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PARSEL

Popularity and Relevance of Science Education for scientific Literacy

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The PARSEL project: Popularity and Relevance of Science Education for Scientific Literacy.

Abstract

PARSEL is an approach, using teaching/learning modules, promoting greater popularity and relevance of science education. As the ultimate goal of this approach is to enhance students' scientific literacy for life within a European Union society, the modules are geared also to promoting learning for responsible citizenry. This is indicated by stating specific learning objectives/competencies aligned with the attainment of educational goals within science teaching through an appropriate context. PARSEL also provides the motive for students to meet their needs through designing the modules based on a three-stage model in such a way that the learning is interesting, promotes extrinsic motivation and is hence favoured by students (it is popular). So as to also promote students' intrinsic motivation, the title and focus of the modules are given a society orientation, using words/situations/graphics familiar to students. Student ownership is promoted and enhanced through strong student participation in the learning. PARSEL also stresses a number of teacher actions to appropriately guide student activities, such as strongly encouraging teacher ownership of the philosophy, promoting students' higher order cognitive skills and acquisition of an image of the nature of science reflection on teacher actions are encouraged and the involvement of formative assessment approaches are included in modules which relate to the student learning outcomes/ competencies and involve the teacher in observation, oral questioning, and/or marking of written work.

Key words: Relevance, popularity, scientific literacy, teacher ownership, education through science, 3-stage model

What is PARSEL ?

PARSEL is a European Commission, FP6 project under the Science and Society banner. This project puts forward an approach designed to raise the popularity and relevance of science teaching through a three-stage philosophical design which is illustrated through a collection of modified, or created teaching/learning modules. The modules cover a series of lessons at the secondary level (grades 7 upwards) and are designed for use within science, or biology, or chemistry, or physics classes. The main objective of PARSEL is to develop, test and disseminate pan-European science education modules which can be used to enhance scientific literacy. The modules are developed according to a common model, by a consortium involving eight Universities and ICASE.

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Why PARSEL ?

Many studies have pointed out that school science at the primary level (grade 1-6) is interesting and enjoyable for students (see review by Osborne, 2003). Students at this age like to interact with practical ideas, make things and utilised these in a variety of settings. As expected, based on psychological considerations, there is little by way of abstract thinking and the science is more related to exploring than drawing analytical inferences.

This situation, however, starts to change at the secondary level. Not only does science move more into abstract learning, but it also coincides with adolescent developments and, with this, students' interests outside the school become a greater focus of attention. Student interest in school science is also affected by its perceived relevance, especially where curricula are 'watered-down' versions designed for preparation for advanced studies (Millar, 2008).

The PARSEL project is an attempt to meet the challenge of putting forward teaching approaches to tackle the issue of a lack of popularity and relevance of school science at the secondary, and especially at the junior secondary, level. In so doing, the PARSEL partners recognise that for some students science is already interesting and relevant (often the more able) and see science careers as attractive. However, this is not the case for the majority of students (Schreiner & Sjoberg, 2004). This concern is also expressed by the European Commission through its recognition that Europe needed more scientists and that a lack of interest in school science is seen as detrimental to such a development (EC, 2004). Nevertheless, the PARSEL partners do not so much focus on making school science a springboard for further studies in science (the old traditional view – Fensham 2008), but see the learning of science as essential for life in general and of importance for all careers.

Because of the diversity of systems within Europe, any project determining its impact on raising the popularity of science and science teaching and promoting greater student interest in science across Europe requires a wider approach than is reasonably possible within one country. An added value of this project is thus the coordinating and collating of exemplars of good practice from a range of countries. This is aided by creating a formulation of the varied factors that leads to exemplar teaching/learning materials in general and which guides the orientation of science teaching towards the promotion of scientific and technological literacy in a more interesting manner.

By careful translation and the testing of selected materials and resources, an additional added value within a country is the greater diversity of materials available. Through strong dissemination within the country, stakeholders can become more aware of a wider range of exemplary type materials and of the potential of such materials for tackling the problem of a lack of popularity of science. The compilation of the exemplar materials from a range of countries simultaneously takes note of research and curriculum developments within these countries, at least at the project level, and the application of the research to the classroom. But the project compilation of materials intends to build on this and tries to go beyond that which is possible at the national level.

The partners of the consortium bring with them considerable expertise in the area of science education (Gräber & Bolte, 1997; Hofstein et al., 1997; Holbrook & Rannikmae, 1997, 2002; Zoller & Tsaparlis, 1997; Gräber, 1998; Bodezin & Mamlok, 2000; Hofstein & Mamlok, 2001; Galvão & Abrantes, 2002; Gräber et al., 2002; Galvão, 2004; Reis and Galvão, 2004a, 2004b; Mamlok-Naaman et al., 2005, Szybek, 2005; Gräber et al., 2006) and in particular the need to increase the relevance of science teaching. A further added value of this project is the bringing together of science education experts from a range of countries to share experiences and visions. This will aid the diversity of teaching/learning materials and resources put forward as exemplars and include greater expertise in developing diverse ways of enhancing dissemination of the materials within a country and across Europe.

