STEDE – Science Teacher Education Development in Europe
Considerations on Primary ScienceTeacher Education

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Note: P. G. Michaelides has presented in Conferences, Seminars and Workshops some of the issues discussed in this document as parts of more extensive papers.

1.-Introduction. The Primary School Curriculum incorporates many different subjects. Together with Language, Mathematics and Science, which form the core part, the Primary School curriculum incorporates courses on Religion, History, Arts and Music, Physical Education, Informatics, Foreign Languages etc. In most cases other school activities such as projects on environmental education, theatre, sports etc are also included to the school curriculum either in a formal way or as optional modules. With only a few exceptions, in every grade of the primary school, the same teacher, 'the general teacher', teaches all these different subjects and activities. Sometimes, for Physical Education, Music, Foreign language and other subjects requiring exceptional skills, 'specialty teachers' are also used together and, hopefully, in cooperation with the general teacher in charge of the class. Quite often, especially in the higher grades of large schools, the different subjects of the school curriculum are grouped into 2 (or 3) groups[1] assigned to separate teachers, with the teacher in charge of each group being 'a more experienced teacher' for the teaching of the corresponding subjects. This is usually done as an internal arrangement within the individual primary school operation, although this is not always foreseen officially. Official regulations in most countries expect one general teacher per grade in the primary school. This is in contrast with secondary education where subjects are taught by 'specialty teachers'.

1.1-Importance of Primary School teaching. The effective teaching in primary school is very important. It also poses unique problems, because:

- Present school students are the citizens of the future and they must posses the necessary knowledge and skills that will allow them to participate in the activities of the society. Compulsory education is the institutional means to acquire these skills and knowledge. Regarding its duration and the age of the students, Primary education consists, in every country, the most significant part of compulsory education.
- The age of the students in primary education is crucial to the development of higher cognitive skills and, also, to the character formation with a self-consistent system of values.
- In many countries[2] the students in the primary education, especially in the first grades of public schools, come with a quite different social and/or cultural background resulting in a very demanding teaching[3].
- A significant obstacle to the learning and the effective acquirement of knowledge in any area are previous misconceptions and erroneous knowledge. These are mainly developed during the first teaching of the relevant subjects[4]. In consequence, the correct teaching in the primary education is important and increases the effectiveness of teaching in the secondary, higher and further education.

[1] for example Humanities (or Humanities and Social Sciences) and Mathematics, Science and Technology.

[2] E.g. Greece and other countries with large numbers of immigrants.

[3] The formation of separate classes in accordance to the social – cultural background could facilitate the teaching but, in modern democratic societies, is considered as racial discrimination and is applied only for recognized ethnic minorities.

[4] This factor is more dominant for the subjects in Science and Technology where due the rapid technological development, the social context cannot act in compensation.

1.2-Systems of Primary Teacher Education. The general teacher of the primary education must possess special knowledge and skills in order to teach effectively the different subjects of the primary school curriculum, as depicted in the previous paragraphs. Thus, the education (initial training) and the continuous in-service training of the primary school teacher becomes of a paramount importance. Until recently[5], Primary Teacher Education was done in vocational schools (Teacher Colleges and Academies), mostly state controlled, with typical study duration of two years and a specific curriculum. The graduates from these schools are still the majority of the Primary School Teachers in the European countries. Under education reforms in most of the European Countries (with similar reforms pending for the rest), these Teacher Colleges and Academies have been replaced (abolished or upgraded) and Primary School Teachers are educated within University Departments. Contemporary systems of primary teacher education are based in a mixture of two extreme approaches:

1. School oriented approach. In this approach, the core curriculum courses of the Primary Teacher education curriculum are closely related to (if not based on) the courses of the school curriculum (objectives, syllabus, etc.). These core courses are supported by 'foundation' or 'background' courses on specific subjects[6] prerequisite to the core courses of the curriculum. This approach has the advantage of being focused on the Primary school teacher job with the learning outcomes being, more or less, directly usable in the school by the prospective teacher. It is also time effective for the general teacher of the primary school who must be able to teach all the different subjects of the primary school curriculum. It has the obvious disadvantage that a reform (e.g. an update) on the school syllabus, as is the case with the subjects on Science and Technology, results in the need for a retraining of the Primary School Teacher. This approach is appropriate for the in-service training. It is also a commonly encountered approach especially in the Teacher Colleges and Academies and in most post-graduate courses on teaching efficiency, a requirement in many states for the appointment of schoolteachers. This approach is based on the assumption (unsupported by empirical data) that a Primary School Teacher may be effective even if he/she is not an expert on the subject he/she teaches.
2. Teacher Oriented Approach. In this approach, the courses of the Primary Teacher education curriculum are focused on the development of knowledge, skills and attitudes that will enable the prospective teacher to meet the demands of teaching the different subjects in the Primary school providing concurrently the necessary background for his/her scientific and professional advance. Under this approach, the prospective teacher must transform the knowledge and skills learned within the Primary Teacher education curriculum courses, into the appropriate school practice. It has the advantage, at least in theory, that the prospective teacher will be able to meet the real situation encountered in the classroom and to adapt effectively his/her teaching in order to cope with a reform in the school curriculum, a feature especially advantageous for the teaching of Science and Technology. This approach has been adopted by some University Departments. For the general teacher of the primary school, it has the disadvantage that it requires a deep understanding of many different subjects. This is not always feasible within the time period of the typical study duration.

1.3-Other aspects. The operation of the Science and Technology part of the Primary education schoolteacher curriculum takes place under less favourable conditions than the other parts of the curriculum. Thus, the Science and Technology education of the prospective Primary schoolteacher is not always adequate resulting in an ineffective Science and Technology school education. Some of the reasons contributing to the inadequacy of the Science and Technology education of the Primary Schoolteacher are, in brief:

- The context in which schools of education operate is oriented towards Humanities. In this context, Science and Technology teaching requires special actions, a condition not always realized from the Science and Technology instructors who, normally, assume their own context. This factor may be enhanced further whenever instructors without adequate experience from Primary school (often from Science and Technology Departments) are used.
- The school background for the majority of the students is on Humanities or Social sciences and many of them have a negative attitude towards Science and Technology.
- The negative results on the learning outcomes due to inadequate teaching will be more prominent for the Science and Technology courses while for the other courses this may be reduced due to the context described previously.

[5] See in: **A/**in the web site: http://europa.eu.int/comm/education/ the pages: eurydice.html, struct/struct.html, cedefop.html. **B/**the Appendices for the case of Greece, Italy and Malta. **C/**Teacher education policies in the European Union: proceedings of the Conference on teacher education policies in the European Union and quality of lifelong learning, Loulé (Alagarve), 22 and 23 May 2000 / European Network on Teacher Education Policies. Available on World Wide Web: http://www.inafop.pt/site_i/entep.html. **D/**UNESCO, '50 years of Education' a 2CD edition- some works are on-line at the site http://www.unesco.org/education/index.shtml.

