The PROFILES Guidebook

This is written in 3 major sections. Within each section the book is divided into a number of sub-parts.

Section A - An Introduction to PROFILES

Sub-parts

1. About profiles – the PROFILES concept.
2. Key terms.
3. Elaboration of the Ideological Foundations on which PROFILES builds.
4. Theoretical Constructs underpinning PROFILES.
5. Involving Stakeholders.

Section B - Operationalising the Professional Development of Teachers

Sub-parts

1. Identifying Teacher Support Needs for PROFILES teaching.
2. Identifying Teacher Needs using a Questionnaire.
3. Other Professional Development Components.
4. Undertaking the Intervention phase(s).
5. Meeting teacher self efficacy needs.

Section C - Establishing and Evaluating Teacher Ownership

Sub-parts

1. Approaches to establishing Teacher Ownership.
2. Gaining evidence of Teacher Ownership.
3. Dissemination of ownership indicators.
4. Participating in networking.
5. Undertaking professional development for other teachers/science educators.

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PROFILES Guidebook for Partners

Section A - An Introduction to PROFILES

This section is divided into 5 stand-alone sub-sections
(The sequencing of the sub-parts is fairly arbitrary)

1. About profiles – the PROFILES concept
   The PROFILES acronym
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   3.1 The Goals of Education (as a whole)
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   3.5 Nature of Science (NOS)
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   4.2 Social (and Cultural-historical) Constructivism
   4.3 Motivation
   4.4 ARCS Model of Motivational Design (Keller)
   4.5 Interest
   4.6 Relevance
   4.7 Activity Theory
   4.8 Maslow's Hierarchy of Needs
   4.9 Marzano's theory of a three mental system
   4.10 Theory of Planned Behaviour (teacher beliefs)
   4.11 Teacher's self-efficacy and task context
5. Involving Stakeholders
   5.1 PROFILES objectives towards stakeholders
   5.2 Applying the Delphi Method to determine stakeholder views
   5.3 Facilitator of the Delphi Study

We note:

Reforms which do not appreciate the important role teachers' play in change often experience difficulty.

Imposed programmes run the risk of failing if teachers do not accept and understand the innovation (Fullan, 1992).

A central issue is that improvement in educational programmes depends on concurrent processes of teacher development which in turn implies work in a setting that enables self-organization and reflective practice (Stenhouse, 1975; Schön 1983).

Improvements in science education should be brought about through:

- New forms of pedagogy:
- The introduction of inquiry-based approaches in schools,
- Actions for teachers training to IBSE,
- Development of teachers' networks

(EC; 2007, Science Education Now)

PROFILES Guidebook for Partners

Section A - An Introduction to PROFILES

Sub-part 1

About PROFILES – the PROFILES concept

The purpose of this sub-part is to give a short overview of PROFILES, indicating the main intentions. As such it is intended to form the basis for more extensive discussions among the consortium partners.

1.1 The acronym 'PROFILES' stands for

PROFESSIONAL REFLECTION- ORIENTED-FOCUS
on INQUIRY LEARNING and EDUCATION through SCIENCE.

1.2 The PROFILES project aims, through needs-driven, professional development for teachers and teacher self-reflection to promote enhanced scientific literacy of students. In so doing, PROFILES promotes the use of an 'education through science' approach (with an IBSE – inquiry-based science education focus), while stressing the need to strengthen student motivation and the teacher being a member of a professional community of practice. Enhancing scientific literacy is an expression used to represent the overall target for science education. This target is amplified later.

PROFILES sets out to achieve this aim through an **innovative approach to a professional development provision for science teachers** which identifies the teacher as a learner, a reflective practitioner, a disseminator of good practice as well as a professional in facilitating relevant and meaningful student learning. This approach is designed to last beyond the duration of the project.

1.3 The project approach is via the following actions:

1. *Establishing close cooperation and networking of the consortium with stakeholders (see A5; C4).*
2. *Providing professional teacher development through a needs-driven programme on innovative IBSE, within education through science (see B1).*
3. *Developing stronger teacher professionalisation by enhancing teacher self-efficacy (see B8).*
4. *Promoting teacher ownership of innovative PROFILES approaches and practices (see C1-3).*
5. *Evaluating and Disseminating the PROFILES ideas, materials and outcomes for enhancing students' scientific literacy by the wider community of science teachers (see C5&6).*

1.4 Specific Objectives of the PROFILES project

In terms of targetted outcomes, the PROFILES project sets out to:

1. Establish a well managed, collaborative and well monitored consortium, which is able to introduce PROFILES ideas into a multitude of individual educational systems and cultures, but especially into the systems to which the project partners relate.

2. Ensure improved students' science learning by offering innovative learning opportunities for pre- and in-service teachers and teacher educators as well as for students within the school, teacher education institutions and non-formal education centres.

3. Take into account stakeholder's views in seeking effective ways to raise teacher ownership (and hence self-efficacy) of innovative science teaching approaches and practices, particularly related to inquiry-based approaches and student centred teaching.

4. Develop methods to disseminate project ideas and successes on a wide scale within Europe (and beyond) and promote networking to raise teacher awareness Europe-wide.

1.5 The intended major outcome is greater professionalization of science teachers in PROFILES conceptual directions sustained by interactive local, regional, national and Europe-wide teacher networks. Attaining this outcome is exhibited initially by greater teachers' competence and self-confidence (self-efficacy) to promote IBSE and other student centred science teaching which students find motivationally stimulating and of value for their development and future aspirations. The ultimate outcome is teacher ownership of PROFILES exhibited by self reflection practices and their dissemination.

1.6 Achieving the intended PROFILES outcome is dependent on convincing teachers that:

1. methods studied and tried in the PROFILES training are designed to ***improve the quality of their own science teaching for the benefit of students;***

2. teachers who participate in the longitudinal training programme experience gains in self efficacy to such an extent that they feel they have a role in convincing other teachers of the need to interact with PROFILES and to offer such support (e.g. colleagues in their schools, from 'nearby schools', etc), thus invoking leadership skills;

3. examining, reflectively, the impact of their teaching, first guided by partners, but later by specific teachers (referred to as '***lead teachers***') is expected of a professional. This aspect is designed to follow-on from the initial PROFILES teacher development (with intervention) so as to raise teacher ownership of developments and practices towards enabling teachers to effectively enhance student's scientific literacy through self-evaluative approaches.

4. creating and participating in teacher networks and other forms of dissemination can play an important role in aiding the promotion of a teacher's self-efficacy and, through the disseminating of teacher ownership of PROFILES ideas, leads to greater enhancement of the scientific literacy of students in general.

1.7 The PROFILES hypothesis

It is hypothesised that teachers' confidence, which is targeted in the PROFILES project through the *effective and sustainable improvement of teaching by promoting of self efficacy of IBSE classroom teaching and teacher ownership of the PROFILES conceptualisation of approaches* *and practices,* can be strengthened by means of ***collaborative interactions and through self-evaluative measures focussing on the teachers' reflective practices, as well as through formative and summative assessment of students' cognitive and affective learning.*** This is promoted as an essential component in enhancing IBSE.

1.8 PROFILES and dissemination

From the initiation of the project, PROFILES emphasises the ***dissemination of products, experiences and evidence-based outcomes of the PROFILES project.*** A variety of dissemination mechanisms are envisaged (i.e. Webpage, Newsletter, Seminars, Workshops) of which a teacher network is perhaps the most novel (see later).

1.9 The PROFILES operational concept

PROFILES is designed in the Description of Work to be put into action via eight work packages

Work Package	Short title	Led by	Coverage
1	Management and evaluation	FUB	Project management and evaluation.
2	Partner Support	UTARTU	Professional support and guidance for partners in meeting and interpreting project goals and actions.
3	Stakeholders	FUB	Bridging a potential gap between science education researchers, teachers, and local actors (various levels of stakeholders) through networking and co-operation.
4	Learning Environment Support	UTARTU	Preparing needs-related teacher training programme materials plus identification of appropriate IBSE-related teaching modules which can be modified and enhanced for use in developing the self-efficacy of teachers in meeting the PROFILES aim.
5	Teacher professional development	WEIZMANN	Planning and Implementation of the (longitudinal) teacher training programme and inter-related classroom interventions through which teachers try out new ideas and approaches leading to teacher self efficacy in PROFILES intentions.
6	Teacher Ownership	WEIZMANN	Building on WP5 and, through self-reflection, reflective case studies (e.g. action research) and evaluation, raise the effectiveness and impact of the (longitudinal) teacher training programme with a special goal of teacher ownership of PROFILES practices.
7	Student Gains	FUB	Evaluating the effectiveness and impact of the teacher professional development programme/intervention and the development of teacher ownership on the PROFILES aim by focussing on student outcomes, both cognitive and affective.
8	Dissemination and Networking	KLAGENFU RT /ICASE	Dissemination of PROFILES outcomes on a national, international and worldwide level and the establishment of PROFILES teachers' networks which are interrelated to other teachers' networks operating on a local, regional national or Europe-wide scale.

PROFILES Guidebook for Partners

Section A - An Introduction to PROFILES

Sub-part 2

Key Terms used in PROFILES and their intended meaning

This section is a glossary of terms, alphabetically arranged, relevant to the PROFILES project. The key terms have been grouped into 5 main sections as indicated:

- *a) General*
- *b) PCK*
- *c) Reflective Practitioner*
- *d) Leader/disseminator*
- *e) Theoretical constructs*

2.1 General Terms

1. *Module*

   This is taken to be a science teaching unit of work. For PROFILES, modules refers to PARSEL-type modules which are based on socio-scientific issues for which student conceptual science gains are acquired through the teaching of the module.

2. *Multi-dimensional scientific literacy*

   In enhancing scientific literacy the student can go beyond operating at a *nominal* level (can recognise scientific terms, but does not have a clear understanding of the meaning), beyond a *functional* (can use scientific and technological vocabulary, but usually this is only out of context as is the case for example in a school test of examination), beyond a *conceptual and procedural level* (demonstrates understanding and a relationship between concepts and can use processes with meaning), and is able to develop perspectives of science and technology that include the nature of science, the role of science and technology in personal life and in society (Bybee, 1993) .

3. *PARSEL*

   This is the name of the FP6 project on which PROFILES builds. PARSEL stands for 'popularity and relevance of science education for scientific literacy.' The PARSEL project produced teaching modules in a range of science subject areas, based on a philosophy of increasing students' intrinsic motivation and student involvement in learning using an education through science approach (www.parsel.eu).

4. *Pedagogical Content Knowledge (PCK)*

   This is a term introduced by Shulman (1986) to relate to the Pedagogical Content Knowledge required by a teacher. Although not excluding science content knowledge, PCK is mainly related to the knowledge and skills a teacher needs to possess for classroom teaching. In PROFILES, PCK relates to the teaching philosophy being proposed and associated theoretical ideas, inter-disciplinary science knowledge background and teaching approaches.

5. *Relevance*

   In PROFILES, relevance is considered from the students' point of view (Holbrook & Rannikmae, 2010). Relevance for students can be considered as something valuable, meaningful and/or useful for students. This implies, when related to student learning, that it occurs in a students' frame of reference. It is situated learning. Situated learning (Lave and

Wenger, 1990) occurs best if it is in a context and culture in which it normally occurs. Relevance is, therefore, a necessary condition for situated learning, although it needs to be recognised that additional considerations apply, particularly the need for learning to take place within an appropriate social context. This important consideration implies that not every scientific context or issue is, in itself, relevant.

6. Responsible citizenship

A proposed, major goal of education is to promote responsible citizens. This is not so much related to legal obligations (staying within the law is clearly intended), but more to social obligations. Helping the community is a major aspect. Moral obligations are also intended. Being a responsible citizen is, at its core, a willing to be less individualistic and put the needs of society before the individual needs.

7. Stakeholder

Any person or organisation with an interest in a situation can be considered a stakeholder. Thus education stakeholders can be students, academics, employment and careers advisors, teaching and learning managers, employers of recent graduates, business deans, professional bodies, libraries, PTAs and other parent organisations, teachers, teacher educators, as well as parents, employers, ministry of education personnel and even members of parliament. Science education stakeholders can be expected to include all the above as well as scientists, science academies ad industrialists. School stakeholders are not only the school board, parents, staff, and students, but also local business owners, community groups and leaders, professional organizations, potential enrolments, youth organizations, the faith community, media, etc. Stakeholders, in this case, are all who affect or are affected by the school's actions.

8. Teacher Ownership

Teacher ownership relates to a teacher holding, expressing and enacting views, educational philosophies and undertaking actions which the teacher believes are in the best interests of the students. Teacher ownership is thus under the control of the teacher. Teacher ownership of the philosophy and teaching approaches advocated in PROFILES is thus a major goal. In addition, teacher ownership is enhanced if teachers feel that they are closely involved in the development and implementation of stages of development.

9. Teacher as learner.

In the context of PROFILES, the teacher as learner is confined to the learning of contemporary science of which the teacher is unfamiliar.

10. *Teacher as effective teacher*

In the context of PROFILES, this refers to teaching as per the PROFILES philosophy and ideas, effectively operationalised to enhance students' learning for scientific literacy

11. *Teacher as reflective practitioner*

In the context of PROFILES, a reflective practitioner is a teacher who is willing to explore ways to consider their own teaching and to find ways to overcome perceived deficiencies while expressing an interest in disseminating outcomes for the benefit of other teachers.

12. Teacher as leader

In the PROFILES context, the teacher as leader refers to a teacher willing and able to run professional development programmes, courses, seminars, workshops etc for other teachers or student teachers (teachers in training) which are in line with the PROFILES philosophy.

13. Training materials

Training materials are hand-outs, modules, power-point slides and other support materials utilised for the professional development of teachers.

2.2 Related to PCK

14. Argumentation

This is recognised as the ability of a student to be able to participate in a discussion or debate, putting forward well reason arguments and also able to reinforce or offer a rebuttal to the arguments of others where these are contrary to evidenced viewpoints.

15. Cognitive/meta-cognitive/ intellectual development

A major component of education, hence including science education is the cognitive development of students. This particular applies to higher levels of intellectual development as amplified by Bloom's taxonomy of cognitive domains, or other frameworks e.g. judgemental or evaluative, analytical or synthesising, relational and extended abstract thinking. Meta cognitive development is also a PROFILES goal in enable students to think about their thinking as a move towards self-determination and self actualisation.

16. Context-based, context-led

Teaching is initiated in a suitable context, which is the PROFILES sense, is seen as intrinsically motivating to students.

17. Collaborative Learning

Collaborative learning involves students sharing responsibilities with each other (and possibly the teacher) so as to come up with methodologies, tasks, assessment, etc., in the attainment of a particular goal. This is typically used in support of student-centred learning.

