STL teaching. These needs to be replaced by a societal driven issues/concerns map (a consequence map). In this, the issues/concerns 'drive' the concepts and this in turn leads to solving a problem or making societal decisions relevant to the aspect of interest. The latter is a further component of the consequence map. The consequence map described here differs from others mentioned in the literature (e.g. Fullick and Ratcliffe, 1996) in that it flows from top to bottom rather than radiating from a central point. It thus differs also from futures wheels (Piel, 1993) in the same way. Just as a concept map arranges the more general concepts at the top and those more specific below, so the consequence map begins with the general issue or concern under consideration. It then flows like a concept map, illustrating the science learning needed to gain sufficient understanding so that the issue or concern can be addressed adequately. At the bottom of the consequence map, is the problem solving or decision making process to arrive at a 'solution' to the issue or concern.

This approach to teaching also means that the sequence is no longer 'science driven' i.e. the sequencing is not necessarily that seen as logical by scientists. Rather the teaching progresses from issue or concern to further issues and tackles the science from the society level of complexity at which it is met in society, breaking it down to the needed level of conceptual complexity for comprehension. And of course this is approached from the macroscopic to the microscopic.

3.4 Teaching Stage 2

Stage 2 is driven by the need to 'know' the science which provides a scientific bearing on the social aspect, concern, issue under consideration. It is no longer CBL, but inquiry-based science education (IBSE). Stage 2 focuses on the scientific ideas and breaks these down into conceptualisations, which take note of the students' prior learning and the constructs (misconceptions) they currently hold and which, with appropriate scaffolding by the teacher, are acquirable. This stage is, by necessity, decontextualised from the society and builds from a scientific perspective (recognising nevertheless the importance of generic skills e.g. cooperation, communication, positive values such as those towards learning, self- and social- development, in aiding the learning process). In stage 2 the intrinsic motivation of the students is heavily reinforced by extrinsic motivation from the teacher and other attributes recognised by the teacher as adding to the motivational aspect.

The teaching within stage 2 is driven by:

- Structuring the scientific learning so as to support the ultimate societal decision making process
- Providing the needed scientific knowledge so as to give a background for the students' subsequent conceptual acquisition process related to the decision making;
- Providing the needed scientific skills (process skills) or additional practice in such skills which provide a platform towards developing a competency of 'scientific problem solving,'

The teaching approach within stage 2 this focuses on:

A. Scientific inquiry. Within scientific inquiry, the major frame is that scientific question is asked and then ways are put forward to answer the scientific question. The role played by the students in this process is crucial. The table below illustrates (in a very simple categorisation) the various involvement of students . This is usually associated with a hierarchy in which young student (primary level i..e. lower than grade 6) are seen as mainly involved in the confirmatory level; the structured level is the major approach as soon as students can handle analytical development (expected grade 6 upwards), guided as soon as possible to involve students in the wider process skills learning (grade 6 upwards) and ultimately, the major target, open inquiry where student tackle the problem solving process in its entirety – expected by at least grade 9 but earlier with more able students).

The following table is adapted from one on: http://edweb.sdsu.edu/wip/four_levels.htm

Level of Inquiry	**Problem is student-generated**?	**Procedure student-designed/selected**?	**Solution is not already existing/known**?
1. Confirmation	-	-	-
2. Structured Inquiry	Either ✓	-	Or ✓
3. Guided Inquiry	Either ✓	Or ✓	✓
4. Open Inquiry	✓	✓	✓

Explanation

1. Confirmation – The scientific question is put forward by the teacher while the students answer this using a prescribed procedure when the results are known in advance to the teacher, but not necessarily the students. The students gain little apart from the procedural skills and the recording of the specific outcomes. This is the standard recipe-type experimental procedure, or the verification approach adopted in testing the validity of a scientific law.

2. Structured Inquiry – Students investigate largely through a prescribed procedure and EITHER there is a teacher-presented scientific question (usually open-ended) where the answer is not known in advance and could vary from student to student, OR there is a student-generated question where the results are known in advance to the teacher, but not to the students.

3. Guided Inquiry - The solution is not already existing/known in advance and could vary from student to student. Students EITHER investigate a teacher-presented question (usually open-ended) using student designed/selected procedures, OR investigate questions that are student formulated (usually open-ended) through a prescribed procedure (although some parts of the procedure may be student designed/selected).

4. Open Inquiry - students investigate questions that are student formulated (usually open-ended) through student designed/selected procedures. The solution is not known in advance and could vary from student to student. Ownership of all aspects of the inquiry belongs to the student.

Adapted from: Herron, M.D. (1971). The nature of scientific enquiry. School Review, 79(2),171- 212.

B. Scientific Knowledge. Building up the background scientific knowledge (and concepts, mathematical, graphical, modelling procedures) relevant to the situation (this is sometimes called the ‘basic’ or ‘fundamental’ science which is the current established ideas as acquired by scientific endeavours throughout history.

C. Scientific Process Skills. Developing a range of scientific process skills so that transference can take place in applying those appropriate for scientific problem solving in new situations.

3.5 Teaching Stage 3

Stage 3 is an essential component of the 3-stage model. Stage 3 is context-based learning, derived from inquiry-based science education. Its aim is to promote competencies so as to enable students to have the ability, or potential ability to solve problems and make decisions, the latter being in a socio-scientific sense. The learning is re-contextualised and is thus back into a social setting and its relevance is thus a key factor again. It leads to socio-scientific decision making.

The teaching within stage 3 is driven by:

- consolidating the scientific learning in terms of the knowledge and process skills gain and the ability of transference to other situations. (the contextual issues that is being addressed)
- developing the generic skills (argumentation, debate, role playing), enabling the value of the science learning to be included into the relevant aspect, concern issues coming from society.
- deriving a justified (well reasoned), collective decision which illustrates the value of enhancing the scientific literacy for all, the value of scientific careers and the role scientists play in society

The teaching approach therefore needs to focus on:

1. reflection and student consolidation of the learning in stage 2 (reinforcement of conceptual ideas).
2. enabling students’ to express their views on the relevance in a manner which encompasses the scientific component.
3. establishing in the minds of students the value of the scientific component when making specific decisions affecting the society or the individual.
4. Involving students in collaborative efforts to put forward points of view through argumentation (debating, role playing, groups discussions) in which impacting components (such as ethical, economic, social, political, environmental and of course scientific) are considered together.
5. deriving justified and hence well-reasoned decisions, expressed both orally and in written (including posters, models, newspaper) formats.