As the partners are well acquainted with the worldwide literature pertaining to the development of scientific and technological literacy (Bybee, 1997; Graber, 1997, 2002; Holbrook, 1998; DeBoer, 2000; Rannikmae, 2001; Fensham, 2004; Sadler, 2004), yet another added value of the consortium is that developments at the international level can also be considered and appropriate additional materials, from outside Europe, have been incorporated in the project, where appropriate.

Raising the Popularity of School Science.

Research has shown (e.g. the ROSE project - Schreiner & Sjoberg, 2004) that whereas science and technology are considered important aspects of life by 15 year old students, the same cannot be said of school science. Students do not like to learn where facts are the focus of attention and especially where the facts are historical, or have little relationship to their lives. Girls have little appreciation, in general, for technological areas stressing how things work, but have more appreciation of more personal related topics related to one’s body, or health. New areas of learning often made attractive by television are interesting to both boys and girls, but rarely taught - for example outer space, or space travel.

Research also points to greater student involvement being more interesting to students and hence students prefer experimental type lessons, or being involved in meaningful discussions, designing posters or interacting with the internet. Student centred learning is thus an important focus for science lessons, which when also stimulating intellectually needs, can be labelled inquiry learning (EC, 2007) without heavily distinguishing between guided inquiry, less teacher controlled open-type inquiry, or authentic inquiry where students very much instigate the investigatory questions. The term popular is used, as indicated in the PARSEL booklet (see appendix), to encompass liking and being interested to study the subject in school. It also refers to liking science in general. It is thus an emotional component that stems from the module and the way science is presented.

The teacher's perception of the purpose of school science is an important variable to explain the failure to make science teaching popular. In this context, the observations by Mead and Métraux (1973) can be summarized as follows: "Scientists tend to transfer their discipline's abstracting methods to everyday life and the classroom instead of enlivening the material with their personality." Of course this ‘science for scientists’ view is particularly stressed in teacher dominated lessons and again, unfortunately in the teaching materials used. Furthermore this is all too often reinforced in teaching resources such as tests and examination papers.

A further reason for the unpopularity of science lessons has to do with the subject’s difficulty. Most topics, especially in the physical sciences, are abstract in nature and do not lend themselves to the students’ day-to-day experiences. Such learning requires thinking at a formal-operational level. However, various studies show that most students have not usually reached this level of thinking (Gräber & Stork, 1984). Sadler and Zeidler (among many others) complain of the poor links of science teaching with society and have suggested that teaching/ learning materials should encompass a socio-scientific issues-based approach (Sadler, 2004; Zeidler et al., 2005).

Raising the Relevance of School Science

The STS movement has shown that links between science and society help students see the relevance of the science they are learning (Yager, 1999). Relevance helps students better appreciate 'why study a topic.' Relevance can also raise student interest (Yager, 1999).

The PARSEL teaching/learning materials have a grounding in activity theory (Roth and Lee, 2003; Van Alsvoort, 2004) and hence focus on motives meeting the needs of society, without diminishing the science conceptual needs of the students. This means the teaching/learning materials, and linked to this, the teaching approaches are encouraged to focus on guiding the conceptual teaching of science towards a societal relevance and towards a daily-life oriented, rather than an orientation towards the discipline in isolation. This has been shown in the literature to be more acceptable to students (and especially to girls) (Zeidler, 2005). As with many STS programmes, the PARSEL preferred approach to relevance is social context-based, attempting to focus on student-perceived, meaningful learning.

Enhancing Scientific Literacy through School Science

There is worldwide consensus that, regardless of any cultural differences that there might be, societies need scientifically literate citizens (AAAS, 1989; NRC, 1996; Bybee, 1997; BLK, 1997; DeBoer, 2000; Holbrook and Rannikmae, 2002; Fensham, 2004; Brown et al., 2005). The National Research Council (1996) of the US, in its Science Education Standards, states: "All of us have a stake, as individuals and as a society, in scientific literacy …. like solving problems creatively, thinking critically, working cooperatively in teams, using technology effectively, and valuing life-long learning. The economic productivity of our society is tightly linked to the scientific and technological skills of our work force." The last point is seen as being broadly consistent with the EU's Lisbon agenda - to become the world's most dynamic knowledge-based society.

Scientific literacy for all citizens not only enhances the society's understanding of science, providing skills needed in everyday, societal and vocational life and developing a climate for public decision-making based on arguments, but also establishes the fundamentals for more science-oriented career choices. Most science curricula across Europe, and indeed around the world, see science education having the goal to enhance scientific literacy (Millar, 2008). PARSEL endorses this.