[6] e.g. introductory courses on (child) psychology and behaviour, on Teaching Methods and Practices, on Mathematics, on Science, etc.

- Due to the rapid developments the learning content of the surrounding society is greatly reduced for the Science and Technology area.
- A kind of competition is developed between (general and specialized) psycho pedagogic courses and courses related to the subjects taught in the school e.g. Language, Mathematics, Science, etc. This is more prominent when the Primary education schoolteacher is one of the alternative graduate choices offered within the Department of Education. In view of the context described previously, whenever such a 'competition' arises, the Science and Technology courses are usually in a disadvantage.
- Science and Technology teaching incorporates experiments and, more generally, observation of natural phenomena and requires special skills, in addition to the common teaching skills required for the teaching in other areas.

In conclusion, Science (and Technology) education of the schoolteachers requires special consideration, in addition to the actions taken for the education of schoolteachers in general.

2.-Science education in Primary School. The objectives of Science education in Primary school may be classified into three main classes:

- Science is a cultural asset of our society, so it has its place in compulsory (especially in Primary) education along with other subjects,
- As the background of modern technology, a basic understanding of Science is necessary for the industrial (or meta industrial) societies,
- Science is advantageous to the personal development.

We comment briefly on every separate class:

2.1-Science as a cultural asset. Science is a characteristic of the human societies. Natural sciences are the first developed and are still, although to different development levels, a common feature throughout Earth. Compulsory education is considered as the institutional means of contemporary societies for the familiarization of the new generations with the society's culture. Consequently Science (and Technology) must constitute a significant part of the compulsory education curriculum, especially of its major part, Primary Education. Modern societies face problems and issues on which the 'best' solution to be chosen is increasingly based on scientific and technological knowledge. If our values lead towards a democratic society, in which citizens have an active role in decision making (e.g. legislation), the literacy in Science and Technology is more and more necessary as a 'democratic right'. Otherwise, a society like the ancient Egypt with the priests replaced by scientists will emerge. Although this reasoning may be equally valid for other subjects, Science is unique, because literacy in other areas may, also, be achieved through other means, i.e. TV, social activities, etc. However, due to the rapid development in the field, Science and Technology literacy may be achieved only through organized actions, like education.

2.2-Science as a Technology Background. Science forms the basis for all modern technology. A technologically advanced society, apart from being dominant within other societies, produces welfare to the advantage of its members. Although arguments of this type are usually applied to professional (technical and/or vocational) education, as already mentioned earlier (see last paragraph in 1.1-Importance of Primary School teaching), the correct teaching of Science in the Primary School is fundamental to the effectiveness of a more detailed Science and Technology teaching later[7]. This is true whether teaching is within the education of Science professionals (Physicists, Chemists, Biologists, …) or of other Professions with a technological background.

2.3-Science as a means for personal development. From all the subjects taught in the Primary school, Science is unique as a means of personal development in cognition, in practical dexterities, in social skills and in the assimilation to a larger group of persons with differing cultures.

- A basic constituent of Science teaching is the experimentation and, more generally, the observation of natural phenomena. For most of the Science syllabus in Primary schools, the observations may be done with direct use of the senses and, possibly, with the help of simple instruments. Within a Piagetian framework, the students in Primary education are before or just starting the stage of formal logic. Science observations, thus, are unique in their advantage to promote the development of abstract thinking. However, the achievement of this objective depends strongly on the use, in the teaching method adopted, of the scientific inquiry on which see a relevant comment later on.
- Setting up simple experiments, organizing observations, manipulating the simple instruments and the similar inherent to Science teaching activities are fundamental for the development of practical dexterities (of a psycho motive nature) which, in our technological society, are useful not only for the technical vocations but also to the general public. This is also a unique feature of Science teaching.
- The assignment of tasks, either individually or in groups, as a teaching practice is an appropriate tool for the development of social skills, provided that the task assigned is within the abilities of the individual(s) involved in its realization and that its successful completion requires some sort of

[7] The learning outcomes from a correct teaching of Science in the Primary School may be incomplete as to the knowledge and/or skills acquired. However, they must not be erroneous and they must not lead to misconceptions..

interaction with other persons. For this purpose all the subjects of the Primary school curriculum are suitable. However, while tasks on other subjects may be completed and by library compilations only, Science offers more opportunities for tasks involving other persons besides the students, for example activities related to the environment either physical or human. This feature is also present, to some extent, for tasks from Social studies, as for example, in subjects relating with the local culture.

- Group work within the classroom is ideal for the assimilation of different persons into a larger group and the formation of an 'esprit de corps'. In the contemporary multicultural environments of most schools this is a necessity in order to avoid the raising of ghettos. It is also necessary to avoid the exclusion of students with deficiencies in verbal communication or otherwise. Tasks involving practical work are more appropriate to this effect because they require an active cooperation between the members of the group while other tasks may be accomplished also by a further split to smaller assignments one for every member of the group. Also, in practical works, oral communication is enhanced or otherwise assisted by other, non-verbal, means of communication and this is very advantageous, especially in multicultural primary schools where, quite often, children speak different mother tongues. Science is again unique in offering more possibilities of tasks involving practical works, e.g. model constructions, conducting an experiment, etc.

2.4-Primary Science syllabus. Comparing the Primary Science syllabus between different countries or between different time periods, a wide diversity is observed. In earlier times the syllabus was usually restricted to facts, simple techniques or demonstration experiments and naïve observations. Consequently, facts and explanations (theories) were interlaced in a rather descriptive teaching with the acceptable theories presented as an indisputable' or 'absolute' truth, a tradition still vivid, although, hopefully, in decline. Of course, creative thinking is rather impossible to be developed under these conditions[8]. Due to the previously presented objectives of the primary school, this was considered as inadequate and, gradually, this kind of syllabus evolved to a syllabus where natural phenomena as a whole are to be studied and are used to spark an appropriate discussion. This kind of teaching however, imposes heavy demands on the Primary Science teacher who, then, is not always successful[9]. Reasons for it may be:

- Natural phenomena are usually complex depending on many parameters. However, Primary school ages are able, in general, for monoparametric relations. It requires special skills on the teacher's part to isolate every time the significant parameter in order to proceed to the teaching.
- Abstraction and formal logic are, in general, not mastered enough by the Primary school ages. So, there is a need of a skilled teacher and of some time in order to link, in a reasonable way, the observations to the accepted explanation or theory. These requirements are not always easy to obtain and, quite often, there seems to be an inconsistency between observations and their explanation[10]. These inconsistencies lead to the memorization of Science facts, which regarding the students conceptions, are mostly irrelevant to their everyday experience.
- Science teacher education, usually consists in a series of courses on specialized subjects, e.g. for the case of Physics mechanics, electricity and magnetism, heat, etc. This is reasonable for a specialist's education[11] but for a Primary Teacher it implies knowledge on many different fields (a kind of a renaissance person versed in all sciences) who must transform this detailed knowledge into an integrated view of the natural phenomenon under study. Often the teacher concentrates at the aspects of the phenomenon under study that are important to him/her, while his/her students may be impressed by other parameters. Again, without a proper action, inconsistencies and/or misconceptions may occur.
- The inclusion of contemporary knowledge, based beyond sensational experience is a necessity. However, its teaching in the primary school poses difficulties and the corresponding teaching alternatives are either, a descriptive teaching demanding a memorization of facts, or, a teaching using metaphors and analogies aiming at creative thinking to relate the facts. The former alternative does not promote creative thinking. In the latter, care has to be exercised on the appropriateness and on the limitations of the metaphor used, which must be well understood or at least be familiar by the

[8] Also, even the factual knowledge acquired although it becomes rapidly outdated, it still remains imprinted and perpetuated in society. It is indicative, that students' concepts on heat are within the caloric fluid theory of the 17th – 18th century although its teaching has been stopped many decades ago.