3.6 General pattern when teaching using the 3-stage model

While the absolute pattern will depend on the situation and prior background of students, the emphasis expected is such that the 3-stage model is illustrated through modules (e.g. PARSEL modules).

Within a module

- Stage 1 approximates to 1 lesson (for setting the scene, but engaging the students in determining stage 2 learning needs could make this longer).
- Stage 2 is at a very minimum 2 lessons (but could be up to 10 lessons)
- Stage 3 approximates to 1 lesson (but involvement in written components could make this longer)

a) How can Modules be utilised to develop a course of 35-40 lessons ?

The focus of science teaching in the 3 stage model moves away from acquiring knowledge and skills and places emphasis on the development of competencies. These competencies are defined as the ***capability to utilise*** the knowledge skills and values gained so as to transfer the learning to new situations in an open inquiry approach.

The modules, by targeting the involvement of the learning on specific aspects/issues, lead (as a final direction) to decision making situations undertaken by the student themselves. The ultimate goal of the course is thus to apply knowledge to new situations/issues. For this, open inquiry learning (IBSE) is now extended to relate to all stages of the 3 stage model, from the recognition of the issue to the justified socio-scientific decisions making. This is possible because of the new approach, here called Social Competency-driven, Inquiry Based Science Education (SC-IBSE).

By extending stage 2, assuming intrinsic motivation is maintained, it is possible to provide a wider science conceptual platform. In the way, curriculum expectations are met, although emphasis is always on student self-determination, in terms of personal and social development on the one hand and IBSE, problem solving activities and transference of socio-scientific decision making on the other.

3.7 How to Select a Module?

The procedure in selecting a module

1. Identify a module in the appropriate subject area of interest
2. Identify the teaching level for the module (whether module can be modified to suit)
3. Check the scientific learning is in line with the expected teaching

If the above three conditions are met, then the next requirement is to examine the module with a view to making modifications to suit the teaching situation.

a) *Meeting needs* – Does the teacher have the necessary attributes to teach the module (modules) selected ?
The in-service professional development programme addresses these needs in terms of teacher as learning; teacher as teacher; teacher as reflective practitioner; teacher as leader (networker/disseminator)

b) *Undertaking intervention*
Undertaking the intervention is basically trying out the module during normal teaching with a view to raising teacher self-efficacy in enhancing students' scientific literacy as determined in PROFILES.

c) *Comparing stakeholder reactions to teaching approaches*
d) *Meeting self efficacy needs*
Determining self efficacy

3.8 Assessment Practices

Assessment practices need to relate to the intended learning. These can encompass diagnostic assessment to guide the teacher, as well as attainment by the students in the various STL domains. Inevitably this means much of the assessment is school-based and largely formative in nature.

Formative assessment can occur within all stages of the development of the teaching material and be used to determine student achievement of all objectives, or learning outcomes. For example, in awarding a social value "score" (based on the specific learning outcome specified) the teacher may listen to the discussions of the various groups and then award a "score" grade* as follows:

x Has not made a meaningful contribution to the decision-making discussions. Does not make a choice other than that based on economic grounds i.e. cheapest.

√ Participates in the discussion and recognises that a choice can be made on scientific as well as economic grounds. Considers other factors e.g. environmental or social, only when given guidance by the teacher.

√√ Plays a significant role in the discussions and reflect on many viewpoints from which a discussion could be made. Selects an appropriate choice based on social as well as environmental, economic and scientific grounds. Appreciates disparity that may occur between the best choice and actual practice within society.

* A 3-point scheme as above is put forward as easy for the teacher to operate quickly. However other schemes (eg 1-5 or A-D can also be utilised based on the teacher's preference).

In this 3 point example, "x" indicates the objective, or learning outcome, is not achieved by the student and more learning is required. The "√" indicates the objective or learning outcome is achieved and the student has attained the level of learning required for this component. The "√√" "score" is reserved for students achieving beyond the level intended and can be considered an important target for the more able students. By accumulating objective, or learning outcome "scores", a meaningful guide to the student's learning in this area is obtained.

Besides social value awards, similar procedures can be used to cover the learning of science process skill learning, personal skills and science conceptual understanding. The "scores" on the various specified learning objectives can be compiled to gain a picture of the achievement within each of the skill areas.

Besides a formative assessment strategies, as above, summative assessment procedures can also be followed. Here the marking of workbooks over time, or tests/examination outcomes are likely to form the measures, but once again the assessment needs to relate to the different STL learning areas.

Section B Operationalising the Professional Development of Teachers

Sub Part 4

Undertaking the Intervention phase(s)

In this phase, the teacher is expected to try our PROFILES ideas in the classroom and to report back on successes and issues. Specific tasks are given to the teachers to undertake after each professional development component. If following the draft programme given earlier, the intervention after each session is expected to be –

Session 1 try out a selected module; indicate changes made (if any) and the reason for this; check, informally, student reactions to the module in terms of interest/relevance, science learning.

Session 2 trying out additional module(s); record modifications made; record student feedback; prepare for collective reflection.

Session 3 continue trying out module(s) record teaching (observation, videotape); develop description of lesson with lesson plan re- stage 1/2), prepare for collective reflective.

Session 4 prepare for becoming a reflective practitioner.

The intervention phases it the teaching undertaken in the teacher's own classroom during the longitudinal teaching programme. It may also apply to the teaching undertaken after a pre-service course, a PROFILES seminar for teachers, conference workshop, etc.