The PARSEL approach focuses on enhancing citizen's need for scientific literacy (contrasting this with a vision of 'scientific literacy' often expressed by scientists). Scientific literacy is thus seen as

> *"developing the ability to creatively utilise sound science knowledge in everyday life, or in a career, to solve problems, make decisions and hence improve the quality of life"* (Holbrook and Rannikmäe, 1997).

It is a sad fact that teaching/learning materials promoting scientific and technological literacy related to responsible citizenship are not common place in European classrooms today. This is largely because curricula in many countries are still dominated by the conceptual acquisition of scientific 'big' ideas, in which abstract, conceptual science is taught and seen as fundamental. However, many examples of teaching/learning materials exist away from curriculum demands and the project partners have many examples, often evolved with students studying to become teachers or for higher degrees such as MEd and PhD. In addition, project partners have had involvement in projects where the goals have allowed greater freedom to develop teaching/ learning materials without curriculum, or external examination constraints. Many of these projects have been developed with the help of industry and have tried to encompass industry needs from science teaching that go beyond content to include managerial and social targets (e.g. Gräber, W., Neumann, A., Erdmann, T., & Schlieker, V., 2006). By drawing together carefully selected exemplar materials and resources and modifying these, as appropriate, to form a coherent set, a degree of teacher ownership is propagated within the network countries, through the testing of such teaching/learning materials in the classroom situation and paying careful attention to student reactions (and especially comments from girls). These tested modules form the base for the dissemination thrust within each partner country.

What Approaches and Measures have been Created?

To promote learning that meets multidimensional scientific literacy demands (Bybee, 1997) for all students, an approach to teaching is put forward which promotes a greater degree of student autonomy, stresses inquiry teaching to promote the acquisition of process skills and utilises society context-oriented approaches. As this demands that teachers possess skills to teach in a wider context, teaching/learning materials assist the teacher in these endeavours. The modules provide a challenging learning environment according to a constructivist teaching/learning paradigm; as well as give guidance to students towards self-regulated and challenging learning in both problem solving and decision making.

This means that teaching/learning modules support the development of cognitive and meta-cognitive strategies, as well as emotional and motivational dispositions in an interesting environment and with relevance for future life and/or careers. In the literature such approaches are found under the keywords Science/Technology/ Society (STS), Science/Technology/ Literacy (STL), Context-oriented and subject-integrated teaching and, more latterly, Socio-Scientific Issue-based teaching (SSI). There is a wide assortment of teaching materials related to these approaches that have strong similarities, but also with different stresses. Unfortunately, these materials are mainly linked to projects and not fully available in any one country, or for any one teaching programme. PARSEL sets out to make such science teaching-learning materials available across Europe through the development or adaptation of modules.

Operational Intentions of the PARSEL Approach

PARSEL is intended to operate, based on a carefully derived PARSEL model allowing interpretations of the intentions for a diverse, pan-European society. The validity of the PARSEL model is its degree of flexibility to accommodate such diversity. The width of these interpretations is illustrated in the variety of teaching/learning modules collected and published on the project website (www.parsel.eu).

Operationalising the PARSEL Model

PARSEL modules exhibit a unique context approach, in which the science conceptual learning is totally embedded in a complex social frame. Each module initiates learning from that which is familiar (a constructivist and motivational approach). Each module ends with revisiting the social situation (going beyond scientific problem solving to applying the acquired learning to a relevant, complex context) and looks for developing students' competence on socio-scientific decision making. This uniqueness is based on a 'PARSEL model' for module development, and also in striving for a pan-European appeal. In line with modern thinking, the PARSEL model is developed on an 'education through science' (Holbrook & Rannikmäe, 2007) interpretation of science education. This means learning in each PARSEL module is intended in four education areas, each with its own emphasis depending on the module and the expectations of the teacher:

- ***Intellectual development*** (especially conceptual science and its applicability to complex situations).
- ***Process skills development***, especially in the problem solving context (with student involvement in an inquiry approach and including as appropriate, experimentation and an understanding of the nature of science)
- ***Personal development*** (related to communication ability, attitudes towards science, scientific attributes such as initiate, perseverance, safe working)
- ***Social development*** (related to interrelating to others – cooperation, leadership skills and social values (especially those developed through justified socio-scientific decision-making)

The derived model can be described as encompassing **three stages**, identified as follows:

Stage 1 - ***contextualisation*** of a situation/issue (a complex situation).

This is the introduction to the society issue as reflected in the title of the module. Relevance is enhanced by linking the title to the society situation rather than attempting to introduce unfamiliar scientific terms. This means the initial teaching concerns the social aspect and it is put in to an appropriate context by means of a 'scenario' – a story, a situation, an elaboration of the title or such triggers to initiate discussion. Based on the considerations in stage 1 students are led to realise that they lack the scientific ideas which are important for a more in-depth discussion. This realisation thus forms the basis for stage 2.