[9] Research has shown that, although Science and Technology subjects start with a positive attitude from young students, in the end they are considered as difficult subjects only for the 'elit' see more in Krystallia Halkia, *'Difficulties in Transforming the Knowledge of Science into School Knowledge'*, Vol. II pp.76-82 (footnote 14)

[10] Some handy examples are: 1-All bodies fall concurrently (statement true in the absence of air). 2-Moving bodies continue to move unless a force is exercised on them (statement valid in the absence of friction, which, however, is difficult to realize in an observation). 3-Earth is orbiting Sun (a statement contrary to experience and every day's language expressions. The statement's validity depends on the reference system used, a subject usually absent from the syllabus). 4-Plants grow from the soil (an ambiguous statement; if it refers to the formation of plant tissues, most of the mass, i.e. the carbon atoms, is obtained from the air).

[11] It is also a very common way in higher education where subjects are taught by specialists, e.g. physicists, chemists, biologists, ….

students. For example, 'atoms are structured like miniature solar systems' may not be an appropriate metaphor, at least for the primary school ages. On the other hand, the basic functions and hygiene of the human body systems may be taught using similarities from simple mechanical systems[12]. The effectiveness of such a teaching, however, depends on the ingenuity and the deep subject understanding by the teacher.

3.-Primary Science Teacher Qualifications. In the question 'who is a good schoolteacher', John, a Science University student by now, had replied that a good teacher should:

- Know the subject he teaches and know how to teach it
- Be able to answer questions even at the next day
- Be able to learn together with his students
- Be able to entail learning preferably within a pleasant student time

John

Although the research was referring to Informatics in the upper secondary school (Lyceum) the above answer may be applied equally well to the Primary Education Science Teachers, at least in Greece, where their initial education in Science presents large margins for improvement, as is still the case for the majority of the Teachers in Informatics at all school levels.

As is evident from what has been presented earlier, the Primary Science Teacher must posses, in addition to the general Primary Teacher Qualifications required, special knowledge and skills (see also Appendix IV). Of these, a brief discussion on Subject matter Knowledge and on the teaching of the Scientific Inquiry is presented below.

3.1-Subject matter Knowledge. Evidently, subject matter knowledge is necessary for an effective teaching of Science at all levels, together with other skills. Research on the qualities of a good Science Teacher and on the characteristics of an effective Science and Technology teaching is constantly accumulating[13,14]. One may reasonably assume that the more detailed, analytic and in depth subject matter knowledge a teacher posses the better a teacher will become but there is evidence on the contrary and, although some skills may be associated with a good teacher, none may be separated as dominant[15]. It seems that it is the kind of subject matter knowledge in whole and the melange of special skills a teacher possess that counts more than his/her separate characteristics. On this viewpoint, the Primary Science Teacher education cannot be an adaptation of the education of a Science specialist but must be re-considered as a whole based on the work and the conditions encountered in school.

3.2-Scientific Inquiry. The Scientific Inquiry is inherent to Science teaching and a rather necessary prerequisite in order to achieve the benefits referred above (especially in '2.3-Science as a means for personal development'). In brief, the basic steps of including the Scientific Inquiry in Science Teaching are[16]:

- **a.-** Making observations from which 'relevant data' are collected.
- **b.-** Examination of the data with the aim to discover patterns, e.g. relations between them or between them and other data.
- **c.-** Making assumptions (hypotheses) about the patterns discovered.
- **d.-** Testing these assumptions. Planning and conducting specific inquiries, usually in the form of experiments, does the testing. The outcomes of these inquiries may reject some of the assumptions made. The goal is to reject all but one of them.
- **e.-** On the basis of the non-rejected assumptions models for the world (or rather that part of the world, which was examined) are formed. From these models complete theories may evolve in an inductive process.
- **f.-** Applying these models, predictions may be made by deductive reasoning on what will be observed in other situations. Then, if what is really observed is in disagreement with the predictions made, the model has to be redefined.
- **g.-** In all these steps above, a way of communicating the findings and thoughts in a clear, precise and unambiguous way is essential.

Referring to step one may infer that the observations for the collection of data precede the formation of hypotheses and theories, i.e. scientific inquiry is an inductive process from the data to the theory. Many

[12] E.g. pipes and water flow for the circulatory system or levers and torques for the muscles and bones.

[13] *'Advances in Research on Teaching', Vol. 2 • 1991 'Teacher's Knowledge of Subject Matter as it relates to their Teaching Practice',* edited by Jere Brophy, JAI Press Inc.

[14] University of Cyprus, *'1st IOSTE Symposium in Southern Europe – Science and Technology Education: Preparing Future Citizens'*, Paralimni-Cyprus 29/4-2/5 2001, proceedings Vol. I & II.

[15] For a review see: Deborah Loewenberg Ball, *'Research on Teaching Mathematics: making Subject-Matter Knowledge part of the Equation'* page 3 in footnote reference 13.

[16] See more in P. G. Michaelides, *'Everyday observations in relation with Natural Sciences'*, University of Cyprus, (A. Gagatsis, editor) 'Learning in Mathematics and Science and Educational Technology', post Graduate Intensive Summer Program', proceedings Vol. II pp 281-300.

philosophers dispute this view on the basis that in order to collect 'relevant data' from the observations, one must have formed already a criterion to distinguish relevant from non-relevant data i.e. one must already have a model, even in a primitive form, from which deductions are made and tested. This dispute between 'inductionists' and 'deductionists' has been proven over time very fruitful for the advance of human reasoning. More on this point may be found in the literature (see for example [17], [18], [19], [20], [21], [22]).

Steps and above are very advantageous for the development of creative thinking. This however depends heavily on the efforts made to try and form new hypotheses, models or theories, which are supported by the data but are also alternatives to the (currently) acceptable ones[23]. From this viewpoint the teaching must be done in a form encouraging students to try and invent as many models as they can to explain the data observed. The commonly encountered practice in Science teaching where from an observation or an experiment only one conclusion (the 'correct theory') is inferred does not improve creative thinking and has also other drawbacks.