The intervention is an opportunity for teachers to try out the PROFILES ideas and, with support, move towards achieving self efficacy in PROFILES ideas and ways of teaching. The following self efficacy components are seen as important for teachers:

4.1 Identifying/modifying suitable modules

To ensure that teachers are in a position to try out modules in their teaching as part of the intervention, it is proposed that teachers are given the opportunity to choose suitable modules well in advance. This is expected to facilitate

(a) Adequacy of time needed for adaptations/translations, etc. that may need to be carried out before the teacher is able to use the module.
(b) Professional development programme preparation by the partner.
(c) Preparation of additional resources.

It is proposed that this process can begin once teachers have been identified as appropriate to be included in the PROFILES professional develop programme by a particular partner.

PROFILES refers to the use of PARSEL-type modules for the professional development and intervention programme. PARSEL modules have been developed based on specific criteria which can be specified as:

THE NEEDS TO BE ADDRESSED
SECTION I MODULE INCLUDES LEARNING OBJECTIVES/COMPETENCIES
A. Material is geared to promoting learning for responsible citizenry (STL/Education through Science) as indicated by stating specific learning objectives/competencies for:
1 *a spectrum of intended student educational gains (above and beyond acquisition of science concepts).*
2. *personal educational developmental skills (for example, attitudes and/or personal aptitude gains in aspects such as safe working, tolerance towards views of others).*
3. *social skills, for example, cooperative, collaborative and/or leadership learning skills.*
4. *nature of science and/or involve developing a sequence of process skills related to problem solving.*
5 *socio-scientific decision making in a real life situation.*
SECTION 2 MODULE ADDRESSES THE NEED FOR RELEVANCE AND POPULARITY FOR STUDENTS
B. **Module is designed to be seen by teachers of science subjects as popular and relevant for students, as indicated by:**
1. *conveys a perceived sense of purpose,, which is related to the overall real life direction of the module.*
2. *learning objectives/competencies indicated in the module are sufficiently comprehensive to meet the 'education through science' intentions.*
3. *adopting an approach, or approaches, which is/are perceived by teachers as being suitable for teaching towards the intended purpose of learning.*
4. *intending to **aid the teacher** in creating a classroom climate. This teacher climate is expected to include aspects, such as, enhancing student curiosity, rewarding creativity, encouraging a spirit of healthy questioning, discussion and reasoning by students.*
5. *the sequence of student activities are suggested in a logical manner from the perspectives, for example, of:* • *the student;* • *moving from real life experiences to gaining educational (especially conceptual) competencies;* • *making decisions on real life situations.*
6. *introduces terms, concepts and procedures on a reasonable 'need to know basis' only, so as to assist students in meeting the learning objectives/competencies without overload.*
7. *teacher notes are included where there is a perceived need to help teachers to, for example,:* • *realise how the science concepts relate to real life situations, and/or* • *undertake student activities in a relevant manner.*

SECTION 3 MODULE TITLE/LAYOUT HAS A SOCIAL ORIENTATION
C Title/focus of the module has a society orientation using words/situations/graphics familiar to students as indicated by:
1. omitting, from the title, conceptual science terminology to be acquired through studying the module (which is unfamiliar and perhaps daunting to the students).
2. illustrating a real life situation as the starting point and amplifying this by a scenario and/or questions.
SECTION 4 MODULE ENHANCING STUDENT OWNERSHIP THROUGH PARTICIPATION
D Student ownership through participation is anticipated to be high as indicated by:
1. including questions and/or tasks for students which, for example, • *directly relate to the learning objectives/competencies to be achieved;* • *provide guidance to the student and teacher on student progress.*
2. providing guidance to explicitly address students thinking relevant to the learning objectives/competencies.
3. being perceived that students will appreciate the module as including relevant and sufficient learning experiences.
4. allowing adequate opportunities for students to, for example : • *put forward ideas related to their learning;* • *cooperate as a member of a team;* • *communicate their learning in interesting ways.*
5. not in conflict with a teacher's classroom climate in which the teacher is encouraging, for example: • *high expectations from* ***all*** *students.* • *enabling* ***all*** *students to experience success;* • *providing all students with a feeling of being involved in popular and relevant learning.*
SECTION 5 MODULE GUIDES TEACHER OWNERSHIP
E. Potential for teacher ownership of the teaching based on the module is high as indicated by:
1. the teaching guide suggested is sufficiently detailed to guide teachers to modify the approach, as per their situation, without heavy time demands.
2. the assessment strategies suggested are sufficiently detailed to guide teachers towards formative and, if appropriate, summative assessment, but allowing adequate teacher opportunities to make modifications.

3. *teacher notes are included, where there is a perceived need, which help teachers, for example, in realising the science concepts related to real life situations and in being confident in making modifications.*
SECTION 6 MODULE EMPHASISES HIGHER ORDER COGNITIVE LEARNING BY STUDENTS
F Intended scientific learning by student emphasises higher order cognitive learning as indicated by:
1. *providing an appropriate balance of firsthand and other experiences (stemming from the real life phenomena being addressed), which are explicitly linked to higher order conceptual science learning competencies.*
2. *includes higher order learning within the problem solving and/or decision making learning.*
SECTION 7 STUDENT APPRECIATION OF THE NATURE OF SCIENCE INCLUDED
G Nature of Science is stressed as tentative, empirical, culturally embedded, theories seen as independent of laws, as indicated by:
1. *suggesting ways for students to recognise/overcome the limitations of science when gathering empirical evidence, putting forward explanations, problem solving and/or concluding/ decision making.*
2. *avoiding dogmatism, or a culturally independent 'right answers' and/or 'right method' approaches.*
SECTION 8 MODULE INCLUDES STUDENT FIRST-HAND EXPERIMENTATION/ MODELLING
H Experimentation/modelling is included so as to ensure gains in cognitive and process skill are high as indicated by:
1. *inclusion of enquiry learning, constructivist approaches and/or experimental problem solving.*
2. *paying adequate attention to availability of materials or potential alternatives, including student made equipment.*
SECTION 9 MODULE INCLUDES SUGGESTED FORMATIVE STUDENT ASSESSMENT STRATEGIES WHICH RELATE TO THE INTENDED LEARNING
I. **Suggested formative assessment approaches are given in the module, which relate to the student learning outcomes/competencies and involve the teacher in observation, oral questioning, and/or marking of written work, as indicated by**:

1.	*including effective formative assessment suggestions (questions and/or tasks) which enable the teacher to specifically ascertain student progress towards acquisition of each learning outcome as part of teaching..*
2.	*student assessment having a direct relationship with the learning objectives/competencies put forward.*
3.	*including adequate ways for students to check and reflect on their own progress in trying to acquire the learning objectives/competencies.*
4.	*where included, summative assessment suggestions are deemed relevant for the learning situation.*

Although PROFILES specifically mentions PARSEL modules, other modules can be used in the professional teacher development and intervention. However, these materials/modules should relate to the criteria as specified above and also promote the 3 stage teaching approach.

4.2 Instructional context based, motivational, social constructivist, student self actualization, teaching strategies *(see section A part 4 for a more detailed discussion)*

Where teachers are not familiar with any of these terms, they need to be part of the professional development programme. PARSEL type materials are context-based in that the teaching is initiated from the context of the society. Textbooks are not, by and large, context-based as their approach is derived from the conceptual science (unfortunately this is likely to be the case even if the textbook mentions applications of the science as an initial 'interest' approach).

Motivation is a key aspect for PROFILES and teachers need to be familiar with both intrinsic and extrinsic forms of motivation, how they can be stimulated and the advantages of engaging with motivation during the teaching.

Social constructivism is the preferred teaching in which student-student collaboration, as well as teacher-student guidance, is seen as essential. Further details are given in the theoretical section. Student self actualisation is geared to the meeting the highest need in line with Maslow's hierarchy of needs.

And of course the teaching strategies are expected to be in line with the above aspects and thus involve student in thinking, creating, suggesting rather than the teacher instructing, dictating and stipulating note-taking by copying for the blackboard or other teaching aids. Student self determination needs to be appreciated and encouraged, even if it is slow in the initial teaching process.

4.3 Instructional Strategies utilising a Scenario

The term 'scenario' is used to indicate the manner in which the students first meet the ideas associated with the teaching module. The scenario can be any stimulus which relates to the title of the module and which provides students with an introduction to the problem, issue, concern and on which, later, students will be called upon to make a decision. Thus the scenario can be a real, or an imaginary story, which triggers the intrinsic motivate of students. But equally it could be a video, set of powerpoint slides, a puzzle/game, or an activity such as making popcorn.

Whatever the manner in which the scenario is presented, the students' role is to show interest, to become involved and reflect on the problem, issue or concern. Students, in trying to resolve the situation being portrayed, need to recognise that

(a) there is a science component which needs to be considered, and
(b) their understanding of the science component is lacking.

Thus the scenario both draws attention to the need to learn science so at to deal with the issue, problem or concern, but also that the teacher needs to be aware of any partial knowledge the students hold, so as to ascertain the appropriate starting point.

Typically it might be expected that stage 1, involving the scenario, takes place in one lesson, but the depth of discussions and the manner in which the teacher solicits feedback from the students on their prior knowledge may involve less, or substantially more, teaching time.

Stage 1 ends when (a) the students recognise the aspects of science they need to learn more about and (b) they can put forward the scientific question (or questions) to which this relates.

4.4 Instructional Strategies through IBSE

Stage 2 is learning the science recognised as missing from stage 1. The sciences to be explored can be expressed by means of a concept map in which case the diversity of coverage of the concept map will depend on the depth of teaching required, the motivation of the students and the teaching time available.

Typically stage 2 involves students in an investigation in which they find a solution to a scientific problem (or problems). The investigation can be thought of in terms of a number of components, not all of which might be applicable in a given situation. For such an investigation, the teaching goal is that students can undertake this unaided. Initially, when students are confronted with an investigation, this will not be possible and teacher guidance and direction will be required. However, with familiarity with inquiry-based learning, the students are able to handle an increasing number of components until finally the students, probably as a group, can undertake the whole investigation as a project with zero, or extremely little, teacher involvement.

The components involved cover:

(a) Specifying the problem (without this the investigation cannot proceed)
(c) Expressing the problem as a scientific investigation
(d) Putting forward a plan for solving the problem which may mean gathering evidence from direct experimentation and/or secondary sources
(e) Making a prediction (or hypothesis)
(f) Indicating the materials required, quantities or concentrations to use, or equipment that needs to be constructed
(g) Determining whether any variables need to be controlled and if so, in what way (eg in determining factors affecting the growth of a plant only one factor needs to be varied at a time)
(h) Undertaking the data gathering aspect which includes determining the number of readings to make, the number of repetitions of the experiment needed, or the degree of accuracy required in making the measurements.

(i) This is follows by recording the data in a suitable manner, using appropriate notations and this in turn leads to interpretation of the findings so as to determine whether the prediction (hypothesis) was appropriate and whether the problem has been solved.
(j) Presentation of the inquiry and the outcomes is the next requirement and this involves the choice of presentation method and approach.
(k) The investigation ends with a conclusion indicating whether the problem has been solved.

If the investigation is 'open inquiry', the students can be expected to undertake all stages by themselves. This is not likely in the lower grades. As mentioned in section B, page 13, it is possible to consider levels of inquiry in which the student involvement in putting forward the way to solve the problem varies.

At primary grades, students may undertake confirmatory inquiry in which al aspects are provided by the teacher. This involves little inquiry learning by the student and the effort goes into the carrying out of the investigation and perhaps sin how to work together with other members of the group.

Structured inquiry involves the teacher providing the science question to answer and the method by which the investigation can be carried out. Students for their part interpret the findings and determine the appropriate conclusion. This involves greater student involvement that the confirmatory type, but the student involvement is still small.