Stage 2 - ***decontextualisation*** (breaking down the complex situation to learn the science).

The scientific ideas, the scientific problems to be solved and the associated process skills, personal and social attributes are now incorporated into the teaching. By following on from stage 1, the relevance of the scientific learning is clearly established. The approach within stage 2 will be familiar to teachers and the module take this opportunity to guide teachers towards guiding or open inquiry style learning and maximizing student involvement in the learning process.

Stage 2 is the major component of the module and inevitably takes the majority of the teaching time. The extent to which scientific ideas are explored or scientific problems solved will depend on the scientific learning deemed necessary for an appreciation of the socio-scientific issues introduced in stage 1. Stage 2 is purely scientific, although educational competences such as cooperative learning, scientific communication and the development of perseverance, initiative, and ingenuity are also intended.

Stage 3 - *recontextualisation* (re-examining the complex situation).

This stage is perhaps the most important. Here the students consolidate their science learning by transferring the learning to the socio-scientific issue introduced in stage 1 and through discussion and reasoning arrive at a socio-scientific decision. In this the actual decision made is of less importance than the reasoning put forward and the degree to which the scientific component is included in an appropriate manner. This stage involves argumentation skills, leadership skills and the ability to reason using sound science ideas and balancing these against other considerations such as ethical, environmental, social, political and, of course, financial arguments.

The manner in which the model encompasses appropriate teaching-learning approaches, identifies the educational skills being developed, pays attention to the science education learning intended, meets popularity and relevance demands and illustrates its grounded in activity theory model is further elaborated in the table below

The 3-STAGE PARSEL MODEL for teaching-Learning Modules (A Theoretical Construct for the Promotion of Scientific Literacy)			
	STAGE 1 **Setting the scene**	**STAGE 2** **Inquiry-based problem solving**	**STAGE 3** **(Socio-)Scientific decision making**
TEACHING-LEARNING APPROACH	Material presented through a real life title and scenario. The scenario provides the stimulus for the subsequent learning.	Teacher guided, student-centred learning materials includes Problem Solving, Nature of Science and/or Conceptual Science Learning (and consolidation of the conceptual learning through adequate feedback - assessment).	Teacher guided, student centred materials includes reasoned (socio-) scientific decision making (and consolidation of the conceptual learning through adequate feedback - assessment).
EDUCATIONAL SKILLS BEING DEVELOPED	Recognition of the link between the real life situation and science learning.	Development of: 1.Process skills in specific setting. 2.Conceptual acquisition. 3.Interpersonal, intrapersonal and communication skills in a specific setting.	Development of: 1.Social/interpersonal skills in a specific setting. 2.Justified decision making involving conceptual science and a variety of relevant social factors. 3.Intrapersonal and communication skills in a specific setting.
SCIENCE EDUCATION LEARNING	Introducing a socio-scientific learning area.	Detailing the related science conceptual learning to be acquired through inquiry based, experimentally driven, problem solving and identified on a need 'to-appreciate-the-issue' basis.	Applying conceptual science to reasoned, (socio-) scientific decision making, related to the issue.
POPULARITY AND RELEVANCE	Stimulating RELEVANCE of science for everyday life and hence raising POPULARITY.	Enhancing POPULARITY by relating the conceptual learning and Nature of Science to the student's real life and/or career.	Strengthening RELEVANCE and enhancing SCIENTIFIC LITERACY.
GROUNDED IN ACTIVITY THEORY	Showing NEEDS and stimulating MOTIVATION for learning.	Providing needed ACTION through appropriate ACTIVITIES.	Providing for needed ACTION through appropriate ACTIVITIES and REFLECTION.

Determining the PARSEL Context

The context chosen for each module tries to relate to student concerns (insofar as this is possible in whole class situations, where individual preferences may be diverse). Generally, the context is a localised social situation, but one which has a science component suitable for conceptualisation of the underlying scientific ideas involved. The title of the module is written using familiar terms (unfamiliar scientific terminology is purposely omitted). Examples include (i) Shampoo – is there truth behind the advertisement ? (ii) Lara is pregnant. (iii) Are you and your family happy with the electricity bill? In each case, the context is given meaning by being illustrated through a scenario.

Unfortunately, the thinking about scientific literacy, at the school level, is often taken to relate to the development of scientific knowledge. Many teaching/learning materials have this as their focus, even where they promote interesting applications of the science, or introduce intriguing investigations and projects. This has not led students to show greater interest in science lessons, or science in general, and is especially true for girls (Osborne et al, 2003). A goal of this project is to give scientific literacy a more societal context and hence emphasise societal needs through exemplary teaching/learning materials so as to bridge the gap between the research based science education literature and the vision of teaching/learning materials and other resources (especially test and examination papers) held by many school teachers. The implication is that science learning in school is for all students and to enable them to deal with societal endeavours – the workplace, the home, within the community.