18. Cooperative Learning:

Where students cooperate with each other, or the teacher, to perform or complete a particular task. Students need not be expected to be cognitively involved in determining the most appropriate methodology to complete the task and hence the interaction can be confined to operating together. In such situations, students are typically assigned to groups and assigned roles in order to make the process more efficient.

19. Continuous Professional Development (CPD)

CPD refers to the continuous professional development of teachers. This is crucial for science teachers in a time of change guiding the teacher to maintain their professional expertise. During its operational life, PROFILES can be considered CPD.

20. Decision making (socio-scientific)

Decision making, in a socio-scientific sense, is arriving at a justified, or well reasoned, decision, taking into account impinging factors. Such factors may be scientific, economic, environmental, social, political, moral, ethical etc and the decision would involve balancing the relative importance of the factors involved. Decision making can be individualistic or through consensus by a group.

21. Hands-on, Minds-on:

A term used to describe constructivist activities that require students to personally use equipment or materials. It is used to distinguish such activities from "hands-on" activities, i.e. those activities students do, but do not actively comprehend, evaluate or question.

22. Inquiry Based Science Education (IBSE)

Inquiry-based science education (IBSE) is based on cognitive constructivism and, at its heart, involves students in asking scientific questions. At its simplest level, IBSE involves students in the development of process skills and asking interpretative questions so as to offer explanations of phenomena. At higher levels, IBSE involves students in asking the scientific question which needs to be solved, as well as utilising process skills and ultimately IBSE involves students in putting forward the initial problem to be solved (see appendix 1). Under such interpretations, IBSE is heavily associated with student centred learning, self determination and self actualisation (Maslow).

23. Inquiry

In science teaching, the word "inquiry" is used to describe two things:

(a) a characteristic of what science is,
(b) what students do in a constructivist way.

When students are inquiring, they are questioning and evaluating the information they are obtaining and/or observations they are making. Such inquiry is a pre-requisite if they are to "interpret" their experiences in class and try to make sense of them. There is no one single teaching methodology that is called "inquiry." Associated ideas are inquiry learning by students and inquiry teaching by teachers.

Typically the types of IBSE are described at three levels – structured IBSE is where the student follows clear instructions in a minds-on, hands-on situation (see terms) in which 'minds-on' plays a fairly minor role; guided refers to the teacher supporting the student to play as strong a minds-on role as is possible; open inquiry, or open IBSE, refers to the student being asked to operate independently of the teacher and the teacher's role is to facilitate where needed and to evaluate progress.

24. Intervention

In the PROFILES sense, this refers to the actions taken by the teacher in their own teaching **during** the longitudinal professional development programme. It may also refer to the teacher actions **after** a specific programme (e.g. pre-service course, teacher seminar, conference workshop). It includes feedback on the actions taken from students and the teachers own reflections or reactions by others (consortium partners, other teachers, teachers on the PROFILES professional development programme, etc).

25. Intrinsic motivation

This is a key term in PROFILES. Although intrinsic motivation may be triggered by the external actions of others, intrinsic motivation refers specifically to the motivation shown by the students themselves. It is considered as a 'want' or a 'need' by students and is thus student driven.

26. Motivation

Motivation, in the science education sense, is the 'drive' students possess to undertake scientific learning or carrying out scientific related activities.

27. Nature of Science (NOS)

This refers to an understanding of the Nature of Science, particularly with reference to the seven, usually accepted, attributes i.e. science is tentative, science is subjective, science is culturally bound, scientific theories differ from scientific laws, science is based on empirical evidence, science is creative, it involves interpretation of observations/evidence.

28. Personal skills (personal development)

Personal skills refer to attributes and attitudes students possess, or are expected to possess. Attributes may include perseverance, initiative, creative thinking, ingenuity, safe working, etc. Attitudes include a willingness to - be involved, think, take action, participate, learn, etc

29. Problem solving (scientific)

This includes a range of abilities enabling the student to be able (as a target) to recognise a problem, express the problem in a scientific manner suitable for investigation, and then to be able to solve the scientific problem in an appropriate manner.

30. Process skills

These are usually recognised as skills to be able to carry out investigations. They can include all or part of – recognising a problem, determining the scientific question or questions, planning an experiment, making a hypothesis, recognising and controlling variables, collecting meaningful data and recoding this data meaningfully, analysing and interpreting data, presenting outcomes in an appropriate format, making conclusions.

31. Scientific Literacy (or scientific and technological literacy - STL)

While many will include acquisition of so-called 'fundamental science concepts, the PROFILES recognition of STL is that it is the capability to transfer science related knowledge, skills and values to unknown situation met within the society (including the workplace and all forms of higher education or lifelong learning) by means of scientific problem solving and socio-scientific decision making.

Enhancing Scientific and Technological Literacy (STL). In PROFILES, enhancing STL is seen as the goal of science education. It is taken for granted that all individuals possess some degree of STL and hence the goal is to build on, or enhance this, in a multidimensional senses.

*Multidimensional STL includes problems so*lving abilities, transference of scientific knowledge skills and value to new situations and the use of creative and reasoning abilities in socio-scientific situations. In teaching the goal is to enhance STL, recognising t*h*at students will always possess aspects of STL from everyday life.

32. *Self efficacy*

Self efficacy possessed by a teacher refers to two major components - the competence to teach students towards enhancing scientific literacy in a motivational manner as the situation demands and possessing the confidence to be able to carry out such teaching in the face of constraints or comments by others.

33. *Social skills (social development)*

These are seen as important attributes of education and hence science education. Within science education they are taken to include cooperation and collaboration, the development of moral and ethical values within a societal context and the ability to undertaken reasoned decision making taking into consideration social attributes.

34. *Socio-Scientific Issues (SSI)*

SSI refers to debatable aspects where decisions need to be made which are based within the real world of the student and which include a contentious scientific component. The issue is one which directly affects the student or the world within which the student operates.

35. *Science-Technology-Society (STS)*

This is a teaching approach which recognises the need to recognise societal issues and hence include values and worldview education alongside of related to cognitive science learning. The degree of emphasis on societal aspects is not fixed.

36. *Student Centred Approaches*

This refers to teaching approaches in which the students are heavily involved at the cognitive, planning and operational levels. Student-centred teaching is heavily associated with constructivism learning where the focus is on student learning rather than the teacher teaching. Typical questions asked in planning for a student-centred lesson are the following:

- What is it I want students to learn (be able to do)?
- Why do I want students to learn it?
- What do the students already know?
- How will I (and the students) know they've learned it?
- What difficulties will students have?
- How do I help students overcome these difficulties?

37. *2-step teacher professional development (model)*

In PROFILES this refers to a longitudinal approach to the professional development of teachers in which the first step is meeting teacher needs to develop self efficacy in teachers to utilise PROFILES ideas in their teaching. The second step is to build on the experiences gain and develop teacher ownership of PROFILES.

38. *3-stage teaching model*

In PROFILES this refers to a contextual beginning (stage 1), a decontextualised scientific learning stage (stage 2) and a recontextualised stage to reconsider the contextual situation utilising the science knowledge gained to develop reasoned decision making.

2.3 Reflective Practitioner

39. *Action Research*
A reflective, cyclic approach to practitioner-driven research enacted so as to tackle a practitioner perceived classroom related problem. More generally Action Research is the study of a social situation (i.e. classroom) carried out by those involved in that situation (i.e. teachers and students) in order to improve both their practice and the quality of their understanding (Noffke & Somekh, 2009). Although usually action research is initiated individually but may be supported and encouraged by others, action research can also be initiated collectively by a group of like minded practitioners.

40. *Case Study*
A case study is an in-depth, often ethnographical, study of a person (e.g. a teacher or a student), persons (e.g. a group of teachers or a class of students), or a situation to describe the factors involved and the impact this has.

41. *Classroom observation*
This is observation usually by an individual, of an actual class in which the observer plays no role other than observation. Classroom observation is undertaken to determine the manner in which the teacher and/or the class operates in a given situation or in handling a particular teaching module.

42. *Collaborative reflection*
In PROFILES, this refers to the reflection on teaching or an aspect of science teaching in which a group of teachers (usually those on the longitudinal professional development programme) consider the teaching of one of their number and offer constructive comments relevant personal experiences of their own and evaluative suggestions.

43. *Formative assessment*
Formative assessment is an integral part of teaching informing both teacher and student on progress being made. Formative assessment may be undertaken in a formal (keeping records) or in an informal manner (forming impressions) and its value is that it can determine the pace and cognitive level of teaching which means an individual student's need.

44. *Portfolio*
A portfolio, which can be in written or electronic form (or a combination of both), is a logically arranged, collection of evidence indicators of the teaching being undertaken. It can contains, but is not limited to, teacher planning materials, teaching material used in teaching, evaluative components plus evidence gained from samples of students work and their levels of attainment together with other evidence collected in the classroom by the teacher.

45. *Reflective practitioner*
In the PROFILES context, this refers to a teacher taking ownership of new ideas and practices by reflecting on their actions and prepared to take action based on the reflection.

46. *Student gains*
In PROFILES student gains refers to the assessment of students who have been exposed to learning by teaching implementing the PROFILES philosophy. The assessment of student gains covers both cognitive and affective attributes.

47. *Summative assessment*
This is the assessment of students undertaken at the end of a unit of study. The unit may be one module or the whole course. It is a terminal assessment indicating gains from prior teaching but is also expected to inform future teaching.

48. *Use-inspired research*
This is a European Commission term which in PROFLES is related to reflective, action research, but may also cover the soliciting of stakeholder views, etc.

49. *Videotape*
In the PROFILES sense, this refers to capturing teaching intended to be based on PROFILES philosophies and actions on videotape with a view to support self-evaluation by the teacher concerned and to enable collective reflection involving others (it can be used as part of the portfolio).

2.4 Leader/Disseminator

50. *Formative assessment*
Unlike summative assessment, formative assessment is designed to inform the teacher of student progress and hence to be an integral part of the pace and direction of teaching. It is an ongoing, non competitive process informing both teacher and students of progress being made on all aspects of education and the degree to which students are ready for further challenges. While teacher make records of the assessment, these are not intended to represent the level of learning attainable by the student, nor a predictor of future success. Formative assessment gives an indication on whether the pace and direction of learning is meeting student needs.

51. *Lead teacher*
This PROFILES term is used to indicate a teacher who is ready and willing to operate as a leader in providing PROFILES professional development to other teachers or teacher educators.

52. *Moodle*
Moodle is an example of a freely available, online platform which can be used for non-face to face professional development as well as providing a forum for teacher networking and exchanging of ideas.

53. *Networking*
This is a key component of PROFILES in which teacher exchange ideas and share successes and concerns by face-to-face communication as well as by electronic plattforms.. The system operated under PROFILES functions for the sole benefit of developing teacher's self efficacy and teacher ownership of PROFILES ideas and can be at the local (within a school or town), regional across a number of towns or a region of a country), nation wide covering the whole country or PROFILES-wide in the sense that it covers all partner countries (McCormick et al. 2011).

54. *Pre-service*
This refers to courses, usually full-time, for students who are training to become teachers in a recognised teacher educator programme. Persons on such programmes are referred to as pre-service students.

55. *Publications*
In the PROFILES sense, this refers to articles placed on the PROFILES website, distributed in written format via the PROFILES network, or articles in newsletters, bulletins, journal or books published by PROFILES or other organisations. Where the material is including original teacher data, the author is able to claim sole copy right. Where the articles carry PROFILE consortium indicators, ideas, developments, etc. it is important that these are carefully referenced.

56. *Seminars*
In the PROFILES sense, this term is used to short 1-2 hour interactive presentations to a group of teachers, or other types of stakeholders to introduce, explain the operation of, or disseminate aspects of PROFILES. An intention is that there will be follow-up leading to PROFILES type intervention e.g. members of the audience, if teachers, being involved in interventional teaching or if other stakeholders, in discussions. However further intervention is not necessarily a component.

57. *Summative Assessment*

Summative assessment is used to gain an indication of achievement following learning. It is seen as a measure of attainment.

58. *Teacher educator*
This term is intended to refer to a person involved in the pre- service and/or in-service development of teachers. It particular applies to persons involved in the pre-service and in-service development of student teachers and teachers.

2.5 Theoretical Constructs

59. *Activity theory*
This is very much based on social constructivism (Vygotsky, 1978) and is an approach to undertaking activities which a directed by student needs whereby this need provides the motive for learning. It is a subject-object interrelation. According to Leotjev, the subject can be interpreted in two ways; namely, a community of practice on the one hand, and an individual practice on the other. The object is a personally relevant target obtained by undertaking an activity (or activities) leading to an ability to take action (in a social constructivist sense).

60. *Constructivism*
The central idea of constructivism is that people construct knowledge (as opposed to knowledge being transmitted into their minds) (Von Glasersfeld, 1978). Most people agree that students "interpret" their experiences in class and try to make sense of them, particularly when grappling with scientific concepts (as opposed to rote memorization of terms). Thus, the problem or difficulty is not typically with constructivism per se, but with:
    a. recognizing the difference between when students are "constructing" knowledge vs. simply absorbing and regurgitating, and
    b. what constructivism implies about the types of teaching methodologies one should use.

61. *Constructivist-based Teaching*
Constructivist Teaching is teaching that allows students to 'interpret' their experiences in class and try to make sense of them. There is no one single teaching methodology that is called 'constructivist teaching.' For example, constructivist teaching is not limited to discovery learning (where students learn through discovery), nor does it necessarily imply that lecturing cannot be part of constructivist teaching. It only implies the need to diagnose what is already in the student's mind (usually used to initiate instruction) and that the focus is on student learning rather than teacher teaching. In neither case does it does specify how.

62. *Didactic Teaching*
It seems to be the convention that people use the word 'didactic' to describe lessons or presentations that are not constructivist in nature. The word 'didactic' is used in the sense that the presentation of knowledge (by the presenter) would be the focus rather than the understanding of that knowledge (by the audience). This differs from 'Didaktik' in a German sense where the term refers to teaching processes directly to enhance student learning.

63. *Direct Instruction*
Direct Instruction refers to the practice where the necessary information is given directly to the student. Typically this is done via lecture, but it may be via powerpoint, video, worksheets, etc.). The advantage of direct instruction is that it is a particularly efficient form of instruction (and thus is commonly used in conference sessions). Its efficiency makes it a common choice for teacher-centred lessons, although it can also be used in response to a perceived need by the students (then perhaps may be seen as student centred). During direct instruction, the focus is on the information being transmitted.

64. *Self Actualisation*
Self actualisation is the highest level in a hierarchical pyramid of 5 levels put forward by Maslow. The first four levels (lower-order needs) are considered *physiological needs,*

while the top level is labelled as a *growth need*. This need incorporates morality, creativity, problem solving, etc.