A simple form of prediction in steps and , is to calculate the value of a quantity, for example by interpolation or extrapolation of other values taken or by using a relation with the values of other quantities (a 'physical law' expressed by a 'physical equation'). Another form of prediction is made by posing questions of the type 'what will happen if …' and trying to answer these using the model or theory. A prediction as referred to in steps and may also be expressed formally as the conclusion of a valid Logic argument. In this argument one of the premises expresses the data from the observations and the other expresses the model or the theory. If the conclusion is tested (usually with an experiment or with another kind of observation) and agrees with the data obtained, no further action is necessary. However if the conclusion and the observations do not agree, an examination of the whole procedure is necessary to see the cause of the disagreement. This disagreement may be due to:

- **i)** Premise of observation not true (for example incorrect or wrong measurements, erroneous observations, etc.),
- **ii)** What actually observed is not what it is thought to be observed,
- **iii)** Error in the premise of theory (wrong application of the theory),
- **iv)** Error in logic, i.e. formation of an invalid argument,
- **v)** The premises are true, the argument is valid still the conclusion is not true (i.e. it is in disagreement with the observations).

Types , and may be spotted and corrected with a relative easiness. In case it is clear that the theory (or the model) does not describe accurately enough the observations made and there is need for modification[24]. The situation however is not always as clear between cases and [25].

Observation skills, proper communication skills and model understanding are also of fundamental importance in Scientific Inquiry and the Science Teacher must be able to guide his/her students appropriately[26].

It is clear that a proper inclusion of the Scientific Inquiry in Science teaching, especially in the Primary Schools where young develop their cognition, may promote considerably abstraction and formal logic skills.

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[17] A. F. Chalmers, 'What is this thing called Science? An assessment of the nature and status of science and its methods', University of Queens land Press, St. Lucia; it has been also translated in Greek by the University Editions Of Crete'

[18] Stephen F. Barker, 'The Elements of Logic', McGraw-Hill book Company 1989

[19] Steven M. Cahn, 'A new Introduction to Philosophy', Harper & Row, publ. 1971.

[20] 'Teaching Science', Routledge, 1994, edited by Ralph Levinson at The Open University.

[21] Albert Einstein – Leopold Infeld, 'The evolution of Physics'.

[22] Max Born, 'Experiment and Theory in Physics', Cambridge University Press.

[23] The formation of more than one test with differing predictions must also be encouraged for steps and .

[24] Always staying within the current formality of Logic. Another type of Logic (i.e. another way of reasoning) means another type of Humans.

[25] As an example, take the neutrino particle. In the late '30s experimental evidence was accumulated from radioactive fission in which the total energy and momentum before the fission did not match the measured total energy and momentum of the fragments. It was thought that there was a case present and the theory (axiom) of Conservation of energy and momentum had to be abandoned but Pauli speculated on case and predicted the existence of a new particle, the neutrino, without rest mass and not detectable in the foresaid experiments, which was discovered later on. The discovery of the planet Neptune may also be considered as a similar paradigm between case (i.e. rejecting the gravitation theory of Newton) and case (i.e. accepting a situation different from the assumed).

[26] P. G. Michaelides 'Conceptual problems in Science Observations' presented to the 2nd Panhellenic Conference on the 'Didactics of Science and the Application of New technologies in Education' Nicosia, May 3-5, 2000 (in Greek)..

4.- Proposal for a Primary Science Teacher education Curriculum. The need for Scientific and Technological literacy has been established as a world wide critical issue[27] with the need for a Science and Technology Literacy of all the citizens an explicitly stated objective, initiating special actions[28]. A key factor to its solution is the appropriate initial Science and Technology training of the School Teacher and especially the teacher in the primary education. The recruitment of effective Science and Technology teachers is a worldwide concern for which special measures are taken[29]. These measures may be considered as an indication of the need for improvement in Science Teacher education. An appropriate Primary Science Teacher education must provide the prospective teacher with the necessary knowledge, skills and attitudes answering, also, the problems and issues referred to previously in 1.2-Systems of Primary Teacher Education, 1.3-Other aspects and 2.4-Primary Science syllabus. Some brief comments on different aspects of the Primary Science Teacher education follow.

4.1-Objectives. As the Primary Science teacher education is not a specialist's education in Science its objectives must be focused to the development of the specific knowledge, skills and attitudes necessary to teach Science and Technology in the Primary School. For example:

- A global view of the basic principles and ideas in Science. Specialized knowledge will be included only to the extent necessary for the demonstration of these basic principles and ideas.
- Development of observation and experimentation skills,
- Mastering the Scientific Inquiry approach to Science Learning.

4.2-Syllabus. The choice and the form of the syllabus must meet the following criteria:

- It has to be relevant to the school curriculum, objectives, teaching methods and subject matter.
- It has to be at a level appropriate for higher education i.e. it must inflict knowledge and skills that will allow the further professional improvement of the prospective teacher.
- It must also include modern subjects like relativity and quantum mechanics[30].

On specific subjects of the syllabus, the themes must be chosen in a holistic way as whole physical phenomena and not in the usual detailed way[31]. The study of these phenomena may be 'polymorphic'[32]. Polymorphic teaching in Science is like the multilevel teaching'[33] extending also to different education levels. It starts with a practical activity (an experiment, a construction, an observation, …) from which data are collected. These data then are analysed along different parallel paths depending on the target education level. For the education of the teachers, the analysis at the level of the Primary school serves also as a methodology of teaching while the analysis at the higher level is intended for the prospective teacher to learn on the subject under study. The polymorphic teaching may induce learning, that combines the advantages of both approaches (school or teacher oriented) presented in 1.2-Systems of Primary Teacher Education, that is:

- It is applicable to the teaching in school directly or with a minor transformation
- It is appropriate as initial training of the prospective teacher, in a higher level, necessary for his/her further professional improvement and education.

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[27] See for example: **a/**J. & Rannikmäe, M. '*Supplementary teaching materials-Promoting scientific and technological literacy*. Paris, France: International Council of *Asso*ciations for Science Education/ UNESCO, **b**/ICASE. SEAMEO-RECSAM, UNESCO, *The. Training of Trainers' Manual for Promoting Scientific and Technological Literacy (STL) for All.* Bangkok 2001: International Council of Associations for Science Education, Southeast Asia Ministers of Education Organisation; Regional Centre for Education in Science and Mathematics and UNESCO Principal Regional Office for Asia and the Pacific, **c/**UNESCO, *The project 2000+ declaration the way forward.* UNESCO, France, Paris 1994 in UNESCO's web site.

[28] .-see: **a/**for the USA the actions of the 'Institute for Science Education and Science Communication' for the development of teaching methods in Science and Technology for students who will not follow a Science and Technology career, **b/** for England and Wales *'Science: The National Curriculum for England'*, **c/**Karidas A and Koumaras P. *'Scientific (and Technological) Literacy for All: Presentation of a Research Model and an Attempt to Constructing a Relevant Proposal'*, Vol. I pp.89-97 of the 1st IOSTE Symposium (footnote 14).