While popularity and relevance are a focus, the learning emphasis in PARSEL modules is through:

- Building students' scientific literacy within a context specific, rather than an isolated science content orientation, and can be expressed as promoting both problem solving skill in a scientific context and socio-scientific decision making skills relevant to society.
- Adopting a societal (rather than a scientist) focus and relating this to a functionality in the workplace, the home, or within the community.

- Moving away from a solely content specific approach having the goal of forming a base for further scientific studies.

Incorporating Problem Solving skills

Learning through scientific problem solving is an essential component of PARSEL modules. It is seen as a key scientific endeavour. Problem based learning (PBL) is heavily promoted at the dominant, stage 2 level (where the science learning is temporarily separated from the society situation (decontextualised) and solutions are purely scientific). Scientific competencies/ objectives, to be developed within PBL in stage two, can be sub-divided into two key areas:

- skills acquisition (process skills) and
- intellectual development (preferably higher order cognitive and meta-cognitive learning)

Socio-scientific Decision Making

This is another key learning feature of PARSEL and is prominent in stage 3 of the PARSEL model. It encompasses:

- justified decision making as an additional component of the PARSEL learning approach;
- socio-scientific issues (SSI) rather than simply considering science issues in isolation from other relevant factors within the society;
- decision making intended to promote reasoning ability, communication skills and especially argumentation;
- making a justified decision in a social environment so as to place the educational learning through science alongside other aspects to be considered, such as economic, ethic/moral, political, sociological and environmental concerns.

Describing the PARSEL Modules

Each module includes the following components (as separate computer files):

1. ***a Frontpage*** which includes the title, abstract and key learning attributes (competencies or objectives).

2. ***a Student guide*** which describes the scenario and indicates student activities (geared to the learning being heavily student centred).

3. ***a Teaching guide*,** which puts forward suggestions for the teaching approach for teachers (only a suggested approach to allow for teacher ownership of the teaching).

4. ***an Assessment file*** which provides formative assessment ideas to enhance assessment for learning (rather than always a summative, assessment of learning, approach).

5. and, in some cases, T***eacher notes*** to provide background information for teachers and/or suggestions for student worksheets which may be useful for the teacher.

Each of these components are now described in more detail.

1. The **front, or cover, pages** indicate:
   a) The title of the module (using familiar terminology and often a question).
   b) The grade level for which the module was written (but usable at other levels with modification if desired by the teacher)
   c) The main science conceptual learning (as might be related to a curriculum)
   d) An abstract of the module
   e) A tabular indicator pointing out the sections (or separate computer files) in the module
   f) The intended learning abilities in the 4 educational areas, expressed as objectives (scientific learning) or as competencies (life skill focused)
   g) A general descriptor of the intentions of the set of modules within the PARSEL project.

2. The **student activity file** comprises a scenario and student tasks. The degree of guidance for the students depends on the level of inquiry (guided, open, authentic) intended by the author of the modules. Both the scenario and the formulation of the student tasks can be modified by the teacher to suit their situation.

3. The **teaching guide** indicates an approach to teaching put forward by the designer of the module. Across the modules they provide a diversity of teaching aspects which can in many cases be interchanged between modules and still keep a student-centred approach. The area of emphasis for the teaching are not indicated and hence this is left for the teacher to determine as this relates to the specific students being taught. In some cases learning outcomes per lesson (in appropriate combinations across, or sub-sets of, the four educational learning areas) are provided to suggest a more detailed focus for the teaching.

4. The suggested ideas for the **assessment** of students concentrate on putting forward formative assessment ideas. These ideas may be given in three styles:
    i. Assessment centred on the skills to be achieved in the four learning areas.
    ii. Assessment related to the learning outcomes specified for the lesson.
    iii. Assessment based on the selected procedure for assessing (whether the teacher chooses to assess through written work, oral interaction, or through observations of the students during their learning).

5. In some modules, **teacher notes** are also included. Where this is the case, the notes cover one or more of the following:
    i. Student worksheets.
    ii. Explanatory notes.
    iii. Background information.
    iv. Details of calculations or answers to questions.