65. *Self Determination Theory (SDT)*

This theory is developed by Deci and Ryan (1985) Self-Determination to distinguish between different types of motivation based on the different reasons or goals that give rise to an action. The most basic distinction is between *intrinsic motivation*, which refers to doing something because it is inherently interesting or enjoyable, and *extrinsic motivation*, which refers to doing something because it leads to a separable outcome. While intrinsic motivation is defined as the doing of an activity for its inherent satisfactions rather than for some separable consequence, extrinsic motivation is that which is driven by external factors, pressure from the teacher, examination pressure, curriculum requirements etc.

66. *Social constructivism*

In this approach to constructivist teaching, collaborative development is favoured and gives value to social experiences in learning. It recognises the important roles of knowledgeable persons – usually the teacher but could be peers and seeks to promote learning through challenges in a social context. However, in social constructivism each learner is seen as an individual with unique needs and backgrounds which need to be taken in to account. Nevertheless as the responsibility for learning resides increasingly with the learner, social constructivism emphasises the importance of the learner being actively involved in the learning process with others. Teachers need to adapt to the role of facilitators helping the learner to develop his or her own understanding of the content (Wertsch, 1997).

67. *Teacher beliefs*

According to The Theory of Planned Behaviour (Ajzen, 2005) an individual's belief consists of three factors: *attitude towards a behaviour* - an individual's positive or negative evaluation of performing the particular behaviour of interest, *subjective norm* - the person's perception of social pressure to perform, or not perform, the behaviour of interest under consideration, and *perceived behavioural control* - the sense of self-efficacy, or belief one is capable to perform the behaviour of interest. In shifting from one educational paradigm – 'science through education' to another 'education through science' to better enhance students' scientific literacy (or STL), the beliefs of the teacher, as a key person in facilitating the learning, become crucial. Of the four major influences on teachers' self-efficacy beliefs (mastery experiences, verbal persuasion, vicarious experiences, and physiological arousal), the most powerful is mastery experiences, which for teachers comes from actual teaching accomplishments with students (Bandura, 1997).

68. *Teacher-Centred Approach*

The term "teacher-centred" is used to describe a class that is not student-centred. Essentially, if the lesson can be evaluated only by examining what the teacher is doing, it is probably a teacher-centred lesson. Typical questions asked in planning for a teacher-centred lesson are the following:

- What do I need to teach?
- How do I explain it?
- How do I make it interesting?

69. *Zone of Proximal Development*

The zone of proximal development (ZPD) is the difference between what a learner can do without help and what he or she can do with help. Vygotsky stated that a child follows an adult's example and gradually develops the ability to do certain tasks without help or assistance. Vygotsky defined the zone of proximal development as: the distance between the actual developmental level, as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers.

PROFILES Guidebook for Partners

Section A - An Introduction to PROFILES

Sub-Part 3

Elaboration of the Conceptual Foundations on which PROFILES builds

A primary focus of PROFILES is striving towards promoting teacher ownership of an innovative, socio-scientific approach to the teaching of science in secondary school. Within this focus, PROFILES strives to promote:

a) A theoretical-based concept for science education in understanding the importance of science in school education.
b) Student motivation as a key component in science education.
c) An innovative 3-stage teaching approach through science education modules.
d) IBSE (Inquiry-based science education) as a major component in promoting science competencies.
e) An ICASE pioneered vision of STL as the focus for enhancing scientific literacy.
f) Incorporating competencies, student tasks and teacher's guides.
g) Utilising PARSEL-style teaching modules.
h) Formative assessment as an essential teaching component for determining student progress in a socio-scientific framework.

This section outlines the ideological foundation on which PROFILES builds.

3.1 Goals of Education (as a whole)

Worldwide, the goals of education are put forward as rather general statements indicating the role education is intended to play in the development of students while at school. As an example, the Melbourne Declaration (MCEETYA, 2008) by State Ministers of Education identifies three key areas through which education can promote the development of students as:

- successful learners,
- self actualised students (confident and creative individuals), and
- active and informed citizens (students who are intrinsically motivated to act).

PROFILES appreciates these attributes as the cornerstone of education.

Related to successful learners, the declaration places stress on:

- Capacity to learn; students playing an active role in their own learning.
- Essential literacy/numeracy skills and ICT (all necessary for science education).
- Ability to think deeply and logically; obtain and evaluate evidence; be creative, innovative and resourceful; plan independently, collaborate, work in teams and communicate; are motivated to reach their full potential (all seen as crucial areas for the gaining an understanding of the nature of science and scientific process skills).

Related to self actualisation, the stress is placed on:

- Sense of self-worth, self-awareness, personal identity to cope with emotional, mental well-being (an aspect of personal development need to cope with scientific problem solving).
- Show initiative, develop personal values/attributes (seen as a major educational area).
- Have confident and capability to pursue further learning (essential for the development of competencies).
- Relate well with others; well prepared for potential life roles; embrace opportunities, make rational and informed decisions and accept responsibilities (essential for socio-scientific decision making).

Related to Active and informed citizens, the stress is to motivate students to:

- Act with moral and ethical integrity.
- Appreciate social, cultural, linguistic and religious diversity, and have an understanding of the system of government, history and culture.
- Understand and acknowledge the value of indigenous cultures and possess the knowledge, skills and understanding to contribute to, and benefit from, reconciliation between indigenous and non-indigenous people.
- Be committed to national values of democracy, equity and justice, and participate in civic life.
- Be able to relate to and communicate across cultures.
- Work for the common good, in particular sustaining and improving natural and social environments.
- Be responsible global and local citizens.

Taking the illustrative example as an indicator, the goals of education can thus be viewed in terms of promoting the self actualisation of students, inculcating a sense of values and through promoting deep thinking, an emphasis on conceptualising and a willingness to value the transference of abilities to new situations.
But what does this say about science education?

3.2. Science Education as part of Education

Accepting the obvious assumption that science education is a part of education, the issue arises concerning the role of science education within the education provision. Two alternatives can be considered -

(a) Science education can be viewed as having very different functions in education from say, mathematics education or language education. In this case, education is presumably **the sum of** science education, plus mathematics education, plus language education, etc. It points to the need, in meeting the overall desired goals of education, to view all components as essential for students and hence all are to be studied at all levels. If students are given a choice of courses/programmes/curricula, they are denied schooling in some attributes indicated earlier as part of the goals of education

(b) The alternative is to consider science education as an approach to education that, although differing in construct from that in mathematics and language lessons, still embodies the same goals of education. In this model, all subject disciplines strive to play a similar role to each other, enabling students to strive towards attaining the overall educational goals from different perspectives. This can be viewed as **reinforcement education,** whereby all educational goals are tackled and promoted through all subject disciplines, but from different contexts, using different stimuli and building from different backgrounds and experiences.

In PROFILES, the second alternative is the one that is seen as the most appropriate.
The second alternative stresses that the goals of education are also the goals of science education (Holbrook and Rannikmae, 2007).

This point is very important because the goals of education refer to the development of the individual (see Melbourne declaration on 3 key areas) rather than specifying any particular content. Thus science education can be considered as that component of *Educating* students which is enacted *through* the medium (context) of *Science.* This contrasts with a commonly utilised alternative in which the emphasis is placed on seeing the goal of science education as the gaining of specific science knowledge (this can be considered as *Science* promoted *through* the *Education* provision offered at schools).

A comparison of similarities and differences in philosophical emphases between 'Science through Education' and the alternative 'Education through Science' (the PROFILES view) is given below (taken from Holbrook and Rannikmae, 2007).

Science through Education	***Education through Science***
Learn fundamental science knowledge, concepts, theories and laws.	*Learn science knowledge and concepts where these are important for understanding and handling socio-scientific issues within society.*
Undertake the processes of science through inquiry learning as part of the development of learning to be a scientist.	*Undertake inquiry-based, investigatory scientific problem solving to better understand the science background related to socio-scientific issues within society.*
Gain an appreciation of the nature of science from a scientist's point of view.	*Gain an appreciation of the nature of science from a societal point of view.*
Undertake practical work and appreciate the work of scientists.	*Develop personal and interpersonal skills related to creativity, initiative, safe working, etc.*
Develop positive attitudes towards science and scientists.	*Develop positive attitudes towards science as a major factor in the development of society and scientific endeavours.*
Acquire communicative skills related to oral, written and symbolic/tabular/ graphical formats as part of systematic science learning.	*Acquire communicative skills related to oral, written and symbolic/tabular/ graphical formats to better express scientific ideas in a social context.*
Undertake decision making in tackling scientific issues.	*Undertake socio-scientific decision making related to issues arising from the society.*
Apply the uses of science to society and appreciate ethical issues faced by scientists.	*Develop social values related to becoming a responsible citizen and undertaking all careers but especially science-related careers.*

Emphasis expected in the Teaching of Science ?

Assuming science education is expected to include the education development of an individual, based on the goals of education, this begs the questions – where is science education best placed to focus emphasis? Turner (2008) put forward 4 major contenders, or arguments, for the teaching of science in school. These were:

a) The Economic Argument

School science represents one end of a vital (if leaky) pipeline which channels science-oriented students from schools through to post-secondary institutions. The pipeline ultimately supplies highly trained scientific and engineering personnel to the economy. These persons are vital for the economic well-being of the country and the national competitiveness.

b) The Democratic Argument

The main responsibility of school science, according to the Democratic Argument, should be to prepare students to be informed citizens and enlightened consumers who can intelligently negotiate the techno-scientific challenges of modern life, politics, and society. An introduction to basic science principles and content would not be absent, but focus would shift toward contemporary technological and real-world applications of these principles and their intersections with students' lives. Science education, the democratic argument insists, should be education about science as well as in science.

c) The Skills Argument

A third important rationale for school science hinges on the claim that certain kinds of science study inculcate desirable transferable skills that include the ability to formulate and conduct experiments, evaluate empirical evidence, appreciate quantitative arguments, carry out inductive generalization, and engage in critical thinking. Proponents of the skills argument urge a curriculum and accompanying pedagogy that encourage hands-on work, that call on students to collectively negotiate the significance and meaning of data, and even to plan and conduct open-ended investigations in the alleged style of adult scientists.

d) The Cultural Argument

Science plays a roll today somewhat like the great mythologies of the civilizations of the past: it provides the great narrative of truth, meaning, and essence that we live by. The proper goal of school science, according to the cultural argument, is to bring students to understand that great story and the enterprise behind it, so that they might not remain ignorant and alienated strangers to modern, scientific culture. Proponents of the cultural argument sometimes urge a strong role for the history of science and the philosophy of science in the school curriculum. Advocacy of both has been an important reform current in science teaching for the last thirty years.

While science education is important in the education system and it is probably not focused solely on any one argument in the absence of others, it is suggested that PROFILES very much favours the democratic argument. In PROFILES, the main reason for incorporating science education into the curriculum is to develop citizens who are able to play a democratic role within society. For this IBSE is not enough. Science education also needs to emphasise creative thinking, problems solving and skills associated with values related, decision making.

3.3. Scientific and Technological Literacy (STL)

Where teaching strives towards students gaining the goals of education through science lessons, many curricula refer to this need as *enhancing scientific literacy* (or scientific and technological literacy in recognition of the interlinking of science and technology in social settings). Thus attaining the goals of education through science teaching and enhancing scientific and technological literacy (STL) are seen as equivalent.

PROFILES accepts this realisation and introduces 'enhancing STL' as the intended outcome of science education
(the word 'enhancing' –to develop further – is important as PROFILES accepts that all students have some STL, deriving from their social background as well as prior learning in school) .

The goals of science education that guide the development of multi-dimensional STL (see section on terms) and which enable science education to play a full part in the achievement of general educational goals, can be expressed in terms of five major components that underline the organisation of curriculum and instruction (Bybee, 1993; but sequencing derived from Holbrook and Rannikmae, 1997):

1. Social development or achieving the aspirations of society.
2. Scientific methods of investigation.
3. Personal development of the student.
4. Career awareness.
5. Empirical knowledge of chemical, physical and biological systems.

The first component ensures science education meets a social (democratic) need. Science education is expected to play a role in the development of persons able to integrate into the society and gain skills to function within the society, as society would intend e.g. science education in relation to cultural, environmental, political and societal understanding, awareness and values. This is perhaps best expressed in science and technology education by guiding students to make justifiable decisions, *transferring* their science and technology conceptual knowledge and skills to a value-laden, societal context, where other societal factors also play a role in the decision-making process.

The second component encompasses the techniques of investigation and the skills and activities of inquiry (observation/data collection, formulation of hypotheses, experimentation, etc.). Include also are scientific problem solving skills (recognising a science problem, planning, investigating and presenting a conclusion), as well as scientific attitudes (e.g. openness, recognition of errors, willingness to develop such skills). It can be summarised as gaining the scientific and technological process skills so as to be able to transfer problem solving abilities to new situations and thus develop competencies in this area.

Components three and four recognise that students are individuals and that science education can play its part in helping individuals aspire to a general education that is relevant to their development and gives awareness of career opportunities. In science education, personal development can include, for example, the development of initiative, ingenuity, creativity, perseverance and working safely with due regard for others. Also included are cooperative learning skills, other interpersonal skills and the ability to utilise, effectively, a range of communication skills. A positive attitude towards science and learning science in school are also intended.

The last component relates to the content to enact the educational learning. It includes facts, concepts, generalisations and conceptual schemes generated by scientists, which enable students to be able *to transfer* such learning to new situations and hence develop scientific competencies. It also includes abstract ways in which knowledge may be organised and transferred for the functional applications of knowledge. This component, unfortunately, has been taken as the major aim of science teaching (the 'science through education' approach), with the canonical knowledge taught associated with the specific subjects areas (chemistry, physics, biology). The content is best viewed as society and culturally dependent. With this in mind, there is no definitive content list that comprises essential learning.

Conceptualising Scientific and Technological Literacy for All (STL)

A common belief, is that STL, as a minimum, includes (Millar,R, 1996)

a) understanding basic scientific terms and concepts;

b) understanding the process of science and technology

c) understanding the impact of science on society.

This belief has dominated the development of curricula around the world in the last 30-40 years. But, as Lutz (1996) puts it, it says nothing about the importance of teaching children to wash their hands after using the toilet and before eating'!! The societal interaction seems to be missing.

This consideration of *values education* and related *personal development* has strong implications for science education. The debates on bringing in an ethical dimension to science are very relevant to attempts to improve the public image of science and the popularity of science teaching. Furthermore, few educational policies around the world omit the ethical and moral aspect from the education provision through schooling. It is expected to be a school responsibility. *Hence it can be argued that social and ethic considerations are important areas for science education at the school level.* It would seem we need to find ways to initiate teaching from societal situations and then develop the conceptual learning that allows students to appreciate the relevance of the science (Holbrook, 1994).