[29] See for example: **a/**Susan Barker and Pilar Reyes, *'Why be a Science Teacher?'*, Vol. II pp.57-68 (footnote 14) for England, **b/**.UNESCO, World Education Forum,'Education for All: Meeting our Collective Commitments', Dakar,Senegal,26-28 April 2000, available also online.

[30] After a century, the time is mature for these subjects to be included in compulsory education. See also more detailed arguments in George Kalkanis *'Which (and How) Science and Technology Education for Future Citizens?'*, Vol. II pp. 199-214 (footnote 14).

[31] For example: Physics→Mechanics→Motion→Linear motion, accelerated motion etc.

[32] P. G. Michaelides, 'Polymorphic Practice in Science', proceedings of the 1st Panhellenic Conference on the 'Didactics of Science and the Application of New technologies in Education', Thessaloniki, April29-May1, 1998 (in Greek).

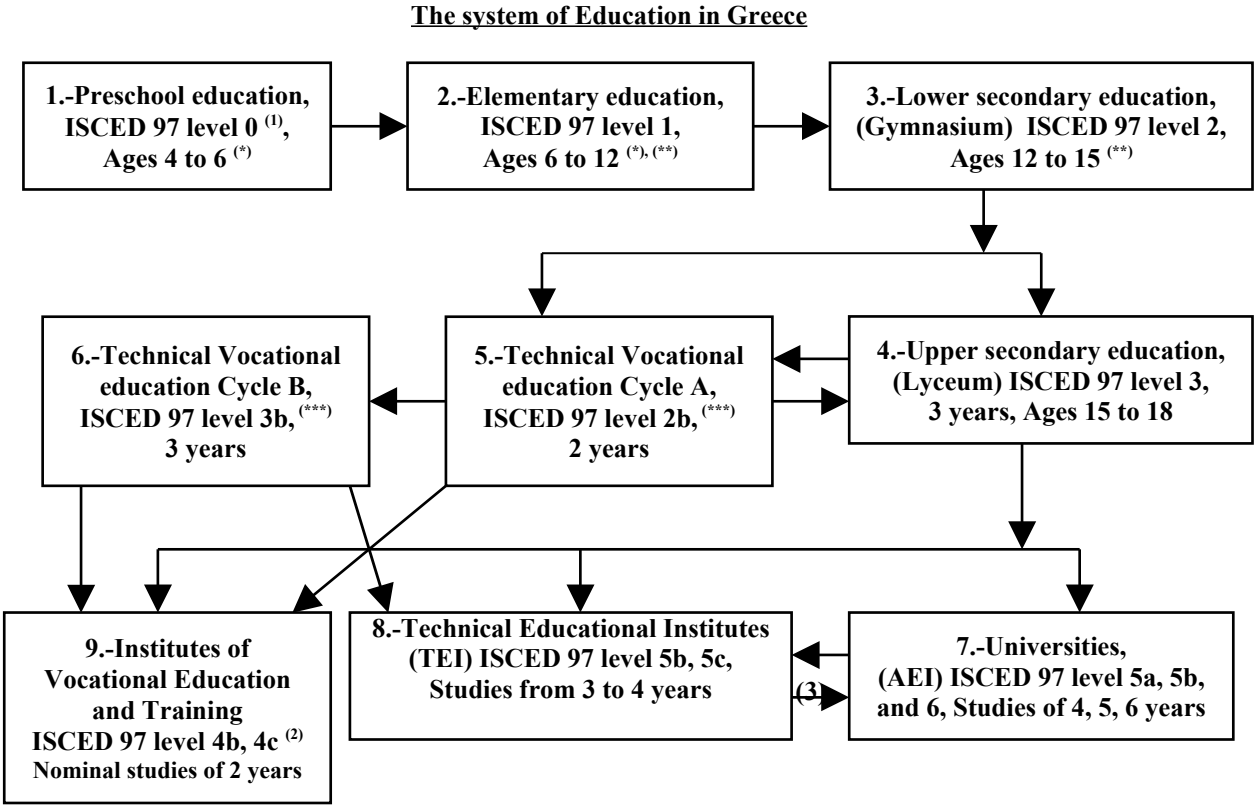
[33] i.e. teaching with objectives at many learning levels and/or sectors.

4.3-Teaching Method. As teaching practice is influenced not only by cognition but also (if not more) by the attitudes developed, the teaching method used for the Primary Science teacher education plays an important role. It must be as close as possible to the teaching required by him/her to use in the school. In view of the previous presentation in '2.-Science education in Primary School' and in '3.-Primary Science Teacher Qualifications' they must be organized in projects (either individually or in groups) on themes from everyday observations with opportunities to exercise the Scientific Inquiry. This approach has the advantages:

- It is consistent with the Primary school objectives,
- It is appropriate to the holistic way of choosing the syllabus themes,
- It may be used directly to school,
- It provides skills useful for an autonomous further learning on the subject,
- It promotes group work, a plausible feature[34],
- It may also be adapted for an in-service training and It may be applied, with slight adaptations within a Distance Education framework

[34]This is an explicit objective in many Primary education systems and a rather desirable feature in greater ages. See also in Iveta Lice, *'The Interaction of Teacher and Pupil in the Classroom'*, Vol. II pp. 76-83 (footnote 14).

The system of education in Greece is summarized in the following diagram:



(*)Primary Education, (**)Compulsory Education (***)(Secondary) Technical and Vocational Education

(1)Unesco' s International Standard for the Classification of Education edition 1997.
(2)Schools officially unclassified.
(3)Enrolment after a selective process, which may include examinations.

Technical Vocational Education (5.- and 6.- above) have replaced from 1998 onwards the various types of Technical Vocational Schools (TEL, TES etc) that will be phased out completely from year 2002. All higher education Institutes (tertiary education) are public at the moment. The Greek constitution explicitly forbids the operation of private universities. The enrollment to 9.-Institutes of Vocational Education is done after a selective process. They offer Initial Training and, formally, they are outside the formal education System.
The enrollment to 8.-Technical Educational Institutes and to 7.-Universities is done after entrance examinations. This system will be phased out completely by the year 2002. From the year 2000 the enrollment to the Universities and other tertiary education establishments will be done via a selective process based on the marks obtained in the school (Lyceum) leaving certificate.

The statistics of education (1995 Yearbook of the National Statistical Service of Greece)

LevelSchoolsPupilsTeachersFigures for 1991. Only classified education is included.**Totals17.388 2.009.774 128.258** For teachers, only school staff is included.**Pre-school**5.518 136.536 8.400 **Elementary**7.653 813.353 43.599 **Gymnasium**1.808 442.815 29.571 **Lyceum**1.158 273.589 20.231 Technical Vocational Lycei not included**TEL,TES etc**572 134.949 10.501 Technical Vocational Education before the reform of 1997**TEI**12 75.679 5.221 **AEI**17 116.938 8.497 **Special**644 12.385 1.696 Special Education – for persons with special needs**others** 3.530 542 Nautical, Ecclesiastical etc. speciality schools

According to the Greek constitution, education is provided for free in the public schools at all levels. This free education covers expenses as the full exception from any tuition or examination fees, the free provision of books and other teaching material as well as health insurance for all the students in the public schools. It includes also, for most of the students, transportation from home to school for free or on reduced fares, housing and meals, etc. The school year in Greece is from mid-September through June. There is a two-week recess at Christmas and at Easter. The school year is divided into to semesters. At the end of each semester examinations are organized. Written examinations are also organized, on a national level, for the last two years of the upper secondary education (Lyceum). Information about education in Greece may be obtained from the web addresses: www.ypepth.gr and www.pi-schools.gr. Another auxiliary address is www.clab.edc.uoc.gr.