PARSEL modules are designed to cover a series of between 4 and 10 lessons (based on each lesson being 45 minutes):

Stage 1 - contextualisation of a situation/issue (a complex situation). During this stage, the teacher introduces the 'scene', issue or area of concern and at the same time determines the students' prior science knowledge, depth of interest and its relevance for the students as a contextual area for science education learning. (approximately one lesson)

Stage 2 - decontextualisation (breaking down the complex situation to learn the science). Science ideas, relevant to the context, are decontextualised from the society. This part draws on science curricula and inquiry (enquiry) learning approaches, leading to student acquisition of related scientific concepts. (a minimum of 2 lessons is anticipated)

Stage 3 - recontextualisation (re-examining the complex situation). Students consolidate their newly acquired scientific learning by being asked to transfer this to the context introduced in stage 1, thus enabling students to utilise relevant science in deriving socio-scientific decisions connected with the society issue or concern recognised by students are being relevant to their lives. (1 – 2, or even more lessons)

Disseminating PARSEL: the process

PARSEL intends to disseminate materials and resources at two major levels - dissemination within the countries of project partners and a wider dissemination within Europe and worldwide. By disseminating to a wide audience through the website, journal article and conference papers, the project hopes to further impact on the raising of interest in relevance worldwide and the use of the exemplary teaching/learning materials across a wider range of countries, or stimulate development of additional materials based on the model.

The national dissemination involves the translation of the exemplar materials into the language(s) used in teaching science subjects at the secondary school level, in each of the countries concerned. The translation is carefully checked by the partners to ensure that the intended meaning is maintained before distribution for testing. The tested materials and outcomes are disseminated to all stakeholders within a country, especially to teachers making use of the local science teacher association and other channels, making use of the website, journal articles and seminar/conference papers and other channels that become available.

The dissemination process had to start with the modules' construction, when the partners first defined a set of criteria for including modules as PARSEL's exemplar material (www.parsel.eu). For instance:

- Modules have to enhance learning for responsibly citizenry, by having learning objectives such as the construction of social and communication competencies, the development of attitudes, the development of decision making, among others;
- Modules have to be perceived by the students as popular and relevant, by conveying a sense of purpose and by creating an inquiry classroom climate, among others;
- Modules have to be student centred and facilitate his/her participation in the activities proposed;
- Modules have to promote higher order cognitive thinking, to have a strong bases on experimentation and to allow the development of a vision of the nature of science as tentative, empirical and culturally embedded; and
- Modules have to facilitate teacher ownership.

Secondly, partner went on to construct modules (or to adapt existing ones), taking into consideration these criteria. After the stage of criteria definition and modules construction, modules were submitted to a process of peer-review. According to detailed group discussion, each partner revised six modules from his partners. All reviewed modules are available on the website (www.parsel.eu).

After all modules had been created, revised and, needed ones, also translated, modules were tried out in the classroom. The trying out process's goals aimed at evaluating students' and teachers' interaction with the material and reporting the outcomes of testing. For that, teams of teachers were formed in each partners' country.

It should be mentioned that an important characteristic of PARSEL is that modules should be implemented in regular classrooms, and should be articulated referring to existing curricula. So, each teacher was free to choose which module to try out, in accordance to his/ her needs and interests, his/ her students' characteristics, and curricula constraints. As a result, by the end of the process not all the modules had been tried out. Nevertheless, the advantages of promoting ownership strongly overpass this limitation, as will be discussed next.

Teacher ownership

Teacher ownership is a key feature of PARSEL modules. Teachers are encouraged to modify modules to better fit their teaching situation and the background of their students while still remaining faithful to the PARSEL model. During the Final PARSEL Conference in Berlin the posters on display illustrated how teachers have used innovative ways to relate the modules to their classroom situation. Other posters illustrated how teacher ownership, geared to dissemination and evaluation, has led to thinking about future module modifications. This information will be available in the conference proceedings which are in the process of preparation and will be published in 2010 (Bolte, C., Holbrook, J., Gräber, W. (eds.) (2010).

Encouraging teachers to take ownership of the modules was seen as an opportunity to promote changes on teachers' practices and even conceptions. Indeed, teachers need to understand expected changes, to agree with it, to perceive it as solutions for the problems they identified and also to develop adequate competencies to implement desired changes (Fullan, 2001). By facilitating teacher involvement with modules implementation and by creating reflexive spaces where teachers can discuss their views and difficulties, PARSEL facilitated teachers' comprehension of some important ideas considering science education and also the process of implementing some of the innovative ideas.

But what does teacher ownership really mean within the PARSEL context? First of all, it means that teachers can choose which modules to implement in their own classroom. This is an important aspect as one concern of PARSEL is that modules can be used in regular classrooms and integrated into regular science curricula. Besides, taking ownership means that teachers can introduce any change in order to adapt modules to their own characteristics, and also to students' and curricula' characteristics. The possibility of introducing changes into the modules was such a central concern that one important criterion in modules construction was that they should provide enough information to guide teachers' work, but simultaneously they should be sufficiently open to facilitate modifications when perceived as needed by the teachers.

Making teacher ownership a central goal of dissemination had implications for the teacher selection process. Indeed, teachers were expected to present some characteristics, the most important of which was to be willing to cooperate with PARSEL partners. So, teams of teachers willing to participate in the trying out stage were formed and it was expected from them to use some of those modules in their classrooms and to evaluate its use, considering students reactions and learning, difficulties, and modifications made.