The STL concept

Scientific and technological literacy is much more than language proficiency, as the French translation of scientific and technological literacy as "culture scientifique et technologique" (UNESCO 1994) strongly suggests. While *communication skill* is a crucial component of literacy - referred to as literacy in its fundamental sense, rather than a derived sense, by Norris and Phillips (2003) - it is difficult to see how any approach to STL is bound simply by language, or by a dominance of the written text. The foundation of STL inevitably relates to the conceptualisation of *need-to-know* scientific knowledge, although many school curricula seem to place higher emphasis on developing a far wider knowledge component than is warranted. To avoid this trap, PROFILES accepts that enhancing STL is based on a justified 'need-to-know' view of science content.

Misconception of STL

STL suffers from two divergent viewpoints:

a) those who advocate a dominant role for specific ideas in science, perhaps promoted within an understanding of the nature of science (AAAS, 1993; NRC, 1996) and hence focus the 'nature of science education' on an *understanding of* the science within society;

b) those who see the 'nature of science education' in the wider educational context and predominantly linked to promoting the functionality of a citizen within society (Roth and Lee, 2004).

The first viewpoint seems to be very prevalent among science teachers today. It builds on the notion that there really does exist so-called *'fundamental ideas in science'* which are seen as essential understanding by all. These fundamental ideas are required learning in building a concept of the nature of science.

The second vision sees enhanced STL as a requirement to be able to adapt to, and play a responsible role in, the challenges of a rapidly changing world. It recognises the need for reasoning skills in a social context, which are based on *sound scientific ideas*, derived from conceptual understanding and linked to the nature of science. And above all, this view recognises that enhanced *STL is for all* (Roth and Lee, 2004) and has little to do with science teaching *solely* focusing on a career in science, or *solely* providing an academic science background for specialisation in science.

The viewpoint taken up by PROFILES is very much aligned with the second vision. PROFILES, however, is NOT involved in developing curricula per se, but in ensuring students receive an education through science which is meaningful in today's context and this has value.

Levels of STL

At the school level, Bybee (1997) has suggested scientific literacy can be considered at four functional levels:

- *nominal* (can recognise scientific terms, but does not have a clear understanding of the meaning);
- *functional* (can use scientific and technological vocabulary, but usually this is only out of context as is the case for example in a school test of examination);
- *conceptual and procedural* (demonstrates understanding and a relationship between concepts and can use processes with meaning), and
- *multidimensional* (not only has understanding, but has developed perspectives of science and technology that include the nature of science, plus the role of science and technology in personal life and society).

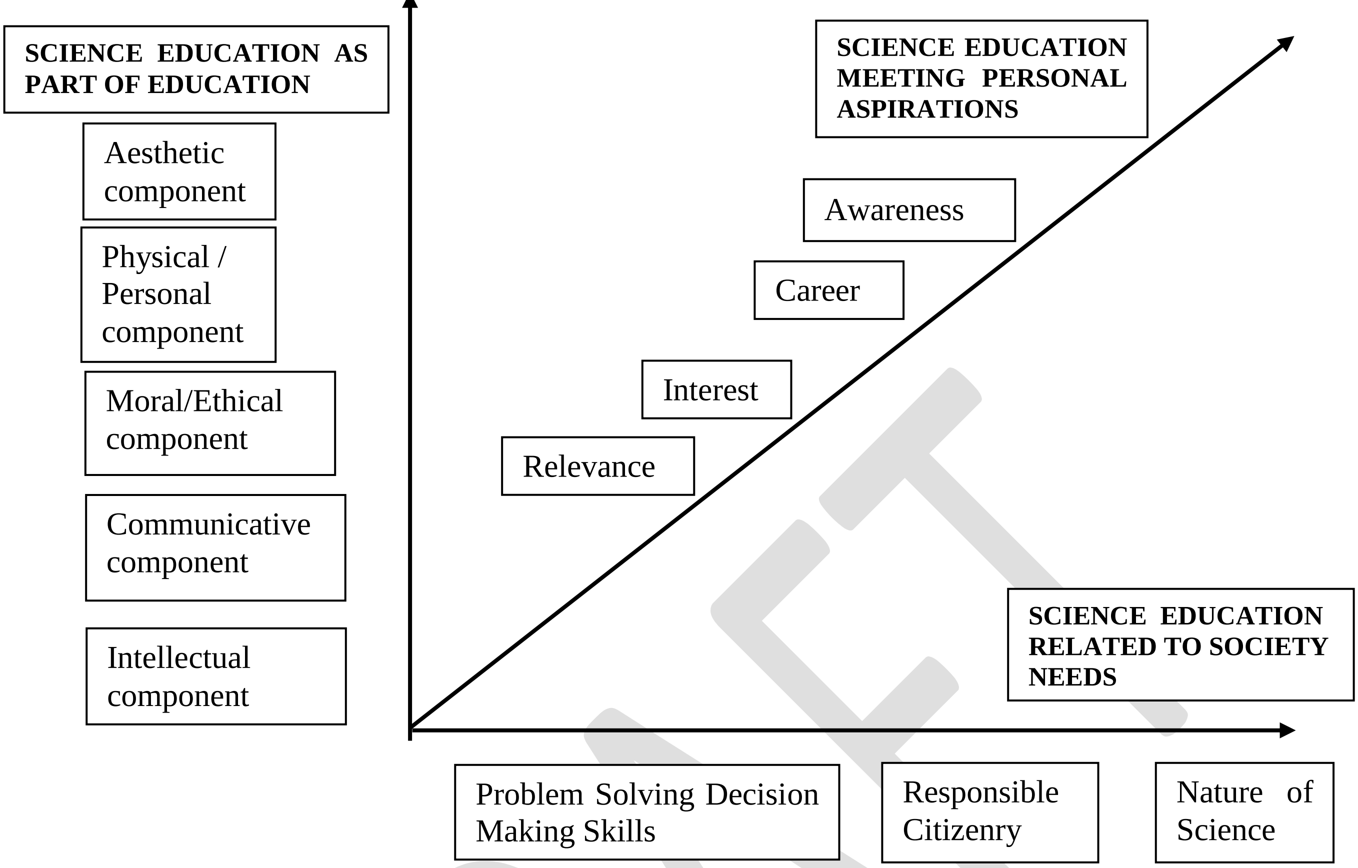
Clearly PROFILES aligns itself very much with the need for students to enhance their multidimensional STL. PROFILES wishes to guide teachers to recognise that functionality, as is so often the target of external examinations, is not a sufficient goal for science teaching.

STL as a Philosophy

It is proposed that STL is both a philosophy and a way of teaching. As a philosophy, it can be represented by 3 major, mutually exclusive, target directions as illustrated in the diagram below (diagram 1). These are respectively — an educational target direction, a society related target direction and a personal needs target direction. All are suggested as essential for STL. This represents a new philosophical viewpoint for science education (Holbrook and Rannikmae, 2007).

Diagram 1.

STL PHILOSOPHY FOR SCIENCE EDUCATION



It is thus postulated that science education needs to be seen as:

i) promoting the solving of problems about aspects of society that are considered relevant. And also to help students, as members of society, to make sound and justifiable decisions about issues and concerns by making use of science knowledge and ideas introduced on a 'need to know' basis, inter-linking this with other pertinent thinking from other discipline areas.

ii) more than simply relating science to society. The intention is seen as developing responsible citizens able to play a full role in society, depending on their status, position and orientation. The science knowledge and understanding thus needs to prepare citizens able to take appropriate actions with regard to issues and concerns in society and to determine, for example, the suitability of newspaper reports, positions taken in debates, or simple claims made by salesmen or advertisers.

iii) not having all the answers and certainly unable to answer ethical or spiritual questions. Gaining an insight into the nature of science as a way of knowing is an important component of learning and illustrates the importance of logic, verifiability and careful interpretation of observations.

The PROFILES project has been developed as subscribing to this vision of STL.

STL as a Teaching Approach

The view of STL teaching proposed here is that which clearly takes away any presumption that the major task of science teachers is to promote 'science for the scientist'. Rather 'science for citizenship' is seen as the goal of STL teaching, stressing both an academic challenge and an attempt to develop a public more appreciative of science. The teaching of STL is thus linked to the role science education can play in preparing future citizens for solving problems, making future decisions and career choices, recognising that many scientific developments in society are unknown today. For this, the societal aspect drives the teaching and the science is included to aid comprehension, encourage learning so as to be able to solve problems, or enhance the making of pertinent decisions.

The proposed STL (scientific and technological literacy) teaching approach is very different from the *uncontextualised* emphasis on scientific principles and concepts used in most textbooks. Students are definitely required to think (minds-on), but the depth of treatment reflects the 'need to know' required for the learning being promoted. Yet the inclusion of scientific principles and scientific concepts advocated in teaching materials marks a strong demarcation between social science and science teaching material. This demarcation is NOT made, as is often the case where teaching rigidly follows the textbook, by the simple addition, or absence, of values education. But as the science and technology in use within society is often very complicated and demanding in conceptual understanding, the STL science taught in schools seeks to find ways to meet this challenge.

The need to make student's prior constructs overt stresses the importance of student involvement in STL teaching. Furthermore, attaining relevance of the teaching suggests the need for student participation in the choice of social context for science learning. And STL teaching recognises that more student activities mean greater opportunities for student learning and also more diagnostic measures of teacher effectiveness.

The STL teaching approach is based on the previously expounded STL philosophy and thus:

a) *science teaching encompasses the range of education goals* (see sub-part B given earlier)

b) *units or modules of science teaching are initiated from a society perspective*
STL science teaching embeds the conceptual science in a socially relevance 'scenario' and includes science knowledge or concepts on a 'need to know' basis. In other words, issues or concerns within society drive the relevance of the teaching (where society can be viewed, provided it is relevant to the student, at a local, national or global level). This means teaching starts from the society and the society interests and then leads to the conceptual learning.
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.

c) *Constructivist approach (*see the later sub-section on educational theories*)*
For STL learning to be meaningful, it needs to be based on students' prior learning and experiences and thus adopt a constructivist approach.

Implications for Teaching

The STL Teaching Approach, following on from the STL philosophy, is based on the following criteria:

a. Intended outcomes for teaching cover all educational goal areas.
b. The teaching definitely promotes science conceptual learning and places great emphasis in this area.

c. The approach to teaching begins from a societal perspective, which is perceived as relevant to the student, or meeting societal needs.
d. The constructivism learning is promoted by a student participatory approach.
e. Students are actively involved in carrying out activities, or tasks, which are related to the intended outcomes.
f. The student activities include scientific Problem Solving and socio-scientific Decision Making.
g. Assessment is directly related to the degree of achievement of the intended learning outcomes specified.

An STL teaching approach is strongly supported by PROFILES.

Student Involvement (see later)
The teaching approach relies heavily on student involvement. And there is a need to base the learning on students' prior constructs, aspects often coming from society rather than prior teaching. The teaching approach is student driven.

A common practice is to solicit students' prior learning by means of brainstorming and from there, involve students in group work to develop plans for future work (investigating projects, jigsaw development of areas of learning, etc). Nevertheless there will be lessons where teachers emphasise the acquisition of conceptual science ideas and students may be required to practice skills of handling scientific data, manipulating variables, writing reports, or undertaking practise in other forms of reasoning skill development, or undertaking calculations (classroom exercises).

PROFILES supports strong student involvement in a hands-on, minds-on approach.

Research Evidence
A major attempt to examine STL teaching, based on the STL philosophy, was undertaken in Estonia with 25 teachers (Rannikmae, 2001). This showed that ten months after a 6-month intervention programme, sustained teacher change was much less than teachers undergoing a temporary change. Sustained change involved less than a third of the teachers who were able to utilise socio-scientific decision- making. The study showed that students preferred the STL teaching, found it was interesting and made gains in dealing with more subjective and critical thinking questioning.

From STS studies, which share the socio-scientific approach, although not necessarily in such an integrated manner, it is clear that a more student centred approach can be shown to lead to better understanding of the science ideas (Yager and Weld, 1999), as well as to an improved understanding of the social issues among science, technology and society (Yager, 1998; Mamlok, 1998; Ratcliffe, 1997). The studies also show that linking the teaching to the society plays a positive role in enhancing the attitudes of students towards science and science teaching (Yager, 1997; Mamlok 1998; Hofstein, 2001; Zoller, 2001). On another note, it seems that STS classes can lead to gains in thinking skills, such as critical and creative thinking and decision–making (Yager and Weld, 1999; Kortland, 2001), while there is little evidence of a drop in gains on the traditional subject matter at the next level of science education (Yager, 1997).

STL teaching sequence
The PARSEL-type teaching material on which the PROFILES project intends to build, goes beyond specifying learning outcomes and puts forward both a students' and a teacher's guide.

The students' guide comprises 2 components:

a) *a scenario that sets the social scene and provides the constructivist context;*
b) *a set of tasks that are specifically intended to lead to the desired learning outcomes* (not on a one to one correspondence, as tasks may cover more that one outcome and reinforcement of outcomes is possible by multiple tasks), and designed for maximum interest and challenge for the students at their particular level of learning (BSCS, 1993).

The teacher's guide section in the PARSEL teaching material is intended to assist the teacher to adopt a STL approach. It details a suggested teaching sequence that illustrates the intended learning. The teacher's guide also provides the link between outcomes and tasks for those teachers needing such reinforcement and, for all teachers, illustrates the manner in which assessment can be effected so that students' achievement of the outcomes can be determined and subsequent teaching action can be taken.

Professional Development of Teachers
The research evidence shows that even with a 6 months intervention study, many teachers are not able to fully grasp the ideas (Rannikmae, 2001). If, at that point, most teachers are left to continue in their own way, they revert to their former practices.

It is important to note that STL is NOT about the teacher using exemplary teaching material, supplied to the teacher. The STL goal is that teachers are able to conceptualise the ideas and appreciate their importance in science teaching. One way suggested, for moving in this direction, is for teachers to create teaching materials of their own, based on exemplars. **There is no attempt to suggest materials can be supplied for teachers to use unchanged**.

One form of professional development that can be used to promote STL teaching is to guide teachers, through workshops, to create their own teaching materials, based on the STL philosophy. The workshops, followed a similar model, first introduced the philosophy to the participants, secondly participants are introduced to exemplar teaching materials and then they are guided to create their own materials, either individually or as a group. From experience, attention needs to be paid to the title and scenario, the need for learning outcomes that encompass both social values and scientific conceptual teaching and the development of student participatory tasks, which related to the learning outcomes. This approach was adopted in the development of many PARSEL-type materials.

The PROFILES project is not specifically set up to develop teaching materials. However PROFILES, being in tune with the STL philosophy and teaching approach, advocates the usage of PARSEL-type materials, adapted for the specific teaching situation as a key component of the intervention interrelated to PROFILES programmes, courses, seminars, etc.