Structure of teacher education programs in Greece.

The education requirements of teachers differ according to the type of the school. The formal level of education of the prospective teacher is a common essential feature at all levels. After the educational reform introduced in 1997, the required qualifications and the appointment procedure of teachers are currently under a transitional period. The education paths of prospective teachers differ according to the school (level and type).

Until recently, teachers for primary education should hold a diploma from the corresponding pedagogical academies for teachers of preschool or of elementary education. The study period in these academies had been increased from 2 to 4 years. The curriculum was pedagogy oriented. Subjects, mainly literature and humanities and, to a lesser extent, mathematics and science were also taught with a curriculum focused on the corresponding school program. At 1983 Departments of Education were formed in the Greek Universities. At the moment within the Greek Universities, there are 8 Departments for Elementary Teacher Education, 8 Departments for Preschool (Nursery) Education and 1 Department for Special Education Teachers (in Volos). These departments are located throughout Greece in the Universities of Athens, Thessaloniki (in Thessaloniki and in Florina), Patras, Ioannina, Crete (in Rethymno), Thrace (in Alexandroupolis), Thessaly (in Volos) and Aegean (in Rhodes). The curriculum in these departments is adapted to their mission[35] with some focused more on the educational sciences others on the vocational education of their students as prospective teachers. In all the departments the curriculum includes school practice of 60 to 120 teaching hours spread out in 2 to 4 semesters. This school practice scales from a systematic observation of another teacher teaching a class up to being in full charge of a school class for some time (of the order of 1 or 2 weeks). Prospective teachers in the Primary Education (levels 1.-Preschool and 2.-Elementary, see the opening diagram) must have a degree from these respective departments. The graduates from these departments are eligible, without further studies, to participate in the teacher appointment procedure for the primary education. Persons holding a degree in Education from corresponding foreign Universities usually have to be 'retrained' or 'reeducated' in order to become eligible for appointment as teachers. Taking courses such as Language and Literature, History, etc. with the Departments of Education in the Greek Universities does this retraining. The teachers in the primary education are 'general teachers' i.e. they teach all the subjects[36] in the class they are in charge of. In this general rule, there is an exception for teachers of music, physical education and foreign languages[37], where specialty teachers are used.

Teachers in the secondary education are 'specialty teachers' i.e. they teach only the subject they are educated for[38]. They must have, in general, a University degree in the subject they are going to teach when appointed. The students in these departments are expected to complete the general coursework that is required of all the students, with no specific provision in the curriculum for students planning to become teachers. As a general rule, a kind of school practice in the curriculum is not included[39]. For the technical and vocational subjects, teachers with a lower level certificate (degree or diploma) may be appointed. With the reform of 1997, after a 5-year transition period, all teachers formally appointed to the schools must have a degree from a University or a Technology Education Institute. In the case of shortage, teachers with lower

[35] According to the Law, the mission of the Departments of Education is to serve the disciplines of educational sciences, to educate the prospective teachers (of the primary education), to contribute to the improvement on the Pedagogy aspects of the education and to contribute to the resolution of education problems in general.

[36] Although not official, in some large schools, the teaching in the last two classes is shared between two teachers, one teaching Humanities and Social Sciences the other Science and Mathematics.

[37] The foreign language mostly taught in the Greek schools is English followed at a distance by French. German and Italian are also taught to a very small extent. There are also some teachers of Russian, Arabic, Turkish etc. mainly in tertiary education. Minority schools have teachers and courses in their own language. In Greece about 2% of her subjects belong to minorities. They are mostly Muslims, half o them of Turkish origin.

[38] Or other affiliated subjects, e.g. a physicist may teach chemistry or biology.

[39] In a few cases some departments include in their curricula such provisions, mostly as an optional module limited, usually, to one or two basic pedagogy courses. It may sometimes include also a systematic observation of another teacher teaching a class within a course of about 40 to 60 hours spread out in 1 or 2 semesters.

qualifications may be used as teachers on a temporary basis. According to the subject they teach, the teachers in secondary education are categorized in 20 classes (PE1 to PE20). Many of these classes include teachers from different (but related) subjects. The most populated classes are PE2 (for Language, Literature, History…), PE3 (Mathematics), PE4 (Science – Physics, Chemistry, Biology…), PE12 (Technology subjects). The graduates of almost every tertiary education department, even leavers of most post secondary education schools, could, in principle, be appointed as teachers (or as assistant teachers to supervise laboratory work), especially in the technical vocational education, although they had not been specially educated as teachers. Consequently the prospective teachers must also have a competence in teaching. Graduates or postgraduates in education are considered to have this teaching competence. Competence in teaching is acquired mainly by successful attendance in a training public school, a pedagogy training school for the technical vocational education. Studies in this school are of full time duration of 6 months (12 for some cases). From this obligation are excepted the prospective teachers in the classes PE2, PE3, PE4 and PE1 (teachers of religion). The reason of this exception was that, in the past, the curriculum in the corresponding departments was adequate for the teaching of the corresponding subject in the secondary schools, a fact no longer valid. This system has many drawbacks including the inadequacy of the pedagogy training school to fulfill the demand and is going to be replaced by a new scheme to be introduced in the near future. Under the new scheme, all teachers in secondary education must have a subject degree of an adequate (meaning tertiary education) level and a certificate of competence in teaching, obtained by formally recognized studies. A draft law on how these studies will be organized is under preparation[40] but until it takes effect the eligibility of the prospective teachers is judged as above.

There are also special education teachers. These are mainly in the primary education. Secondary education special schools are mainly vocational schools, with special education teachers as councilors. The teachers in special education are primary education general teachers with special studies[41] or experience in special education. The whole system of special education is under revision, a draft law has been prepared but it has still to be presented before the parliament.

The field experience of teachers in the primary and secondary education is only that obtained during their studies. Some of them may acquire additional real practice by working as temporary replacements of teachers in leave of absence. Upon their appointment new teachers attend a short training of one to three weeks. This training is focused mainly on administrative issues of the operation of the schools. Aspects of the curriculum and pedagogy are also discussed. Further training is offered only after some period in service[42].