A better type of inquiry teaching is guided inquiry in which the teacher guides the students, but tries to provide as little of the thinking as possible. Usually this still involves the teacher in providing the science questions (and hence the teacher forms the bridges between stage 1 and stage 2 of the 3-stage process). Students still undertake the interpretation and derive the conclusion, but increasing the students are also involved in the planning, prediction, controlling variables, specifying of the equipment and materials and determine the repeating of observations, degree of accuracy of recording readings, etc.

4.5 Instructional Strategies on Socio-scientific decision making

Having gained scientific learning from stage 2, this is not seen as the end of the topic. This conceptual knowledge is now in need of (a) consolidation to ensure adequate learning has taken place and (b) transferred to the issue, problem of concern which was initiated in stage 1. The goal is to utilise the new-found science learning in resolving the situation, ensuring the scientific component is carefully considered. In so doing other factors may impinge on the decision, such as economic, environmental, social, political, as well as ethical and morale considerations.

Stage 3 thus leads to an argumentation situation in which students are called upon to put forward their views, justified by well thought out arguments. In so doing, students are also called upon to refute the arguments of others, where appropriate, and guide or persuade the group or the class towards an appropriate and meaningful decision, backed up by well through out arguments. Often it is not enough for the decision to be made at an individual or a group level, but to move towards a consensus decision by the whole class. This can involve undertaking degrees of compromise to enable the whole class decision to come to fruition. This parallels decision making in a societal setting where persons can have different points of view by allowing the democratic decision of the majority to hold sway.

4.6 Student-centred Classroom Management

Clearly inquiry learning, as advocated for stage 2, involves strong classroom management on the part of the teacher. The teacher takes on a facilitator role and, as advocated by Vygotsky, challenges students within their zone of proximal development to determine the solution to the inquiry problem and to make informed decisions. This inevitably involves student-centred teaching in which the students play increasingly more independent roles.

Sections 4.3-4.6 referred to the students' role in the inquiry process, but students can be expected to play a management role (organise themselves), a facilitation role (seek and obtain the necessary facilities and to return them for re-use in a reusable format), collaborative role (in which students work together aiding their learning and gaining leadership skills). This can only happen is the teacher has firm (but largely unused) control of the classroom/laboratory situation.

4.7 Undertaking Formative Assessment feedback strategies

Section 3.8 drew attention to the need for formative assessment and put forward a simple mechanism by means of which a teacher can record progress being made.

A key aspect of formative assessment is the recognition that it is about the progress being made and not the attainment that a students shows at that particular point of time. Clearly, as students progress they improve in their ability and leaner how to undertake various activities or to express thoughts, etc. Through such learning the students not only progress but eventually reach a zenith in their undertaking of actions, thinking or level of achievement. At this time any formative assessment undertaken will be the same as that gained through any measure of achievement as is the case for summative assessment. This assessment can be used as a measure of potential for further development, a predictor of likely future success, or simply as a determination of their achievement level at that point in time.

In striving for popularity and relevance, PARSEL-type modules involve students in learning on an ongoing basis, with learning at one stage dependent on prior learning. Measuring the learning gains during the teaching can facilitate progress, enable learning to focus on achieving the outcomes and for teaching to move on where outcomes have been acquired.

The foundation on which the promotion of popularity and relevance of science teaching are based, pay attention to learning beyond that which can be recorded by pencil and paper (for example, cooperative skills, argumentation skills, experimental skills, leadership skills). This calls for assessment strategies, which can focus on a variety of procedures.

The procedures have been identified as assessment undertaken by the teacher by:

- marking student work presented in a written format (text, graphs, tables, symbols, etc), or
- observing (including listening to) student activities (discussions, inquiry planning, experimental procedures, oral presentation of work), or
- asking oral questions to students as individuals, as a group, or as a class.

Formative assessment sometimes referred to as 'assessment for learning' can be undertaken in a variety of ways. Below three separate styles are indicated, but there is no suggestion that these approaches cannot be interrelated should the teacher so choose.

The three styles are described as:
1. **Assessment centred on competencies** to be achieved within the intended goals of education.
2. **Assessment related to the learning outcomes** to be achieved, per lesson.
3. **Assessment based on selected, teacher-chosen procedures** – by teacher marking written work; by teacher observing students; by oral communication with the teacher.

Carrying out formative assessment
The teacher is able to decide when formative assessment is appropriate, how often it is carried out and what is actually assessed on each separate occasion. With this in mind, it is clear that formative assessment may, or may not occur every lesson. And within a lesson formative assessment,

- may, or may not assess each student on a particular occasion, and
- may, or may not assess all aspects that were targets for the lesson.

As with all assessment measures, feedback to students can be given:

- through a written mark for each assessed component (each question or learning outcome),
- orally, or
- through a global written mark, or grade (more often this is summative i.e. given at the end of teaching).

What form of mark/grade should be awarded ?
This is for the teacher to decide. However, as the assessment takes place in the classroom, on an on-going basis within the teaching, it is important for the assessment strategy to be simple.
- The simplest approach is to measure whether the competency has, or has not, been achieved by each student during the teaching of the module (2-point measure - yes/no)
- Some teachers may want additional measures and these can be added but they increase the complexity. (The examples given use a 3-point measure - x – competency not attained; √ competency is attained to the satisfaction of the teacher ; √√ competency is not only attained, but the student has exhibit learning beyond that expected by the teacher).
- Some teachers may wish to use a 5 point scale – 1,2,3,4,5. For this it is important teachers assess each competency separately and not use a summative, global measure; combined measures will not be so helpful in guiding students in their learning of specific competencies.
- Where a teacher is unsure of any measure given (reliability concerns), formative assessment techniques allow the teachers to assess more than once and take an average of (or ignoring one) assessment measure.

APPROACH 1 - Assessment based on learning competencies given for the Module

Each module (in its frontpage) lists the competencies which are suggested to be taught through the module and hence to be acquired by students. This formative assessment approach attempts to determine whether the students have acquired each competency through the outcomes of the learning shown by the students in undertaking the various activities.