Criteria for STL Exemplary materials
Where teachers create teaching materials, it is important that they do relate to the STL philosophy. The following criteria are put forward for STL teaching materials (Holbrook, 1997; Holbrook and Rannikmae, 1997).

a.	***Stipulates educational goals***	Outcomes are specified in achievable terms for a theme or particular set of lessons, which interrelate to a scenario. At least one outcome is put forward for each educational goal area.
b.	***Promotes science learning***	Science concept outcomes refer to the acquisition of such concepts during the teaching process. Students are **NOT** expected to have acquired the concepts prior to the teaching. If the concept is complex, the number of teaching lessons will increase to reflect the learning.
c.	***Begin from a societal perspective***	Based on constructivist ideas and in an attempt to maximise interest, the teaching of topics in STL begins from an issue or concern in society relevant to the student. Preferably the students' identify the issue or concern. "Societal" refers to the citizens, and interactions, within the local environment, within the world of work, and within the 'global village' (which may extend beyond Earth to space, or whenever

		issues/concerns have impact in the society themselves in, both for the present and the future).
d.	***Student participation***	If constructivism is to be put into practice, it is essential for students to be involved. This is achieved by student involvement in the thinking, doing and expressing of the learning. Students are thus expected to be involved: (i) Individually, in written work, making presentations and taking part in brainstorming sessions. (ii) in small group work - for problem solving, investigations, experimental explorations and discussions on findings, or exploratory ideas or making decisions that involve multiple factors or in preparing for class presentations (iii) as a whole class - for brainstorming and making commentary on group presentations, or arriving at a class consensus decision making position.
e.	***Student activities/tasks tied to the outcomes***	The activities put forward for students need to be clearly related to the learning, thus promoting the achievement of the specific outcomes set out for the teaching of the topic. As the outcomes cover all educational goal areas, the tasks also relate to these (not necessarily on a one-to-one correspondence, because activities may cover more than one outcome, or activities may only partly relate to any one outcome to be achieved). The link between the outcomes and the activities is crucial for STL teaching.
f.	***Engaging in scientific Problem Solving and socio-scientific Decision Making Activities***	Scientific questions arise from the issue/concern (a problem), which can be investigated scientifically to arrive at a 'solution to the problem', once the students have acquired the relevant conceptual understanding. For socio-scientific decision making, it is essential to consider all the factors involved, then decide on the relative importance in arriving at a decision, based on careful deliberations. One of the factors involved in the decision-making process will derive from the science conceptual learning, whereas others are likely to be economic, social, environmental, political or ethical/moral factors. Decision-Making is based on factors that are not always stable and the decision can shift with time, circumstances and public opinion.
g.	***Assessment linked to achievement of the objectives***	It is essential that assessment measures student achievement in terms of the outcomes put forward and not merely record students' involvement in activities. Thus, recording that students took part in a discussion (an activity) says nothing, whereas stating that students were able to put forward a decision with appropriate justifications shows students achieving the outcome set in this area. The assessment of students will be both during and after the teaching. An advantage of assessing during the teaching process is that multiple measures can be obtained over time, leading to a more relevant measure of the skill measured. Thus observation by the teacher is likely to be an important assessment tool alongside interactive oral work and student written records.
h.	***Involve demanding (higher order) thinking skills***	Undertaking the activity is an appropriate learning exercise for the learner i.e. it provides an intellectual challenge at an appropriate level for the students. It utilizes constructivist principles - moving from information and understanding already in the possession of students, to the new learning situation. It involves analytical or judgemental thought.
i.	***Include a communication skill component***	Due consideration is given to enhancing a wide range of communication skills appropriate for the dissemination of scientific ideas and social values. This will involve oral (group discussion, debate, role playing), graphical, tabular, symbolic, pictorial as well as written forms.
j.	***Include a comprehensive teacher's guide***	As problems, issues and concerns coming from society are often interdisciplinary in character, with the science ideas unfamiliar to the teacher, full explanations are needed to help teachers make use of the materials in a meaningful and interesting manner. The teacher's guide also needs to highlight the link between activities put forward and the outcomes expected of the teaching in terms of educational objectives. The teacher's guide needs to detail a suggested teaching strategy by which the student centred approach is exemplified.

3.4. Inquiry-Based Science Education (IBSE)

An inquiry-based curriculum and inquiry-based teaching techniques relate to a learning process or strategy rather than any specific set of lessons. The European Commission sees this as an essential component of science education (Science Education Now, 2007). The Profiles project is specifically required to include IBSE.

IBSE aims to enhance learning based on:

(1) increased student involvement;
(2) multiple ways of knowing, and
(3) sequential phases of cognition.

And sets out to achieve this by:

a) promoting *student-derived* investigations, with the intention that in this way the knowledge gained is more relevant and meaningful. (*This investment in the curriculum and learning process leads to active construction of meaningful knowledge, rather than passive acquisition of facts transmitted from a lecturer).*

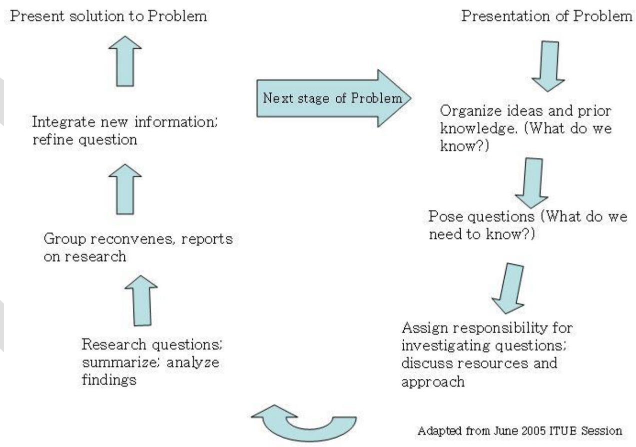
b) engaging students' multiple intelligences with the intention that in this way more types of students are successful contributors and students are engaged on more than one level. (*In addition, this process mirrors the Bloom's learning phases, which leads to more complete cognition by building on previously learned knowledge*).

c) including student-student collaboration with a view to reinforce the assimilation of knowledge, while teacher-student collaboration is seen as building trust for future learning.

IBSE is sometimes known as project-based curriculum, and in this context typically adheres to the following guidelines:

- Starts with an intrinsically motivating situation, concern, issue which leads to raising the scientific question.
- An open-ended question or demonstration initiates the scientific inquiry (as opposed to beginning a lesson with definitions and explanations).
- Gather responses and subsequent questions from students with little comment or direction.
- Require students to collaborate on designing experiments or methods of inquiry.
- Student teams conduct experiments or gather data.
- Interpretation leads to problem solving
- (If appropriate) Re-evaluate question based on new data and re-experiment or collect new data based on revised question.
- Students present findings as an oral presentation, a poster presentation or an evaluative write-up.

This is illustrated in the following diagram:



3.5 Nature of Science (NOS)

The concept of the nature of science is complex and full agreement is difficult to obtain, but aspects of importance for the teaching of science in school do seem to attract common agreement (Halai, 2005). Lederman (2000) suggested these aspects can be considered as:

- Scientific knowledge is tentative (subject to change).
- Empirically-based (based on and/or derived from observations of the natural world.
- Theory-laden (subjective).
- Necessarily involves human interference, imagination and creativity (involves the invention of explanations).
- Necessarily involves a combination of observations and inferences

- Is socially and culturally embedded.
- Appreciating that scientific theories are not the same as scientific laws and that one does not change to another.

Haklai and Hodson (2004) suggest the following are important in the understanding of the Nature of Science in the context of school science:

- Scientific knowledge is simultaneously reliable and tentative.
- Although no single universal step-by-step scientific method captures the complexity of doing science, a number of shared values and perspective characterise a scientific approach to understanding nature.
- Creativity is a vital ingredient in the production of scientific knowledge.
- A primary goal of science is the formation of theories and laws, which are terms with very specific meanings.
- Contributions to science can be made and have been made by people the world over.
- The scientific questions asked, the observations made, and the conclusions in science are to some extent influenced by the existing state of scientific knowledge, the social and cultural context of the researcher and the observer's experiences and expectations.
- The history of science reveals both evolutionary and revolutionary changes. With new evidence and interpretation, old ideas are replaced or supplemented by newer ones.

These aspects clearly have implications for the manner in which science in taught in school. The following examples may give weight to this supposition

a) Scientific models are representations and care is needed that they are not taken to represent the real situation. This especially relates to atomic structure and bonding in chemistry.

b) Observations do not necessarily provide the same perspective for all. See diagram below (is it a rabbit or a duck?)

Luckily science is based on inferences as well as observations, but clearly care is needed in making inferences so that one perspective is taken in isolation.

c) 'The' scientific method does not exist. The way in which archeologists and astronomers undertake their research differs remarkably to that undertaken by a chemist or biologist.

d) Just because a chemistry equation can be written and balanced does not mean it truly represents the reaction. This is true, for example, in writing an equation for the reaction between aqueous copper sulphate and aqueous potassium iodide. Empirical evidence is required in all cases.

PROFILES Guidebook for Partners

Section A - An Introduction to PROFILES

Sub-part 4

Theoretical Constructs underpinning PROFILES

This section identifies theoretical constructs which are seen as important in promoting PROFILES. These constructs relate to:

- *Constructivism*
- *Social (and Cultural-historical) Constructivism*
- *Motivation theories (including interest and relevance)*
- *Activity Theory*
- *Needs (self actualisation)*
- *Marzano's theory of a three mental system*
- *Theory of Planned Behaviour (teacher beliefs)*
- *Self efficacy theory*

4.1. Constructivist principles

Constructivism, and the need for students to form overt constructs, appropriate for learning, is at the very heart of STL (Lutz, 1996). By embedding the science conceptual learning in a social issue or concern and ensuring the science is seen as relevant in the eyes of the student, it is inevitable the teaching builds on students' prior constructs, or ideas. These prior constructs, or ideas, may have come from interactions within society, or earlier learning within the school.

Formalisation of the theory of constructivism is generally attributed to Piaget (1950) who articulated mechanisms by which knowledge is internalized by learners. He suggested that through processes of *accommodation* and *assimilation*, individuals construct new knowledge from their experiences. When individuals assimilate, they incorporate the new experience into an already existing framework without changing that framework. This may occur when individuals' experiences are aligned with their internal representations of the world, but may also occur as a failure to change a faulty understanding; for example, they may not notice events, may misunderstand input from others, or may decide that an event is a fluke and is therefore unimportant as information about the world.

In contrast, when individuals' experiences contradict their internal representations, they may change their perceptions of the experiences to fit their internal representations. According to the theory, accommodation is the process of reframing one's mental representation of the external world to fit new experiences. Accommodation can be understood as the mechanism by which failure leads to learning: when we act on the expectation that the world operates in one way and it violates our expectations, we often fail, but by accommodating this new experience and reframing our model of the way the world works, we learn from the experience of failure, or others' failure.

Constructivism is a theory describing how learning happens, regardless of whether learners are using their experiences to understand a lecture, or following the instructions for building a model airplane. In both cases, the theory of constructivism suggests that learners construct knowledge out of their experiences. However, constructivism is often associated with specific pedagogic approaches that promote **active learning,** or **learning by doing.**

Constructivist learning intervention

A constructivist learning intervention is thus an intervention where contextualised activities (tasks) are used to provide learners with an opportunity to discover and collaboratively construct meaning as the intervention unfolds. Learners are respected as unique individuals, and instructors act as *facilitators* rather than as teachers.

4.2. Social Constructivism

In social constructivism, each learner is seen as an individual with unique needs and backgrounds. Social constructivism not only acknowledges the uniqueness and complexity of the learner, but actually encourages, utilizes and rewards it as an integral part of the learning process (Wertsch, 1997).

Social constructivism encourages the learner to arrive at his or her version of the truth, influenced by his or her background, culture or embedded view of the world. Historical developments and symbol systems, such as language, logic, and mathematical systems, are inherited by the learner as a member of a particular culture and these are learned throughout the learner's life. This also stresses the importance of the nature of the learner's social interaction with knowledgeable members of the society. From the social constructivist viewpoint, it is thus important to take into account the background and culture of the learner throughout the learning process, as this background also helps to shape the knowledge and truth that the learner creates, discovers and attains in the learning process (Wertsch, 1997).

The social constructivist outlook leads to a number of learner attributes:

(b) The responsibility of learning needs to reside increasingly with the learner (Glasersfeld, 1989). (Von Glasersfeld (1989) emphasizes that learners construct their own understanding and that they do not simply mirror and reflect what they read. Learners look for meaning and will try to find regularity and order in the events of the world even in the absence of full or complete information).

(c) *The motivation for learning.* According to Von Glasersfeld (1989), sustaining motivation to learn is strongly dependent on the learner’s confidence in his or her potential for learning. These feelings of competence and belief in potential to solve new problems (in PROFILES we will use the term - self efficacy), are derived from first-hand experience of mastery of problems in the past and are much more powerful than any external acknowledgment and motivation (Prawat and Floden, 1994).

(d) *The role of the instructor as facilitator*. According to the social constructivist approach, instructors adapt to the role of facilitators rather than teachers involved in the transmission of knowledge (Bauersfeld, 1995). A facilitator helps the learner to get to his or her own understanding of the content. Thus, the following table applies:

A typical teacher	*A facilitator*
Tells (eventually, even if a questioning approach initiates the situation).	Asks (facilitating/breaking-down the challenge to enable the student to respond as the challenge becomes within the ‘zone of proximal development (Vygotsky, 1978)
Lectures from the ‘front’ (indicates the direction; stands at the front as the	Supports from the ‘back’ (encouraging students when this is seen as necessary; allows students to take the

focus of attention).	lead and facilitates)
Gives answers according to a set curriculum.	Provides guidelines and creates the environment for the learner to arrive at his or her own conclusions.
Mostly gives a monologue.	Is in continuous dialogue with the learners (Rhodes and Bellamy, 1999).
Sees students as a class (the unit for teaching is the class).	Adapts the learning experience 'in mid-air' by taking the initiative to steer the learning experience to where the learners want to create value.

(e) *Cooperative learning.* If the teacher is a facilitator who is both a consultant and coach, the teacher and students work together in cooperative learning. Some strategies for cooperative learning include:

- Reciprocal Questioning: students work together to ask and answer questions.
- Jigsaw Classroom: students become "experts" on one part of a group project (one part of the jigsaw) and teach it to the others in their group (this completing the puzzle).
- Structured Controversies: Students work together to research a particular controversy (Woolfolk, 2010).

(f) *Involving social constructivism - Learning as an active, social process.* Social constructivism, strongly influenced by Vygotsky's (1978) work, suggests that knowledge is first constructed in a social context and is then appropriated by individuals (Bruning et al., 1999; Cole, 1991; Eggan & Kauchak, 2004). According to social constructivists, the process of sharing individual perspectives- called collaborative elaboration (Van Meter & Stevens, 2000) - results in learners constructing understanding together that wouldn't be possible alone (Greeno et al., 1996).