In tertiary education (universities and other higher education institutes) the prospective teacher must have an education at the Ph.D. level. In some exceptional cases (arts such as music, sculpture and painting, physical education, …) the formal requirement of a Ph.D. may be replaced by prominent professional experience in the respective subject field. This exception is done on a departmental only basis after the Government has approved a faculty decision[43]. The faculty of the corresponding department selects the teaching staff, which then is appointed by Presidential Decree or Ministerial Decision, depending on the position. In the case of new departments, special electoral bodies are formed consisting of faculty members from similar or affiliated departments. According to the Law the professional and scientific achievements, any previous educational experience, any previously administrative duties and the overall personality of the prospective higher education teacher are, in this order, the qualifications taken into account during the

[40] Possible paths under examination include one or more of the following:

- Full studies in a subject followed by (formal) postgraduate studies in education sciences or by special training on the didactics of the subject with nominal full time duration of at least one (or half a) year.
- Studies in a subject on an adapted curriculum in which about 70-75% will include courses related to the subject and the rest (about one year out of the four) in the didactics of the subject. These studies will be within the same departments. An alternative is for graduates of the full subject studies to undertake also the curriculum part on the didactics.
- Reorganization and expansion of the current scheme of the pedagogy training school with upgraded formal studies meeting the foreseen demand.

[41] Until now education for teachers in special education was available only at a postgraduate level. The department for elementary teachers' education of the University of Crete provides a specialization (kind of major or minor subject choices) within the common curriculum leading to the (formally) unified degree. From 1999-2000 in the University of Thessaly at Volos a department of special education begun its operation.

[42] They may of course attend seminars and other similar events, if any, organized on specific issues on the initiative of the school councillor but these are not addressed usually to the new teachers.

[43] Teachers without a Ph.D. degree may be found also in some departments that were upgraded to tertiary education from a lower level, a situation mostly encountered in the TEI. These were teachers under the previous status and kept their positions, usually with reduced responsibilities (e.g. they are excluded from the new faculty members' procedures).

selection procedure by the faculty. There is no provision for initial teaching training in any of the tertiary education schools.

After obtaining their degree (or diploma) as described above, prospective teachers may enter the procedure for their appointment as teachers in the primary or secondary education. After the 1997 educational reform, this system for the appointment of teachers in the primary and the secondary education is in a transitional phase from the old system to the new. The old system was introduced in 1964 as a step towards civil equality within the then prevailing political situation of Greece. It is to be phased out completely by the year 2002. Within that system, prospective teachers as soon as they got their degree or diploma made an application for appointment as teachers and were put in a kind of a waiting list yearbook ('epetirida'). There are separate lists for preschool education, for elementary education[44] and for the various classes of the secondary education teachers. According to needs, the Minister for Education makes the appointments from these lists. Teachers in the public schools are civil servants. The appointment is done on a priority order based solely on the time of the application of the candidate teacher. Supplementary qualifications were taken into account only after the appointment affecting e.g. the salaries. By the time of the appointment, the prospective teacher, must also meet the requirements of the competence in teaching (for the technical vocational subjects – see above) and the other requirements for a civil servant[45]. For private schools, the school proprietor makes the appointment, also from the same waiting lists but without the order constraint. This system was adequate until late 70's because of a general shortage in teachers. By now some of these lists are so long that a waiting period of some decades is foreseen for the new entrants.

Under the new system, every second year written examinations are organized by the higher council for the selection of the civil service personnel (ASEP), an independent of the government public authority. Prospective teachers, if they meet the formal education requirements of degree or diploma and of teaching competence, contest on written examinations about their knowledge on the subject and its didactics. They must achieve a 70% mark at least in each subject in order to be considered for appointment. In the next two years teachers in the public schools are appointed according to their marks on these examinations[46]. In the private schools the teachers are appointed also from these lists but without the order constraint. There are plans to ameliorate this system by including in the selection process and other aspects apart from the two written examinations but not anything specific at the moment.

Issues that confront teacher education in Greece are the level and the contents of the curriculum in the formal education, special teachers for multicultural education and the in service training of the teachers.

Under the current teacher education schemes, the primary education teachers are offered sound studies on the pedagogy aspects but not a corresponding sound knowledge of the different subjects they are supposed to teach. By contrast, the secondary education teachers are offered sound studies on the subject they are going to teach but little or non-at all training in the didactics. In both cases, the situation is worse because, due to the long time from graduation to their appointment under the still valid old scheme, there is a need for an education refresh. In primary education, the teachers with a diploma from academies are given the opportunity to enroll as students in the corresponding University Departments of Education and obtain the corresponding degree. The curriculum these teachers have to attend is a special curriculum in which the previous diploma is taken into account. A similar situation is expected to arise in the technical – vocational education. The new procedure for the appointment of teachers poses the question of adapting the curriculum to the specific professional requirements for a teacher, especially for the teaching competence of secondary education teachers[47].

The collapse of the Soviet Union alliance resulted in a flood of emigrants to Greece. They are estimated to 400.000 or more (or about 10% of the workforce). To these another 400.000 persons of Greek origin[48] have to be added. To meet the requirements of an appropriate education there is a need for teachers specially educated in intercultural and multicultural education. A similar need also exists for Gypsies who have settled in some areas around the large cities mainly these of the Athens and Thessaloniki complexes.

In service training is provided under different schemes. One is by leave of absence for further education or for post-graduate studies. Further education is provided by the state in teachers' colleges[49] where subject matters from the school curricula and their didactics are taught. The duration of this further education is two

[44] With separate quota for the graduates from the Departments of Education and from the academies.

[45] e.g. absence of a criminal record, fulfilment of military obligations (conscription) for the males, ...

[46] the priority order is determined by the sum of the marks obtained. To this sum a small percentage is added depending on previous experience as temporary replacements of teachers in leave of absence.

[47] See footnote 40.

[48] They come from South Albania (North Epirus), where a large Greek Minority exists and from the former Soviet Union. The later are mostly refugees of the Greek minority from North Turkey (Black See area) from the period of World War I. Political refugees of 1949 from the civil war in Greece following World War II are also repatriated from the countries of the former Easter Block.

years. There are also schemes for short informal (continuous) training. One includes an intensive training of three months during which the teachers are relieved from their teaching and other duties in schools. Within the other scheme, the teachers attend special courses during their own time and in parallel with their school duties. These schemes are under revision because they do not seem effective and impose many obstacles in the normal operation of the schools. The update in the school objectives, especially for upper secondary education, general and vocational, has imposed new demands on teachers and a corresponding need for training.

[49]By now these colleges operate as special schools under the corresponding University Departments.

Appendix II. Education in Malta **Suzanne Gatt**,

The Present Educational System

Children can start attending government school at the age of three. This is optional and parents can start sending their children at any time during the year soon after their third birthday. Kindergarten education serves to socialise children to schooling but no formal teaching as yet takes place.

Compulsory education starts at the age of five with primary school. Children spend the following five years learning English, Maltese, Mathematics, Religion, Social Studies and Science, together with Physical education and Creativity. English is taught as from the first year and is the main language used for Mathematics. Science is introduced in the third year. However, it does not get the time and emphasis it deserves since it is not examined as in the case of the other subjects.