Here is an example taken from the module on'How Happy are You and Your Family with the Electricity Bill?

Able to award a social values grade (competency 1). The teacher listens to the discussions within the groups and the presentations to the class	
x	Not able to contribute to the discussion in a meaningful way
√	Participates in the discussion and is able to record the decision and the justification for this
√√	Not only participates in the discussion and puts forward a point of view but is able to do this with persuasion and can offer counter-arguments to points made by others.
Able to award a science method grade (competency 2). The teacher marks the student questionnaires before the students begin collecting data from the community	
x	Not able to suggest appropriate items for the questionnaire.
√	Able to suggest items for the questionnaire and to put these into a useful sequence. Able to suggest how to use the questionnaire to collect relevant data.
√√	Able to suggest key items for the questionnaire which are suitable and relevant for the community and is able to put forward a sampling plan that reflects the need for sampling of the community for a fair result.
Able to award a personal skills grade (competencies 3). The teacher observes the students during the group work	

APPROACH 1 - Assessment based on learning competencies given for the Module

x	Does not cooperate with others during the group discussions and activities.
√	Participates in group work meaningfully, in the discussions and in the devising of questionnaires and recording of work in written form.
√√	Not only participates in the group work and in the discussions and written work, but takes on a leadership role helping others to participate.

Able to award a science concept grade (competencies 4, and 5). The teacher listens to explanations by individual students during the group work	
x	Not able to explain the meaning of power, the relationship between power and energy and the mechanism for calculating electricity used in the home
√	Able to explain the meaning of power and the relationship between power and energy with the help of the teacher. Able to read an electricity bill and determine the energy used.
√√	Able to fully understand and record, in a meaningful way, the meaning of power and its links to energy. Able to read the electricity bill. Can deduce appliances that have been used by scrutinising the bill.

APPROACH 2 - Formative Assessment carried out, per lesson

In this approach the teacher assesses the learning outcomes specified for the lesson. Each learning outcome, specified for the lesson, can be assessed separately. It is not necessary, unless the teacher so wishes, to assess all students, nor to cover all learning outcomes. The teacher decides which attributes are most important on any given occasion.

It is important for this form of assessment that the teacher puts the teaching first. Formative assessment, as it is part of teaching, must be abandoned where it interferes with other teaching needs.

Here is an example taken from ‘Preventing Holes in Teeth - Are beliefs justified?’

LESSON 1			
	DIMENSION	Suggested Criteria for Assessment The student:	Mark/grade given (x,√,√√)
1	Creates written report based on sources of information	Finds suitable sources of information	
		Extracts meaningful information for a presentation to other students	

LESSON 2			
	DIMENSION	Suggested Criteria for Assessment The student:	Mark/grade given (x,√,√√)
1	Presentation	Presents the information obtained in a clear and practical manner.	
		Presents showing an understanding of the subject.	
		Uses precise and appropriate scientific terms and language.	
		Presents with clarity and confidence using an audible voice.	

LESSON 2 (cont.)			
	DIMENSION	Suggested Criteria for Assessment The student:	Mark/grade given (x,√,√√)
2	Cooperates in a group in writing a	Cooperates with others in the group in compiling the report.	

	report	Illustrates leadership skills – guiding the group by thinking creatively ensuring no overlap in the report from the presentations.	
		Shows tolerance with, and gives encouragement to, the group members.	
3	Shows understanding	Able to explain the causes of tooth decay and methods for their prevention	
4	Asking questions	Willing to ask questions during the presentation of others.	
		Able to recognise where the group did not have answers to questions	
		Cooperate with others in making a written record of the questions for which the group did not have answers.	

LESSON 3			
	DIMENSION	Suggested Criteria for Assessment The student:	Mark/grade given (x,√,√√)
1	Answers questions	Provides correct written answers to questions given orally	
		Provides answers in sufficient detail especially when called upon to give an opinion or decision	
2	Writes a plan or report of an investigation	Puts forward an appropriate research/ scientific question and/or knows the purpose of the investigation/experiment	
		Creates an appropriate investigation or experimental plan to the level of detail required by the teacher	
		Puts forward an appropriate prediction/hypotheses	

		Develops an appropriate procedure (including apparatus/chemicals required and safety procedures required) and indicates variables to control	

LESSON 4		
	DIMENSION	Suggested Criteria for Assessment The student:
1	Record experimental data collected	Makes and Records observations/data collected appropriately (in terms of numbers of observations deemed acceptable/accuracy recorded/errors given)
2	Interpret or calculate from data collected and making conclusions	Interprets data collected in a justifiable manner including the use of appropriate graphs, tables and symbols
		Creates a written report on the experiments and includes appropriate conclusions related to the research/scientific question

LESSON 5			
	DIMENSION	Suggested Criteria for Assessment The student:	Mark/grade given (x,√,√√)
1	Scientific or socio-scientific reasoning	Gives a justified socio-scientific decision to an issue or concern, correctly highlighting the scientific component	
		Records the decision of the group and presents to other groups	

APPROACH 3 - Formative Assessment, based on the selected procedure for assessing chosen by the teacher

APPROACH 3 - Formative Assessment, based on the selected procedure for assessing chosen by the teacher

In this approach the teacher determines the type of assessment to be adopted – by marking written work, by oral interaction with students (as an individual, as a group or as a class), or by simply observing (and listening). It is possible the teacher may wish to assess using different methods for different stages in the module.

Here is an example taken from 'Should Zero Emission Cars be made Compulsory ? Is it feasible ?'

Suggested Student Assessment based on the Teacher's Marking of Written Material	
DIMENSION	Criteria for Assessment The student:
Creates questions for further investigation regarding the scenario.	Puts forward appropriate questions during groupwork.
	Able to presents questions to other groups.
Writes a plan and a procedure for an investigation to produce hydrogen.	Puts forward potential sources of hydrogen.
	Devises an appropriate plan to produce hydrogen and can give explanations for its formation.
	Develops an appropriate procedure (including apparatus/chemicals required and safety procedures required) and indicates variables to control.
Develop a procedure during group work for the investigation and the testing of the product.	Develops an appropriate procedure (including apparatus/chemicals required and safety procedures required) and indicates variables to control.
Record experimental data collected.	Records observations appropriately.
Answers questions.	Able to recognise different ways of storing hydrogen and justify the most appropriate method.