(g) Social constructivists view learning as an active process where learners should learn to discover principles, concepts and facts for themselves, hence the importance of encouraging guesswork and intuitive thinking in learners (Brown et al.1989; Ackerman 1996). Other constructivists agree with this but emphasize that individuals make meanings through the interactions with each other and also with the environment in which they live. Knowledge is thus a product of humans and is socially and culturally constructed (Ernest 1991; Prawat and Floden 1994).

(h) *Dynamic interaction between task, instructor and learner.* A further characteristic of the role of the facilitator in the social constructivist viewpoint is that the instructor and the learners are equally involved in learning from each other (Holt and Willard-Holt, 2000). This means that the learning experience is both subjective and objective and requires that the instructor's culture, values and background become an essential part of the interplay between learners and tasks in the shaping of meaning. Learners compare their version of the 'truth' with that of the instructor and fellow learners to get to a new, socially tested version of 'truth' (Kukla, 2000).

(i) *Collaboration among learners*. Most social constructivist models, such as that proposed by Duffy and Jonassen (1992), stress the need for collaboration among learners, in direct contradiction to traditional competitive approaches.

(j) The social constructivist paradigm views the context in which the learning occurs as central to the learning itself (McMahon, 1996). Decontextualised knowledge does not give us the skills to apply our understandings to authentic tasks because, as Duffy and Jonassen (1992) indicate, we are not working with the concept in the complex environment and experiencing the complex interrelationships in that environment that determine how and when the concept is used. One social constructivist notion is that of authentic or situated learning where the student takes part in activities directly relevant to the application of learning and that take place within a culture similar to the applied setting (Brown et al. 1989).

(k) *Knowledge should be discovered as an integrated whole*. Knowledge should not be divided into different subjects or compartments, but should be discovered as an integrated whole (McMahon 1997; Di Vesta 1987). This also again underlines the importance of the context in which learning is presented (Brown et al. 1989). The world, in which the learner needs to operate, does not approach one in the form of different subjects, but as a complex myriad of facts, problems, dimensions and perceptions (Ackerman, 1996).

(l) *Engaging and challenging the learner*. Learners should constantly be challenged with tasks that refer to skills and knowledge just beyond their current level of mastery. This captures their motivation and builds on previous successes to enhance learner confidence (Brownstein, 2001). This is in line with Vygotsky's zone of proximal development. (To fully engage and challenge the learner, learners must not only have ownership of the learning or problem-solving process, but of the problem itself (Derry, 1999)).

(m) *The structuredness of the learning process*. It is important to achieve the right balance between the degree of structure and flexibility that is built into the learning process. Savery (1994) contends that the more structured the learning environment, the harder it is for the learners to construct meaning based on their conceptual understandings. A facilitator should structure the learning experience just enough to make sure that the students get clear guidance and parameters within which to achieve the learning objectives, yet the learning experience should be open and free enough to allow for the learners to discover, enjoy, interact and arrive at their own, socially verified version of truth.

Assessment

Holt and Willard-Holt (2000) emphasize the concept of dynamic assessment, which is a way of assessing the true potential of learners that differs significantly from conventional tests. Here the essentially interactive nature of learning is extended to the process of assessment. Rather than viewing assessment as a process carried out by one person, such as an instructor, it is seen as a two-way process involving interaction between both instructor and learner. The role of the assessor becomes one of entering into dialogue with the persons being assessed to find out their current level of performance on any task and sharing with them possible ways in which that performance might be improved on a subsequent occasion. Thus, assessment and learning are seen as inextricably linked and not separate processes (Holt and Willard-Holt, 2000).

According to this viewpoint instructors should see assessment as a **continuous and interactive** process that measures the achievement of the learner, the quality of the learning experience and courseware. The feedback created by the assessment process serves as a direct foundation for further development.

4.3. Motivation

To be motivated means *to be moved* to do something. Self-Determination Theory (SDT; Deci & Ryan, 1985) distinguishes between different types of motivation based on the different reasons or goals that give rise to an action. The most basic distinction is between *intrinsic motivation*, which refers to doing something because it is inherently interesting or enjoyable, and *extrinsic motivation*, which refers to doing something because it leads to a separable outcome.

Intrinsic motivation is defined as the doing of an activity for its inherent satisfactions rather than for some separable consequence. When intrinsically motivated, a person is moved to act for the fun or challenge entailed rather than because of external prods, pressures, or rewards (Deci et al, 1999).

The inclinations to take interest in a novel situation, to actively assimilate, and to creatively apply our skills is not limited to childhood, but is a significant feature of human nature that affects performance, persistence, and well-being across life's epochs (Ryan & LaGuardia, 1999). Intrinsically motivated activities are said to be ones that provided satisfaction for innate psychological needs. Thus, researchers explore what basic needs are satisfied by intrinsically motivated behaviours. The Self-determination theory (SDT) focuses primarily on psychological needs—namely, the innate **needs for competence, autonomy, and relatedness**—but we of course recognize that basic need satisfaction accrues in part from engaging in interesting activities (Deci et al., 1999).

Cognitive Evaluation theory (CET), presented by Deci and Ryan (1985), argues that interpersonal events and structures (e.g., rewards, communications, feedback) that conduce toward feeling of competence during action can **enhance** intrinsic motivation for that action, because they allow satisfaction of the basic psychological need for competence. Accordingly, for example, optimal challenges, effectance promoting feedback, and freedom from demeaning evaluations are all predicted to facilitate intrinsic motivation. Several studies showed that positive performance feedback enhanced intrinsic motivation, whereas negative performance feedback diminished it (Deci and Ryan, 1999). Many studies have focused on aspects of the social context that make it autonomy-supportive versus controlling. In autonomy-supportive contexts, instructors empathise with the learner's perspective, allow opportunities for self-initiation and choice, provide a meaningful rationale if choice is constrained, refrain from the use of pressures and contingencies to motivate behaviour, and provide timely positive feedback (Deci et al., 1994).

Although, the role of rewards is not unequivocal, Deci and Ryan (1999) maintain that virtually every type of expected tangible reward made contingent on task performance does, in fact, **undermine intrinsic motivation**. Furthermore, not only tangible rewards, but also threats, deadlines, directives, and competition pressure diminish intrinsic motivation because, according to CET, people experience them as controllers of their behavior. On the other hand, choice and the opportunity for self-direction appear to enhance intrinsic motivation, as they afford a greater sense of autonomy.

Several studies have shown that autonomy-supportive (in contrast to controlling) teachers catalyse in their students greater intrinsic motivation, curiosity, and the desire for challenge. Students who are overly controlled not only lose initiative but also learn less well, especially when learning is complex or requires conceptual, creative processing (Deci and Ryan, 1999).

Extrinsic motivation

According to SDT, extrinsic motivation can vary greatly in the degree to which it is autonomous. Persons who accomplishes their task, only because they fear some kind of sanctions for not doing it, is extrinsically motivated because they are doing the work in order to attain the separable outcome of avoiding sanctions. Persons, who do the work because they personally believes it is valuable for their career are also extrinsically motivated because they too are doing it for its instrumental value, rather than because they finds it interesting. The latter case entails personal endorsement and a feeling of choice, whereas the former involves mere compliance with an external control.

Many of the educational activities prescribed in schools are not designed to be intrinsically interesting. A central question thus concerns how to motivate students to value and self-regulate such activities, and without external pressure, to carry them out on their own. This problem is described within SDT (1999) in terms of fostering the *internalisation and integration* of values and behavioural regulations. Internalisation is the process of taking in a value or regulation, and integration is the process by which individuals more fully transform the regulation into their own so that it will emanate from their sense of self. Thought of as a continuum, the concept of internalisation describes how one's motivation for behaviour can range from amotivation, or unwillingness, to passive compliance, to active personal commitment (Figure 2).

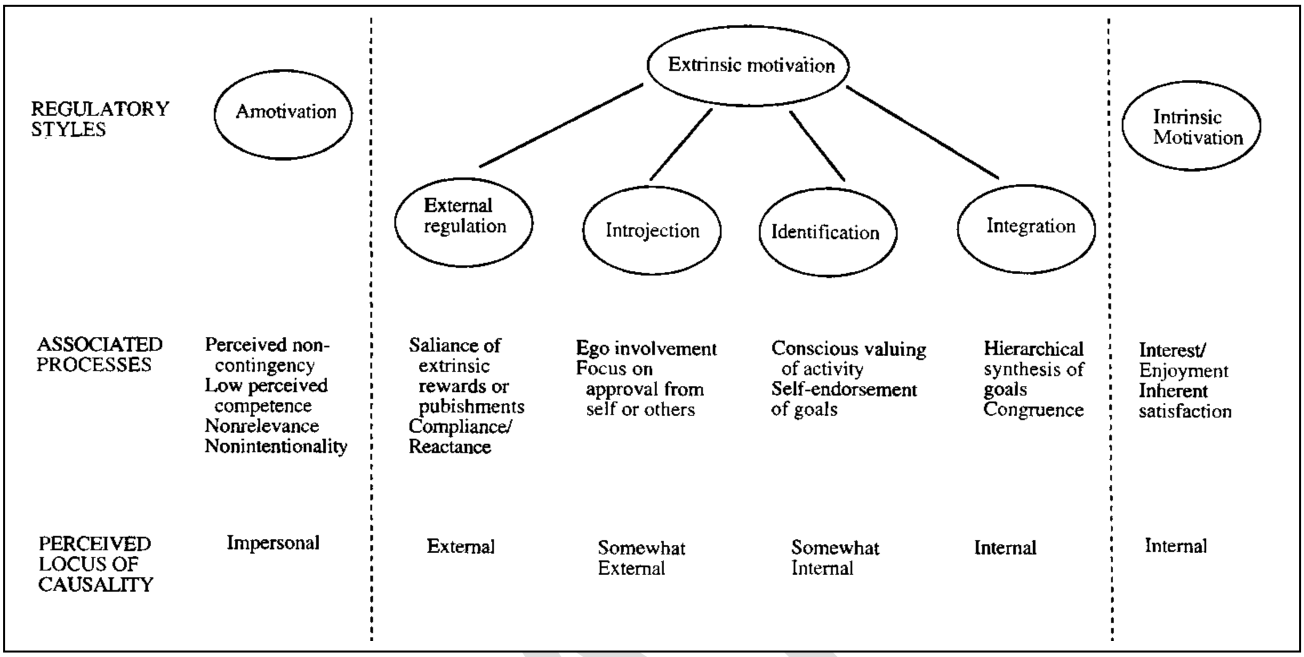


Figure 2. A taxonomy of human motivation (Deci and Ryan, 1999)

4.4. ARCS Model of Motivational Design (Keller, 1983)

According to the ARCS Model of Motivational Design, there are four aspects in promoting and sustaining motivation in the learning process: Attention, Relevance, Confidence, Satisfaction (ARCS).

a. Attention

- Keller suggested attention (extrinsic motivation) can be gained in two ways:
  (1) Perceptual arousal – uses surprise or uncertainly to gain interest. Uses novel, surprising, incongruous, and uncertain events; or
  (2) Inquiry arousal – stimulates curiosity by posing challenging questions or problems to be solved.
- Methods for grabbing the learners' attention include the use of:
  - Active participation -Adopt strategies such as games, role-play or other hands-on methods to get learners involved with the material or subject matter.
  - Variability – To better reinforce materials and account for individual differences in learning styles, use a variety of methods in presenting material (e.g. use of videos, short lectures, mini-discussion groups).
  - Humour - Maintains interest by use a small amount of humour (but not too much to be distracting)
  - Incongruity and Conflict – A devil's advocate approach in which statements are posed that go against a learner's past experiences.
  - Specific examples – Use a visual stimuli, story, or biography.
  - Inquiry – Pose questions or problems for the learners to solve, e.g. brainstorming activities.

b. Relevance

- Establish relevance in order to increase a learner's motivation (utilising extrinsic motivation in an attempt to trigger intrinsic motivation). To do this, six major strategies are described by Keller:
    - Experience – Tell the learners how the new learning will use their existing skills. We best learn by building upon our preset knowledge or skills.
    - Present Worth – What will the subject matter do for me today?
    - Future Usefulness – What will the subject matter do for me tomorrow?
    - Needs Matching – Take advantage of the dynamics of achievement, risk taking, power, and affiliation.
    - Modelling – First of all, "be what you want them to do!" Other strategies include guest speakers, videos, and having the learners who finish their work first to serve as tutors.
    - Choice – Allow the learners to use different methods to pursue their work or allowing s choice in how they organize it.

c. Confidence

- Help students understand their likelihood for success. If they feel they cannot meet the objectives or that the cost (time or effort) is too high, their motivation will decrease.
- Provide objectives and prerequisites – Help students estimate the probability of success by presenting performance requirements and evaluation criteria. Ensure the learners are aware of performance requirements and evaluative criteria.
- Allow for success that is meaningful.
- Grow the Learners – Allow for small degrees of growth during the learning process.
- Feedback – Provide feedback and support internal attributions for success.
- Learner Control – Learners should feel some degree of control over their learning and assessment. They should believe that their success is a direct result of the amount of effort they have put forth.

d. Satisfaction

- Learning must be rewarding or satisfying in some way, whether it is from a sense of achievement, praise from a higher-up, or mere entertainment.
- Make the learner feel as though the skill is useful or beneficial by providing opportunities to use newly acquired knowledge in a real setting.
- Provide feedback and reinforcement. When learners appreciate the results, they will be motivated to learn. Satisfaction is based upon motivation, which can be intrinsic or extrinsic.
- Do not patronize the learner by over-rewarding easy tasks.

4.5. Interest

Interest is seen as the immediate outcome of a situation. Interest includes an affective component (e.g., positive affect) and cognitive components such as knowledge and values. Students can acquire two different kinds of interest: *individual (personal) interest* and *situational interest* (Krapp, 2002). Researchers conceptualize personal interest as a relatively stable disposition, personality trait, or characteristic of the individual.

Situational interest refers to the context of learning (Krapp et al., 1992). Krapp et al. (1992) refer to the different features that can generate interest, such as novelty, surprise, complexity, ambiguity, and inclusion of certain types of themes. Situational interest derives from contextual features and may not include any personal interest. Also, referring to Krapp (2002), in certain conditions, situational interest could become an individual interest. Nevertheless, situational interest tends to be quite short-term.

Hidi (2000) suggested that situational interest involves both positive affect and increased attention to the task as a function of the affective involvement. In fact there are believed to be two phases of situational interest. In the first phase, situational interest is triggered or activated. In the second, interest is further maintained. Thus, situational interest is aroused or activated as a function of interestingness of the context.

Hidi (1990) noted, that interest (as personal or situational) may result in less conscious attention given to the task. Hidi and Anderson (1992) suggested that when interest is high, there does not have to be as much effortful selective attention; that, in fact, interest could result in more spontaneous attention and less cognitive effort, but still have a positive influence on learning.