Each partner developed his/her own plans and ways of working with the local team of teachers. Most partners developed some meetings with the teachers, where they were exposed to PARSEL's philosophy and modules and where they learned about the three stage model and the evaluation methods and instruments (Gräber & Lindner, 2008; Holbrook, Rannikmäe & Kask, 2008). During these seminars teachers were encouraged to present their ideas, doubts and difficulties and give reasons for choosing modules. The website was an important resource made available to them, as they were able to find important (complementary) information about the PARSEL project, its ideas and goals and also information concerning modules. Teachers were supported during the implementation process by ways of seminars, tutorial approaches, and internet tools.

Dissemination: Final considerations

To be involved with changes is a major factor contributing to successful change in practices and conceptions. But this is a slow process, as it implies special contexts where teachers can develop new competencies and reflect on their own experiences relating it to innovations.

In the context of the PARSEL project most modules were implemented in each partner's country by a small amount of teachers. Each partner involved in average eight teachers, which represents about 600 students involved with this new way of teaching and learning science. Nevertheless, by forming such small teams of dynamic and enthusiastic teachers, each partner had the opportunity to support changes, to deal with uncertainty and with difficulties that emerged during the implementation process and most important of all to facilitate teacher ownership. University-teacher collaboration was an important issue in creating contexts of change. But, managing change has to be a continuous process and not a punctual one. This is a limitation within any project. Projects by definition are time limited. What will happen to university-teacher collaboration? Will it be finished after the project ends? Will teachers involved with PARSEL maintain recently developed ideas and practices? How will they manage opposing contexts, difficulties related to time and curricular constrains? Will they give up when they face students' resistance concerning this type of teacher-learning approach? These are important questions that deserve reflection.

Having strongly sought to promote teacher ownership was a positive issue of the project, as it empowered teachers to deal with difficulties they will meet in the future. And also, by involving teachers with the new ideas and practices, PARSEL created a context that can facilitate its dissemination, as by deeply believing in it teachers are motivated to share it with their school peers. A facilitating factor in this process of local dissemination will be modules characteristics. Indeed, their appellative character, being easy to apply and being sufficiently open to promote articulation with curricula, are characteristics that can captivate other teachers at school and that also can motivate teachers continued use. However, mention should be made to the way teachers will take ownership of modules. Will they use it but maintain the same practices? Will they "apparently change" without really changing? Once more, this issue calls attention for university-teacher collaboration, as an essential path for promoting desired changes.

Based on acceptance of the exemplary materials in the countries of the project, the project can put emphasis on the wider dissemination of the materials into other European countries, noting potential language limitations stopping materials being usable directly in the classroom. This dissemination makes use of partner contacts with others in the field of education, journal articles, conferences and also the ICASE worldwide network, which is mainly in English.

PARSEL Modules' Evaluation

It should be noted that in assessing the PARSEL modules it was vital to use and develop measures which are highly aligned with the nature, content, and pedagogies that were adopted and implemented. In the project we chose to relate to the

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theoretical framework which was suggested by van den Akker (1998). Van den Akker suggested that while implementing a new curriculum; the main goal is to reduce the gap between theory and practice.

Following this idea, we tried to assess the gap between the developers' intentions and the results which were expressed in the field. Our idea was to explore the perceptions of the students and the teachers that participated in the project and to compare them to the developers' intentions.

In the current chapter we chose to focus on the students' attitudes toward the PARSEL modules, the way in which they perceived it, and how the modules were implemented by their respective teachers. We intended to explore the students' reactions referring to the intentions of the developer to make the modules interesting and relevant for enhancing scientific literacy. Moreover, the developers of the various science oriented modules made a genuine attempt to develop modules which are highly student centred both regarding the content as well as the instructional methods (pedagogies) which were used.

The research questions

There are many questions which arise relating to the implementation of the PARSEL modules:

- Was the module interesting and useful?
- Was the module perceived by the students as relevant to their lives?
- Did the module enhance the students' scientific literacy?
- Was the module student centered?
- Did the module develop cognitive skills?
- Was there any change of their attitudes and beliefs towards science after learning the PARSEL module?

We claim that the answers to these questions could be used in one's attempt to bridge the gap between the intended curriculum and the operational curriculum.

Methodology in different countries

The evaluation of the implementation was based on data which were obtained from teachers and students who were involved in the process of the implementation of the modules. Thus, two sets of instruments were used to obtain answers to the above written questions. At the same time, it was recognized that the instruments should not be too detailed, in order to avoid taking away valuable teaching time or involving the teachers and/or students in extensive out-of-learning programme tasks.

As a result, some research tools were suggested, and each PARSEL group chose the tools that fitted the educational situation in its respective country (based on the students' characteristics and educational system). There were classroom observations, interviews with teachers and students, and different kinds of student- and teacher questionnaires.