	Able to record problems in using hydrogen as a fuel.
	Able to present graphically the flammability of hydrogen.
	Able to provide full and appropriate illustration of the working of a fuel cell.

6	Create a report.	Makes a detailed report of all activities undertaken and the underlying scientific interpretation.
7	Scientific or socio-scientific reasoning.	Able to give a justified, socio-scientific decision to whether zero emission cars should be made compulsory, highlighting the scientific component.

Suggested Student Assessment based on the Teacher's Oral Questioning		
DIMENSION	Criteria for Assessment The student:	Mark/grade given (x,√,√√) per student or group
Answer oral questions from the teacher to the individual.	Provides correct oral answers to questions given orally by the teacher on ways that hydrogen might be obtained.	
	Provides answers in sufficient detail on the pollution problem with current fuels, including cars running on electricity.	
Answer oral questions asked to the group.	Able to explain the work of the group and the actions undertaken by each member.	
	Understands and can explain the science involved using appropriate language.	
	Willing to support other members in the group in giving answers when required.	
Answering oral questions to	Understands the purpose of the work and shows knowledge and understanding of the subject using appropriate scientific language.	

individuals in the group.	Can exhibit non-verbal activity (demonstrate) in response to the teacher's questions, as appropriate.	
	Able to explain the work of the group and the actions undertaken by each member.	

Suggested Student Assessment based on Teacher Observation
Criteria for Assessment The student:
Contributes to the group discussion and able to put forward ideas.
Cooperates with others in a group by agreeing or commenting on the views of others.
Illustrates leadership skills – guiding the group by thinking creatively and helping those needing assistance (cognitive or psychomotor); summarising outcomes.
Shows tolerance with, and gives encouragement to, the group members.
Draws appropriate conclusions related to the research/scientific question.
Contributes to the group work during the inquiry phases in suggesting sources of information.
Seeks sources of information for the group.
Illustrates leadership skills – guiding the group by thinking creatively and helping those needing assistance (cognitive or psychomotor); summarising outcomes.
Presents outcomes for the production of hydrogen by the various approaches with explanations related to the reactivity series, half cells and the tow stage breakdown of water using natural gas.
Presents by illustrating knowledge and understanding of the subject.
Uses precise and appropriate scientific terms and language.
Presents with clarity and confidence using an audible voice.
Makes the presentation in a clear and practical manner with justified decisions.
Presents by illustrating knowledge and understanding of the subject.
Uses precise and appropriate scientific terms and language.

Presents with clarity and confidence using an audible voice.
Contributes to the group discussion on whether zero emission cars should be made compulsory.
Illustrates leadership skills – guiding the group by thinking creatively and helping those needing assistance.
Shows tolerance with, and gives encouragement to, the group members.

Which approach to use ?
The teacher should use which ever approach interests them most. And of course, the teacher can use a combination of approaches

I can't teach andalso assess during the lesson
Why can't you ? Here assessment and feedback from students are the same. Are you suggesting that teachig does not involve feedback? Surely feedback from the students is important.

But formative assessment is too time consuming!
This is a common fallacy. It is important to realise that formative assessment is part of teaching. Formative assessment is a very appropriate way to gain feedback from students during teaching. The time consuming part is making a record of the assessment and hence this part needs to be as simple as possible.

On the contrary, the giving of summative 'tests' is a time-consuming component, because this is not part of teaching and therefore takes away teaching time. And of course such tests are mainly written in nature. Much can be gained from oral feedback and from watching the students in their work.

How can I teach students and undertake assessment ?
This is a crucial question and it heavily depends on the meaning attached to the word 'teach'. If it means lecture (or teacher centered delivery), then feedback from the students during the lesson will always be limited. It will always be difficult to know whether the students understand, have ideas to put forward, or are capable of self-organisation.

Clearly formative assessment is associated wiht student centred teachign. When the students 'do', the teacher is there to guide, assist and provide feedback on the success of the students. By keeping a record of this, the teachr undertakes formative assessment

There is insufficient time in the lesson to assess all students.
There is no suggestion that the teacher must assess all students in a lesson. But if a teacher chooses to do this, then the assessment system must be kept simple. Assessment from observing all students is clearly possible in every lesson no matter how many students in the class (the length of the observation will be small and not all operations will be observed, but the teacher can gain an impression – teachers do this naturally)

In a 40 minute lesson, with 40 students, I can have a maximum of 1 minute for student assessment per lesson. Is assessment possible?

It depends on the teaching. If students are working individually or in groups, the teacher can go around the classo or around the groups. If the time needed to assist (teach) per individual/group is small i.e. the teacher is mainly gaining feedback, then it is possible

On the other hand, if the indivudual or groups need much assistance from the teacher – they are doing something for the first time – then clearly seeking meaningful whole class feedback is neither desirable not feasible .

I can assess students using formative assessment, but why do I need to make a record?

When and how the teacher makes a record is under the teacher's control. But students gain useful feedback from the progress (or lack of progress) they make and teachers need a record of student progress for reporting purposes. And, importantly, there is little point in undertaken formative and summative assessment together. While summative assessment will also be useful, it is the formative assessment that helps the teaching and is thus desired for the most part.

If I give a student a negative mark, it will be detrimental to their record

The more formative assessment occasions, the more the record will reflect the student achievements. A single negative component will be marginalised, whereas a series of negative marks will indicvate that the student progress is not to the satisfaction of the teacher and it is this that is being recorded.

But teacher records will be biased!

Yes, it will be. But this is always the case. The 'good' teacher tries to be as fair and consistent for students as possible. Formative assessment will assist this by reminding the teacher where attention to some students (usually the silent ones) is neglected.