Based on their literature review, Schraw, Flowerday, and Lehman (2001) made three suggestions to promote situational interest.

a) teachers should increase *student autonomy*. This is especially useful for pupils with very low motivation.
b) teachers need to provide *better texts.* Texts should be coherent and informationally complete as well as vivid and surprising to the reader. Students should be familiar with the texts: they should either be part of a familiar context, or the teacher should prescribe background reading to help students better comprehend the scientific principles they are studying in the classroom.
c) teachers should help students to *process information at a deeper level*. Interest increases active learning and vice versa. Active learning leads to situational interest.

Häussler and Hoffman (2002) suggested seven principles for physics teaching to promote student interest:

1) opportunities to marvel;
2) content linked to prior experience;
3) first-hand experience;
4) discussion about the topic's relevance for society;
5) connection with applications;
6) connection with the human body, and
7) demonstration of the benefit of quantitative level concepts.

4.6. Relevance

Relevance in education refers to the meaningfulness of the subject matter forming the education. This can refer to the topic, the method of delivery, the goals, or to anything that relates to the goals.

Relevance is seen as differing from interest (which can relate to popularity or liking) as interest is seen as emotional. Relevance is seen as a function of:

(a) the students' perception of the relevance of the initial introduction for self;
(b) relevance of the subject to the student, where subject incorporates comprehensibility, opportunity to participate, classroom climate; satisfaction and performance (assessment) by self from the learning;
(c) students' perception of curriculum perception/implementation by the teacher plus assessment demands;
(d) students' satisfaction with teacher perception (ability) to meet student needs and enthuse.

For the teaching of science subjects to be more relevant for students:

- there is a need for student participation in the choice of social context for science learning;
- an increase in student activities and with this greater opportunities for student self learning;
- there needs more potential diagnostic measures of the effectiveness of the teacher;
- this calls for maximising student involvement and the important move away from teacher centred approaches.

When relevance relates to the student (i.e. relevance in the eyes of the student), then relevance is a measure of appropriateness, importance, need or want for the student, as perceived by the student. Expressed in mathematical notation (Holbrook and Rannikmae, 2009), the total relevance for the student ($R_{s,t}$) is a function of $R_{s,x}$, $R_{s,y}$, $R_{s,z}$, $R_{t,c}$, $R_{t,p}$

where -

$R_{s,x}$ = students perception of the relevance of the initial introduction for self;

$R_{s,y}$ = relevance of the subject to the student, where subject incorporates comprehensibility, opportunity to participate, classroom climate;

$R_{s,z}$ = satisfaction and performance (assessment) by self from the learning;

$R_{s,t,c}$ = students' perception of curriculum perception/implementation by the teacher plus assessment demands;

$R_{s,t,,p}$ = students satisfaction with teacher perception (ability) to meet student needs and enthuse.

Whereas $R_{s,x}$ comes for the initial teaching set up (the 'set' to a lesson or series of lessons), $R_{s,y}$, $R_{s,z}$ play a role later in sustaining relevance in the teaching.

$R_{s,x}$ is thus seen as having the potential to be the most crucial aspect of relevance for students. It is linked with intrinsic motivation. When $R_{s,x}$ is seen as high by students, then learning is more likely to take place ($R_{s,t} \sim R_{s,x}$). In addition, popularity, enjoyable and liking (interest) are more likely when $R_{s,x}$ is high.

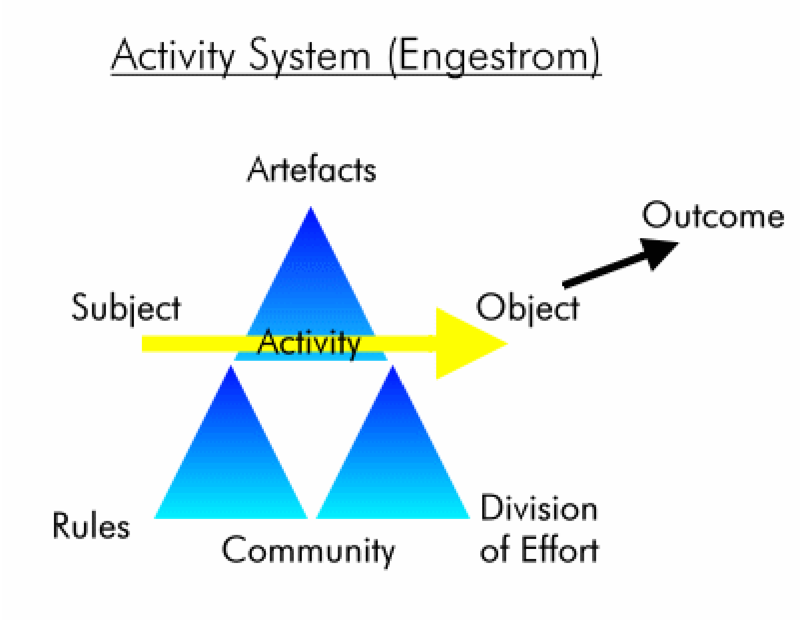
Irrelevance for the student, however, is not dependent on $R_{s,x.}$ This component can be absent ($R_{s,x} = 0$), but $R_{s,t}$ can still be positive. Irrelevance is given by $R_{s,t} = 0$. In the absence of examination pressure, $R_{s,x}$ can be the most important motivator of students. This suggests motivation is dependent on relevance.

4.7. Activity Theory

Activity Theory is a framework, or descriptive tool for a system. People are socio-culturally embedded actors. There exists a hierarchical analysis of motivated human action (levels of activity analysis). The unit of analysis is *motivated activity, directed at an object* (goal). Activities consist of goal-directed actions that are conscious.

In Activity Theory, the learner (the subject) expresses a need, which instigates the motive for studying an object through undertaking an activity or activities. According to Vygotsky (1978), the learner and the object being studied are not separate entities; they mutually define each other during the human activity. The learner (the subject) makes meaning for an object by use of a particular interpretation of the topical conditions of that person's life.

Activity Theory seeks to answer the basic question of 'what is activity?' in the following way (see diagram):



In order to reach an *outcome* it is necessary to produce certain *objects* (e.g. experiences, knowledge, and physical products). Human activity is mediated by artifacts (e.g. tools used, documents, recipes, etc.). Activity is also mediated by an organization, or community. Also, the community may impose rules that affect activity. The subject works as part of the community to achieve the object. An activity normally also features a division of labour.

The basic modelling of activity is a hierarchical structure with three distinct levels. Leontiev (1978) proposed these three levels in an activity as ‘the activity level’, ‘the action level’ and ‘the operation level’.

- Activity towards an objective (goal) carried out by a community. A result of a motive (need) is that it gives rise to the need for this activity. Activities are realized as individuals and cooperative actions. Activities can thus be differentiated based on their motives (*Answers the Why? question*).
- *The Actions* level are basic components of activities. They are subordinate to the larger activity. The goal of an action is a conscious goal that guides the action. Different actions may be undertaken to meet the same goal. (*Answers the What? question*)
- *The Operations* level are ways of executing actions. Operation structure of activity typically automated and not conscious concrete way of executing an action in according with the specific conditions surrounding the goal (*Answers the How? question*)

The line distinguishing between action and activity is difficult to define, as goals and motives can often overlap or be used interchangeably. Activity theory thus allows the constituents of activity to dynamically change as conditions or context change.

4.8. Maslow’s Hierarchy of Needs

Maslow’s Hierarchy of Needs has often been represented in a hierarchal pyramid with five levels. The four levels (lower-order needs) are considered *physiological needs*, while the top level is considered *growth needs*. The lower level needs need to be satisfied before higher-order needs can influence behavior. The levels are as follows (see pyramid in Figure 1 below).

- **Self-actualization** – morality, creativity, problem solving, etc.
- **Esteem** – includes confidence, self-esteem, achievement, respect, etc.
- **Belongingness** – includes love, friendship, intimacy, family, etc.
- **Safety** – includes security of environment, employment, resources, health, property, etc.

- **Physiological** – includes air, food, water, sex, sleep, other factors towards homeostasis, etc.

Figure 1. Maslow's Hierarchy of Needs Pyramid.

Deprivation Needs
The first four levels are considered *deficiency* or *deprivation needs* ("D-needs") in that their lack of satisfaction causes a deficiency that motivates people to meet these needs. *Physiological needs*, the lowest level on the hierarchy, include necessities such as air, food, and water. These tend to be satisfied for most people, but they become predominant when unmet. During emergencies, *safety needs* such as health and security rise to the forefront. Once these two levels are met, *belongingness needs*, such as obtaining love and intimate relationships or close friendships, become important. The next level, *esteem needs*, include the need for recognition from others, confidence, achievement, and self-esteem.

Growth Needs
The highest level is *self-actualization*, or the self-fulfillment. Behaviour in this case is not driven or motivated by deficiencies, but rather one's desire for personal growth and the need to become all the things that a person is capable of becoming (Maslow, 1970).

4.9. Overview of the Marzano's three mental system

Marzano (1998) presents a model of three mental systems—

- the **self-system**,
- the **meta-cognitive system**, and
- the **cognitive system**.

A fourth component of the model is knowledge. Marzano's model is trying to integrate the traditional three domains: cognitive, affective, and psychomotor.

The knowledge domains include *information*, *mental processes*, and *psychomotor skills*.
The cognitive system includes processes that address *storage* and *retrieval*, *basic information-processing*, *communication* and *knowledge utilization*.

The cognitive system is responsible for the effective processing of the information which is essential to the presenting task. For example, if the task given requires solving a problem, the cognitive system is responsible for the effective execution of the components involved in problem solving. If the task given requires the generation of a novel idea, the cognitive system is responsible for the construction of the new concept. The processes within the cognitive system act on an individual's knowledge base (Anderson, 1995).

The Marzano's knowledge domain and cognitive system have their roots in Bloom's taxonomy (Bloom et al, 1956).

The metacognitive system can control any and all aspects of the knowledge domains and the cognitive system. The metacognitive domain has been described as responsible for the ‘executive control’ of all processes and it’s components as responsible for organizing, monitoring, evaluating, and regulating the functioning of all other types of thought (Brown, 1984). The components of the metacognitive system are organized into four categories:
(a) *goal specification*, (b) *process specification*, (c) *process monitoring*, and (d) *disposition monitoring*.

a) Goal Specification:

In Marzano’s model (1998), the metacognitive system does not set goals - more specifically, the metacognitive system does not "decide" whether to engage in a presenting task. Deciding whether or not to engage in a presenting task is a function of the self-system. Once the self-system determines that the individual will engage in a given task, it is the job of the goal specification function within the metacognitive system to determine the exact nature of the situation when the task has been completed.

b) Process Specification

The process specification function according to Marzano (1998) is charged with identifying or activating the specific skills, tactics, and processes that will be used in accomplishing the goal that has been passed on by the self-system and operationalized by the goal specification function of the metacognitive system. When the learner is engaged in a novel task, the process specification function must determine not only which algorithms, tactics, and processes to use, but the order in which they will be executed. Snow and Lohmann (1989) explain that this type of thinking requires a great deal of "conscious thought" as opposed to the more "automatic thought" that is used in routine and familiar situations.

c) Process Monitoring

The process monitoring function monitors the effectiveness of the actual algorithms, tactics, and processes that are being used in the task. As its name implies, the process monitoring function is charged with making executive decisions regarding the use and timing of processes and resources.

d) Disposition Monitoring

The disposition monitoring function addresses the extent to which the task is carried out in ways that optimize the effectiveness of the algorithms, tactics, and processes being used. This function is responsible for accuracy, clarity, restraint of impulsivity, intensity of task engagement and task focus.

According to Marzano (1998) the metacognitive system is mostly comprised of pure procedural structures with no nonlinguistic or affective elements. Each of the four metacognitive functions - goal specification, process specification, process monitoring, and disposition monitoring - are, to a great extent, innate. There is, however, some informational knowledge within the metacognitive system that is typically learned by an individual which could have some nonlinguistic and affective nature.

The self-system in Marzano’s model (1998) consists of an interrelated system of beliefs, attitudes, and emotions. The interaction between them determines both motivation and attention and produces the goals that are executed by the metacognitive system. Once the self-system has determined that a presenting task will be accepted, the functioning of all other elements of thought (i.e., the metacognitive system, the cognitive system, and the knowledge domains) are dedicated or determined. The basic categories of self-system are: (a) self-attributes, (b) self and others, (c) the nature of the world, (d) efficacy, purpose, motivation and attention.

(a) **Self-attributes.** Researchers and theorists such as Bandura (1979) and many others have demonstrated that one of the most important aspects of one’s sense of self is his beliefs about personal attributes, for example beliefs about physical appereance, intellectual ability, athletic ability, social ability, and so on (Schunk & Pintrich, 2008). It is the combined effect of these beliefs that constitutes one's overall self-concept of self.

(b) **Self and Others.** Beliefs about self and others deal with one's perception of the nature of formal and informal groups and their relationship to the individual. The extent to which an individual perceives that she has high status within groups that she values determines the individual's overall sense of acceptance. Some psychologists (Murray, Maslow, Roger) assert that human beings have an innate drive for acceptance within one or more groups individuals have a need to perceive that they "belong" (need for belonginess) (Schunk & Pintrich, 2008). Thus, one's perceptions regarding his or her status in valued groups will have a profound effect on motivation (Marzano, 1998).

(c) **Nature of the World.** Within this category would be an individual's causal theories about the relationship of various entities. For example, within this category an individual will have 'theories' about why specific events occur. These will include their beliefs about physical, emotional, sociological, and supernatural forces and how they came to affect specific situations and events (Marzano, 1998).

(d) **Self-efficacy.** According to Bandura (1986), self-efficacy is defined as, "*People's judgements of their capabilities to organize and execute courses of action required to attain designated types of perfomances*" (see also Schunk & Pintrich, 2008). Self-efficacy affects choice of activities, effort, and persistence. In other words, beliefs about efficacy address the extent to which an individual believes that he/she has the resources or power to change a situation (accomplish a task). However, Bandura's research indicates that a sense of efficacy is not necessarily a generalisable construct. Self-efficacy beliefs are assumed to be more dynamic, fluctuating, and changeable than the more static and stable self-concept and self-competent beliefs (Schunk & Pajarers, 2002). One's self-efficacy for a specific task on a given day might fluctuate due to the individual's preparation, physical condition (sickness, fatigue), and affective mood, as well as external conditions such as the nature of the task (length, difficulty) and social milieu (general classroom conditions) (Schunk & Pintrich, 2008).

(e) **Purpose.** This category of self-system beliefs deals with one's perception about purpose in life. This set of beliefs ultimately exerts control over all other elements in the self-system because the purpose or purposes identified for one's life dictates what the individual considers important.

Marzano points out that processing **always starts with the self-system**, proceeds to the metacognitive system, then to the cognitive system, and finally to the knowledge domains (Figure 1).