Discussion and implications

Popularity, relevance and scienctific literacy were defined by the PARSEL project as follows (Blonder, Kipnis, Mamlok-Naaman, & Hofstein, 2008):

Popularity - this refers to students in favor of science lessons and who wish to study the subject in school. It also refers to liking science in general. It is thus an emotional component that stems from the module, but also by the way science is presented.

Relevance - the students recognize that the modules are worthy of study. They understand the purpose in studying the modules and are thus motivated to study them.

Scientific literacy - scientific literacy enhances society's understanding of science by providing skills needed in everyday social and vocational life. It develops a climate for public decision-making based on arguments, and also establishes the fundamentals for more science-oriented career choices.

In order to understand the results we obtained in this study, we may have a look at one of the modules that were implemented in Israel. The particular module "Brushing up with chemistry", which was originally developed in Greece (Tsaparlis, & Papaphotis, 2002) and tried out in Israel, shows that the terms of popularity, relevance and scientific literacy were integrated into the PARSEL modules, as shown in results of the semantic differential for one class that learned this module. In this module, students should become acquainted with toothpastes and products that we use in everyday life, in order to be able to decide which toothpaste is better to use and to buy. They learn what are toothpastes composed of and what is the function of each ingredient. Which are the various kinds of toothpastes, and what is the importance of regular brushing of teeth both for maintaining healthy teeth as well as for general health? For this module, students usually start with initial work at home, studying the ingredients of various commercial toothpastes, and then work in groups during class time in order to systematize the study of the ingredients. Then the students should prepare in the lab basic toothpaste and compare its cleaning power with commercial toothpastes, by using them to clean a coloured egg. The learning begins at home, where the students examine their own toothpaste and record its ingredients. This setting by itself makes the module relevant for each student. The module bridges the gap between school chemistry and real life, makes the science learning in school popular and relevant and promotes the students' scientific literacy.

We have described how the PARSEL group has investigated and evaluated the students’ and teachers’ perceptions regarding learning and teaching with the PARSEL modules. We focused mainly on three countries with different educational systems and different science curricula. Diverse modules were taught in each country and different research tools were used to evaluate the implementation of the PARSEL modules. Despite those limitations, in all three countries we found similar results. The qualitative tools indicated that the students found the modules to be popular and interesting. They also felt that the key ideas underlying the PARSEL project were relevant and as containing materials and activities to develop important component that are related scientific literacy.

The PARSEL teachers in Estonia, Portugal, and Israel obtained positive feedback from their students following the teaching of the PARSEL modules. In Portugal, teachers valued the possibility of making a connection between science and students' daily life (Galvão et al., 2008). In Estonia, the teachers considered the PARSEL modules to be valuable tools in enhancing students' interest and curiosity. This was due to the difference in lessons from the normal teaching pattern, and this raised students’ interest (Holbrook et al., 2008). In Israel we found that the teachers aligned their teaching with the philosophy and the teaching style of the PARSEL project and at the same time they adopted the modules to their own needs, their own school, and their own students (Blonder et al., 2008). It is assumed that the process of adaptation of the PARSEL philosophy increased the teachers' ability to teach the modules in accordance with the developers' intentions, and thus reducing the gap between the developers' intention and the actual curriculum that was taught before in the science classes.

As mentioned above, although each country used a different set of evaluation tools and strategies, the overall picture obtained from all the countries is similar. Nevertheless, there is a need to deepen our understanding of those parameters (e.g. relevance, popularity and interest) and to further develop research based evaluation methods which will be more reliable and more useable for the teaching of science programmes that are based on societal issues. We believe that the change in the goals of science teaching for all students will necessitate the development of new research and assessment agenda.

Outlook

We have experienced the PARSEL approach as a very fruitful strategy to, with support from engaged teachers, promote teaching/learning modules that are popular and relevant to students, as well as enhancing scientific literacy and allowing students to see science careers in a more favourable way. It has been established an efficiently working network of researchers and practitioners, which should be maintained beyond the end of the PARSEL project runtime. The PARSEL website (www.parsel.eu) will still exist as the internet platform for archiving developed material, exchange new ideas referring to the further development of the PARSEL approach and its modules and strategies, and as a forum of communication among PARSEL partners, wider network participants and all interested colleagues. The PARSEL partners still publish PARSEL ideas and materials via journals, conferences and workshops throughout Europe and beyond. Together with interested teachers existing modules will still be implemented and tried out, while the evaluation results lead to revisited and optimized materials. The dissemination aims at PARSEL partner countries but also at other European nations and countries out of Europe. There is a great interest in Asian countries to implement PARSEL modules, some of them have e.g. been translated to Chinese and have successfully been tried out in Nanjing, China. We hope for a growing PARSEL community and an increase in initiatives of developing new PARSEL modules. The PARSEL partners will give any necessary support to make this endeavour a great success.

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Appendix: The PARSEL booklet