Teachers are very good predictors of student success from the informal observations they undertake in their teaching. Formative assessment can be merely the keeping of a record of this. Just as the teacher's judgement is generally back-up by summative assessment methods, formative assessment will be similar.

What do I do if some individuals or groups need much of my time. How can I assess all?

The task of the teacher is to teach. Feeback (assessment) is part of the teaching. Clearly you cannot gain feedback if the students need help. It is the skill of the teacher to know how much assistance students should be given at a particular time and of course this takes precedence over gaining feedback.

But be careful ! If students need more help than you had anticipated, then something is wrong. Student progress is lower than you were expecting and you will need to modify your teaching. However dont simply ignore the feedback so that you can 'catch up on time.' Both you and the students need to know about their progress.

How often do I undertake formative assessment?

The teacher decides. Written work can be marked outside the class and can thus be marked frequently if the teachers feels this useful. Observations can go on continuously in the lessons, although not all students need be assessed at any one time (observations will assess attributes and possible attitudes, rather than cognitive gains). Feedback from oral questioning is more usual from inidividuals or groups and can be as frequent or as prolonged as the teacher feels appropriate.

Section B Operationalising the Professional Development of Teachers

Sub part 5

Meeting Self efficacy Needs

It is important to determine the level of self efficacy of the teachers following the professional development programme and its accompanying interventions. This can be achieved by means of a questionnaire, as indicated below:

5.1 Evidence-based evaluation of teacher's self efficacy

PROFILES sets out to promote teacher self efficacy, in terms of competence and confidence, in undertaking classroom practices based on PROFILES ideas and subsequently evaluated through student motivation and student learning gains in enhancing scientific literacy:

5.2 Evaluation of teacher's self-efficacy

Evaluation of the self efficacy of teachers and the manner in which their teaching has developed, can be determined by means of validated questionnaires and triangulated through videotapes, observations, comments/modifications on modules, discussions with others (project partner/lead teachers –face-to-face or via Moodle type learning) and/or discussions during training sessions (collective efficacy).

The questionnaire below is adapted from an instrument developed on TSES (Teachers Sense of Efficacy Scale) (Tschannen-Moran & Woolfolk Hoy, 2001) and relates to:

5.3 Efficacy for identifying suitable modules

- To what extent are you able to determine a suitable module for PROFILES?
- How well can you modify module components for your situation?
- To what extend can you involve modules which are seen as motivational (intrinsically) by students?
- To what extend are you able to match the assessment (feedback) strategies to the module selected?
- How well can you integrate a module into the curriculum?
- To what extent do you correlate PROFILE related modules with the goals of science education?
- To what extent are you able to develop modules to promote independent learning by your students?
- To what extent are you willing to follow a socio-scientific linking of modules as opposed to a linking of topics by means of scientific concepts?
- To what extend are you willing to promote in students' value judgements as opposed to acquiring scientific concepts?
- To what extend are you willing to promote the development of students' communication abilities through science?
- To what extent do you value students gaining an appreciation of the nature of science?

5.4 *Efficacy for Instructional Strategies*

- To what extent can you engage students using the 3 stage model?
- How well can you implement teaching strategies in your classroom recognized as student-centred?
- To what extent can you provide an alternative explanation or example when students are confused ?
- To what extend can you craft good questions for your students?
- How much can you gauge students' comprehension of what you have taught?
- How well can you establish routines to keep activities running smoothly?
- To what extent are you willing to use a constructive rather than a behaviourist approach to teaching in science lessons?

5.5 *Efficacy for Instructional Strategies utilising a scenario*

- To what extent are you able to involve students in utilising a scenario?
- To what extent can you utilise a scenario to guide students to appreciate a need to learn associated science?
- How much can you do to foster students' creativity?
- How much can you do to help your students think critically?

5.6 *Efficacy for Instructional Strategies through IBSE*

- To what extent can you guide students to put forward scientific questions for investigation?
- To what extent are you able to develop student learning in using a structured inquiry approach and guide them to gain skills towards a more guided inquiry approach?
- To what extent are you able to develop student learning through guided inquiry and lead students towards open inquiry skills?
- To what extent are you able to promote open inquiry, (where students are already at the guided inquiry operational level)?
- To what extend are you willing to abandon the teaching of scientific concepts when you deem they are shown to fall outside the students' zone of proximal development?

5.7 *Efficacy for Instructional Strategies on socio-scientific issues*

- How well can you guide students to consolidate their scientific learning and transfer this to a new situation?
- How well can you engage students in socio-scientific discussions/debates/role playing etc?
- To what extent are you able to encourage group decision-making among students?

5.8 *Efficacy for Classroom Management*

- How much can you do to promote cooperative learning between students and the teacher?
- How well can you encourage supportive collaborative learning among your students?
- To what extent are you able to get students to ask creative scientific questions worthy of investigation?

5.9 *Efficacy for Student Engagement*

- How much can you ensure the teaching, is motivational for students?
- To what extend can you develop initiative in your students?

- How much can you do to get students to believe they can do well in science lessons?
- How much can you do to adjust your lessons to the proper level for individual students?
- How much can you do to help your students to value learning?
- How much can you use a variety of assessment strategies?
- How well can you respond to difficult questions from your students?
- How much can you do to motivate students who show low interest in school work?

A 9 point scale can be used where 1=nothing, thru 3 = very little 5= some influence 7=quite a bit 9=a great deal

5.10 Reporting on self-efficacy

Although it is predicted the self efficacy instrument will provide valuable insights, it is not suggested that this is sufficient in establishing the level of self efficacy. Other useful measures are:

(i) Soliciting the type and manner in which modifications to teaching materials are undertaken and hence the degree to which to relate to the PROFILES 3 stage model, IBSE development in students and to enhancing students' self actualisation.

(ii) Assessment strategies, especially those directly influence further teaching, which reflect learning for enhancing scientific literacy

(iii) Collaborative reflections, with other teachers, on PROFILES related beliefs.

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