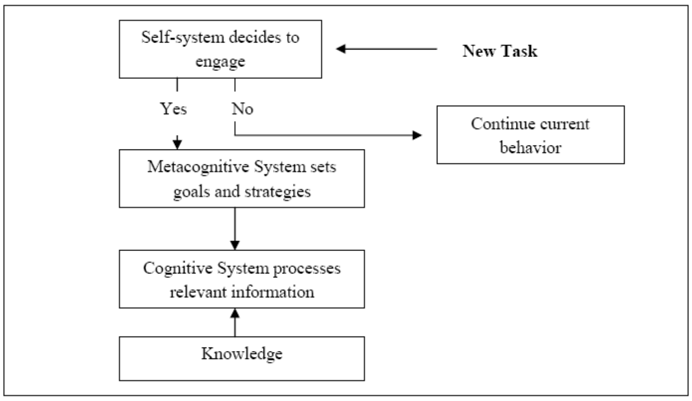


Figure 1

4.10. Teachers' beliefs

According to The Theory of Planned Behaviour (Ajzen, 2005) an individual's belief consists of three factors:

- *Attitude towards a behaviour*, This refers to the individual's positive or negative evaluation of performing the particular behaviour of interest,
- *Subjective norm* , this is the person's perception of social pressure to perform, or not perform, the behaviour of interest under consideration, and
- *Perceived behavioural control*, the sense of self-efficacy, or belief of which one is capable to perform the behaviour of interest.

Several researchers (Bybee, 1993; Haney, Czerniak & Lumpe, 1996; Tobin, Tippin & Gallard, 1994) support the notion that teacher beliefs are precursors to change, playing a critical role in restructuring education. Changing teacher beliefs may be a necessity for developments which promote student learning. And also, in encouraging a shift in beliefs, it is necessary to identify potential barriers to change. Some researchers (Loughran & Luft, 2001) show the possibilities to change teachers' beliefs through different interventions, extending potential for improvement of educational practices.

Research on the operationalization of teaching for the enhancement of STL has shown that is not easy to change teachers' thinking and practice (Rannikmäe, 2001; 2006). Traditional ways of teaching and learning have been shown to be quite viable in the chemistry classroom, based on current measures to judge learning success and have been relatively resistant to changes. Because providing the opportunity for changing their beliefs is essential for teachers' development (Lappan & Theule-Lubienski, 1994), it is important to understand not only what teachers believe, but also how their beliefs are structured and held in order to be better able to address STL ideas.

The metaphorical analysis by Green (1971) provided a useful multidimensional perspective of how beliefs are structured. Green focussed on three different aspects of belief structures and on the evidentiality of beliefs:

A) the quasi-logical relation between beliefs. They are primary or derivative.
B) the relations between beliefs having to do with their spatial order or their psychological strength. They are central or peripheral.
C) Beliefs are held in clusters, as it were, more or less in isolation from other clusters and protected from any relationship with other sets of beliefs.

Green discussed the notion of beliefs that are in isolation from each other and connected to specific contexts. Applying his analyses to chemistry teaching it is realised that it is quite possible for teachers to simultaneously hold that *problem solving is the essence of chemistry teaching* and that *students best learn chemistry by taking notes and memorizing what is to be learned.* This shows that isolation can occur when contradictory belief structures are developed in contexts but where the beliefs are not explicitly compared (Green, 1971).

4.11. Teacher's self-efficacy and task context

Bandura (1977) introduced the concept of self-efficacy beliefs as an assessment of one's capabilities to attain a desired level of performance in a given endeavor. He proposed that belief in one's abilities was a powerful drive influencing 'motivation to act', the effort put forth in the endeavour, and the persistence of coping mechanisms in the face of setbacks. It is important to note that self-efficacy is a motivational construct based on self-perception of competence rather than *actual* level of competence. A teacher's self-perceived level of competence may be either higher or lower than an external assessment of teaching skill.

Self-efficacy theory, applied in the educational realm, has sparked a rich line of research into how teachers' self-efficacy beliefs are related to their actions and to the outcomes they achieve (Tschannen-Moran et al., 1998). According to social cognitive theory, teachers who do not expect to be successful with certain students are likely put forth less effort in preparation and delivery of instruction, and to give up easily at the first sign of difficulty, even if they actually know of strategies that could assist these students if applied. Self-efficacy beliefs can therefore become self-fulfilling prophesies, validating beliefs either of capability or of incapacity.

There are four major influences on teachers' self-efficacy beliefs. These are:

(a) The most powerful is *mastery experiences*, which for teachers comes from actual teaching accomplishments with students (Bandura, 1997). Efficacy beliefs are raised if a teacher perceives her or his teaching performance to be a success, which then contributes to the expectations that future performances will likely be proficient. Efficacy beliefs are lowered if a teacher perceives the performance a failure, contributing to the expectation that future performances will also fail.

(b) *Verbal persuasion* has to do with verbal interactions that a teacher receives about his or her performance and prospects for success from important others in the teaching context, such as administrators, colleagues, parents, and members of the community at large.

(c) *Vicarious experiences* are those in which the target activity is modelled by someone else. The impact of the modelled performance on the observer's efficacy beliefs depends on the degree to which the observer identifies with the model. When a model with whom the observer closely identifies performs well, the self-efficacy of the observer is enhanced. When the model differs in ways that seem salient to the observer, for example in terms of the level of experience, training, gender, or race, then even witnessing a very competent performance may not enhance the self-efficacy beliefs of the observer.

(d) *Psychological and emotional* arousal also adds to a feeling of capability or incompetence. The feelings of joy or pleasure a teacher experiences from teaching a successful lesson may increase her sense of efficacy, yet high levels of stress or anxiety associated with a fear of losing control may result in lower self-efficacy beliefs.

Teachers' sense of efficacy

A teacher's sense of self-efficacy is a judgement about his/her capabilities to influence engagement and learning on the part of students, even those difficult or unmotivated (Woolfolk-Hoy 2004). Similarly, research indicates that a teacher's sense of efficacy beliefs affect his/her students' achievement, motivation and attitudes towards the subject they are studying (Ashton and Webb 1986; Ross 1992; Midgley, Feldlaufer, and Eccles 1989). In addition, teachers with high senses of efficacy are more open to new ideas and more willing to experiment with new teaching methods to meet student needs. Such teachers also tend to exhibit higher levels of planning and enthusiasm; they therefore will work harder with a struggling student and persist longer if difficulties arise. On the other hand, low-efficacious teachers exhibit a weak commitment to the profession, tend to be more authoritarian, use more teacher-centred approaches and blame others for failures (Evans and Tribble 1986;Czerniak and Schriver 1994).

PROFILES Guidebook for Partners

Part A - An Introduction to PROFILES

Sub-part 5

The Need for Stakeholder involvement

> If we want to be successful in school improvement, a broad curricular framework is necessary that takes into account a school culture of partnership between different communities of teachers, students, teacher educators, educational researchers, administrators and the democratic public. This requires collaboration beyond narrow boundaries of science subjects in schools.

An important consideration of PROFILES is the need to "bridge the gap between the science education research community, science teachers and local actors (stakeholders – see terms for meaning) in order to facilitate the uptake of inquiry based teaching" (FP7-science in society-call, 2009, 21).

5.1 PROFILES objectives towards stakeholders

PROFILES intends to involve a wide range of stakeholders from the initial phase of the project and maintain interaction with them throughout the project. Initially, views and opinions are collected, while at a later phase stakeholders are involved through discussions on progress and outcomes of the project activities. In putting forward new approaches and in trying to implement innovative practice of inquiry-based science teaching, PROFILES proposes to:

(1) take a range of stakeholder views into account (objective 1), and
(2) actively solicit their support for the wider dissemination of best practices (objective 2).

These two objectives are seen as important, especially when innovative practices for science teaching incorporate socio-cultural considerations (Harrison et al., 2008), as this emphasis is relatively recent, particularly at secondary school level.

The particular value in involving stakeholders, initially through activities such as a Delphi study, but additionally as partners in the development, evaluation and dissemination of the projects activities and outcomes, is seen as:

(a) disseminating the stakeholders' views so that they are known – and hopefully appreciated – by teachers;
(b) allowing the seeking of a stronger partnership between various stakeholders and science teachers;
(c) aiding the implementation and dissemination of PROFILES ideas, intentions and objectives to facilitate the uptake of innovative science teaching and the enhancement of scientific literacy.

5.2 Applying the Delphi Method to determine stakeholder views

The following key characteristics of the Delphi method focus on the issues at hand and separate Delphi from other methodologies:

1. *Involving stakeholders*

   Stakeholders are all who have an interest in the area under investigation. In the case of PROFILES, the stakeholders are those who feel they have an interest in, or are affected by, the science education offered at the secondary school level. Clearly this applies to science teachers, students studying science (or a sub-division of science) and parents of the students. However, because the headmaster/mistress impacts on the functioning of the teacher and students, these persons also have an interest and can be considered stakeholders. This also applies to curriculum developers, assessments/examination personnel and of course science educators involved with the pre-serve or in-service professional development of teachers.

   When it comes to those impacting on the students, the stakeholder net widens to include University professional staff, academy of sciences, science centres/museums and also future employers. As students studying science may or may not embark on a career interrelated with science, employers can be a wide group – industrial employers, commercial employers, social service employers and as well as local entrepreneurs. All can be considered as stakeholders.

   So far the Ministry of Education has not been mention but their role in guiding the educational system means they are also a stakeholder, especially those involved with science education. Impacting on the Ministry of Education are politicians in general both at the local level (town mayor etc) and at the national level.

   The range of stakeholders is thus truly wide and involves some very familiar with science and scientific ideas but also others who have had little to do with academic science since embarking on their own career/

2. *Structuring of information flow*

   The main contributions from the stakeholders are collected
   (a) in the form of open questions to solicit their views in as general a way as possible
   (b) in the form of answers to questionnaires,
   (c) in the form of sequencing priorities, or importance of aspects, derived from previous responses, and
   (b) their comments to these answers and the manner in which PROFILES is focussed.

   It is usual for the WP leader to control the focus and the interactions among the partners as the Delphi study progresses by processing the information and guiding the direction of the study. Local partners play a major role in ensuring the translation of instruments is meaningful and filter out irrelevant content solicited from the stakeholders.

3. *Regular feedback*

   As the PROFILES Delphi study progresses, stakeholders are involved in commenting on:
   (a) their own forecasts,
   (b) the responses of others and
   (c) on the progress of the panel as a whole.

   At any moment stakeholders can revise their earlier statements. This is a particular advantage of the Delphi study because, while, in regular group meetings, participants tend to stick to previously stated opinions and often conform too much to group leader, the Delphi method prevents it.

Anonymity of the participants

Usually all stakeholders maintain anonymity. Their identity is not revealed even after the completion of the final report. This stops them from dominating others in the process using their authority or personality, frees them to some extent from their personal biases, minimizes the "bandwagon effect" and "halo effect" and allows them to freely express their opinions, encourages open critique and admitting errors by revising earlier judgments.

5.3. Facilitator of the Delphi Study

The WP leader coordinating the Delphi method is the *facilitator*, and facilitates the handling of responses by each partner's *panel of stakeholders*, (selected by partners because they are expected to hold opinions related to science education in some way). The facilitator sends out the initial starter and questionnaires to the partners (who then translate these before sending to the stakeholders. The stakeholders follow the guidelines and present their views. This can be by regular mail, e-mail, telephone conversation or even face-to-face contact. Responses are collected and analyzed by the partner to allow the identification of common and conflicting viewpoints. Once translated these are sent to the facilitator (WP leader) who then compiles the 2nd round questionnaire.

A second round of the Delphi study is developed based on the common viewpoints gradually working towards synthesis, and building consensus. Additionally **PROFILES** pays careful attention to stakeholders' views both before, and during, implementation of the project.

A similar process takes place for the 3rd round when stakeholders are asked to prioritise key aspects derived from the 2nd round questionnaire.

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Appendix 1 **Position Statement on Scientific Inquiry (NSTA, 2004)**

Introduction

The *National Science Education Standards* (NSES p. 23) defines scientific inquiry as "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world." The Science as Inquiry Standard in NSES includes the abilities necessary to do scientific inquiry and understanding about scientific inquiry.

Scientific inquiry reflects how scientists come to understand the natural world, and it is at the heart of how students learn. From a very early age, children interact with their environment, ask questions, and seek ways to answer those questions. Understanding science content is significantly enhanced when ideas are anchored to inquiry experiences.

Scientific inquiry is a powerful way of understanding science content. Students learn how to ask questions and use evidence to answer them. In the process of learning the strategies of scientific inquiry, students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defend their conclusions.

The National Science Teachers Association (NSTA) recommends that all K-16 teachers embrace scientific inquiry and is committed to helping educators make it the centerpiece of the science classroom. The use of scientific inquiry will help ensure that students develop a deep understanding of science and scientific inquiry.

Declarations

Regarding the use of scientific inquiry as a teaching approach, NSTA recommends that science teachers

- Plan an inquiry-based science program for their students by developing both short- and long-term goals that incorporate appropriate content knowledge.
- Implement approaches to teaching science that cause students to question and explore and to use those experiences to raise and answer questions about the natural world. The learning cycle approach is one of many effective strategies for bringing explorations and questioning into the classroom.
- Guide and facilitate learning using inquiry by selecting teaching strategies that nurture and assess student's developing understandings and abilities.
- Design and manage learning environments that provide students with the time, space, and resources needed for learning science through inquiry.
- Receive adequate administrative support for the pursuit of science as inquiry in the classroom. Support can take the form of professional development on how to teach scientific inquiry, content, and the nature of science; the allocation of time to do scientific inquiry effectively; and the availability of necessary materials and equipment.
- Experience science as inquiry as a part of their teacher preparation program. Preparation should include learning how to develop questioning strategies, writing lesson plans that promote abilities and understanding of scientific inquiry, and analyzing instructional materials to determine whether they promote scientific inquiry.

Regarding students' abilities to do scientific inquiry, NSTA recommends that teachers help students

- Learn how to identify and ask appropriate questions that can be answered through scientific investigations.
- Design and conduct investigations to collect the evidence needed to answer a variety of questions.
- Use appropriate equipment and tools to interpret and analyze data.
- Learn how to draw conclusions and think critically and logically to create explanations based on their evidence.
- Communicate and defend their results to their peers and others.

Regarding students' understanding about scientific inquiry, NSTA recommends that teachers help students understand

- That science involves asking questions about the world and then developing scientific investigations to answer their questions.
- That there is no fixed sequence of steps that all scientific investigations follow. Different kinds of questions suggest different kinds of scientific investigations.
- That scientific inquiry is central to the learning of science and reflects how science is done.
- The importance of gathering empirical data using appropriate tools and instruments.
- That the evidence they collect can change their perceptions about the world and increase their scientific knowledge.
- The importance of being skeptical when they assess their own work and the work of others.
- That the scientific community, in the end, seeks explanations which are empirically based and logically consistent.

--Adopted by the NSTA Board of Directors
October 2004

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