No streaming takes place in the first four years and children are grouped according to the month of their birth. At the age of nine all children sit for common annual exams in English, Maltese, Mathematics, Religion and Social studies set by the central Education authority. Streaming is then introduced in the last two years. At the end of primary education, all students sit for a competitive national eleven plus exam. The exam consists of five papers: English, Maltese, Mathematics, Maltese, Social studies and Religion. Science does not form part of the entry requirement for secondary education. About half of the students sitting for the exam pass.

All primary children proceed to secondary school, whether they pass the 11 plus exam or not. Students spend the following five years at secondary school up to the age of sixteen when compulsory schooling ends. Those who pass the 11 plus exam go to grammar type schools known as Junior Lyceums. These schools were set up in October 1981 and the top 50% of students are considered to attend these schools. However, about 30% of Maltese children attend church or private schools. It is, therefore, difficult to compare the ability of students attending these schools with those attending Junior Lyceums. Students who fail their 11 plus exam proceed to what are called area Secondary schools, similar to the secondary modern schools once present in the U.K.

All students at government secondary schools follow the same curriculum, irrelevant of whether they are Junior Lyceum or Area Secondary Schools. A total of ten subjects are studied. Students study three languages, English, Maltese, and any one subject of their choice. Integrated science is taught in the first two years. Subject choice takes place at the end of the second year. Choice falls mainly in three categories: the sciences, languages or Business. A third language is kept by all students. Science is compulsory at secondary level but all students attending government schools study Physics.

The end of secondary education is marked by school leaving exams. Up to the beginning of the 1990's, students still sat for the traditional Ordinary Level exams set by the Universities of London and Oxford. In 1992, the University of Malta decided to offer similar exam known as the Secondary Education Certificate (SEC) in all subjects at Ordinary level and Advanced level. As from 1994, all Maltese students sit for their SECs.

Post secondary education consists mainly of sixth-from education leading to entry into University. Technical education exists but this is mainly aimed for those students failing the educational system. Entry requirement into sixth-form is six SEC passes: English, Maltese, Mathematics, one Science and two other subjects. Before 1995, students studied three subjects at Advanced level, similar to the traditional English model. In 1995, this system was discarded for one similar to the European Baccalaureate. The aim was to make education wider, reducing the amount of specialisation previously present. All students study two subjects at Advanced level and an additional three at Intermediate, which is equivalent to one third of an advanced. Students studying sciences at Advance level (Physics, Chemistry, Biology or Mathematics) have to study arts subjects at Intermediate, particularly an additional language. Those opting for arts and languages have to study at least one science subject (Physics, Chemistry, Biology or Physics) at Intermediate. Students at Sixth-form also study a sixth subject known as 'Systems of Knowledge', which aims to give students a cultural background. Those who pass their exams and get their final matriculation certificate will proceed to University.

Provision of Education in Malta

Education in Malta is not exclusively provided by government. The strongly Catholic background of the island is reflected through numerous church schools, which exist. Around 30% of Maltese children attend these schools. Privately run schools have also been recently cropping up. Government and church schools are free of charge since government heavily subsidises church schools while private schools receive no financial help and so are extremely expensive. All primary schools are co-educational. In the case of secondary schools, government and church schools are single sex, whereas private schools are co-educational.

Church schools cater for different ages of students. Many have both primary and secondary levels, covering the whole compulsory age. A number, however, have only secondary schools with a highly selective 11 plus exam. Entry into primary church schools is usually by lots. Many parents would like to send their children to such schools. However, children living in the school's catchment area or are considered as 'special cases' have preference. However, children whose brothers or sisters already attend a church school are automatically admitted to that school. As already mentioned, entry to church secondary schools is through a commonly run 11 plus exam (separate from that for government schools) The order of merit is then used for choice of the preferred school. In the case of privately run schools, each school runs its own type of assessment of the students they accept.

Post-secondary education is mainly run by government but a number of church schools also have their own sixth forms. All sixth-forms follow the same system and all students are eligible to government grants whichever school they attend. Technical and trade schools, on the other hand, are only offered by government.

Science in the NEW Millennium

In preparation for the new millennium, the Maltese government has felt the need to review the educational system and update the 1988 Education Act (1988). A number of changes concerning science are being proposed in the recently published National Minimum Curriculum (1999).

Changes put forward concern both the primary and secondary education system. The role of science has been fully consolidated at primary level by being listed as one of the core subjects. Formative assessment, similar to the other subjects, is to be done along the primary years. It is, however, not specified whether science would be examined in the same way as the other established subjects for entry into Junior Lyceum. A move away from one single science subject to a form of co-ordinated science is being planned at secondary level. It is believed that students would benefit more from a wider spectrum of knowledge from the different sciences than from the narrow approach to one single science (Physics, Chemistry or Biology) currently in place. It is emphasised that this change has to take place gradually in order to ensure that educators have enough time and chance for curriculum development and preparation of teachers for its implementation.

A shift from pure 'scientific knowledge' (Education Act,1988), to a more content-process balanced view accompanies these decisions. Science is to be portrayed as a human enterprise with its problems and uncertainties rather than the objective collection of unquestionable facts reflected by today's practice.

Demands of NMC (National Minimum Curriculum) on graduating teachers in delivering primary science education.

Graduating teachers need to have several abilities relating to science education in order to fulfil the demands of the NMC. These abilities involve background in the various aspects of science: knowledge, skills and attitudes, in addition to pedagogical ability.

Graduating Teachers, thus, need to develop a number of competences:

Science Knowledge:

- to master basic scientific knowledge and the processes (observation, classification etc.) involved
- to be aware that science manifests itself in different areas of specialisation - physical, natural, medicine technology etc. and how they still interconnected.
- to be able to ask questions and attempt to answer them through systematic observation
- to be aware of developments in technology and to make use of them.
- to understand the relationship between schoolwork and its application to everyday experiences.
- to be familiar with persons from the past and present who have distinguished themselves in science, how they managed to solve problems and their way of communicating their work.

Skills

- to be able to recognise concepts, use scientific language, observe, measure, analyse, solve problems, gather and interpret data, make generalisation, create models, communicate, work in a team and design experiments.
- to be able to apply knowledge to everyday situations.
- to be able to make effective use of scientific and technological apparata both in laboratory and everyday settings., be able to use computers, audio-visual aids means, security devices etc.
- to be able to safeguard the natural environment in a sensitive manner.

Attitudes

- to understand their responsibility in relation to the natural environment and animals.
- to be aware of the changing nature of scientific knowledge, that it cannot offer clear answers to anything.

- to appreciate the importance of science and technology to life.
- to develop a positive and critical attitude towards scientific and technological developments..
- to recognise the limitations of science and scientific attitudes.
- to be ready to engage in experimentation in different aspects of science and technological developments.
- to be ready to work to ensure that everyone benefits from the positive results of science and technology.

Pedagogical ability:

- to help children understand basic ideas in science.
- to be able to help children link schoolwork to everyday applications and experience.
- to present science as a systematic means of asking and attempting to answer questions about them.
- to integrate educational content in order to adopt a multidisciplinary approach.
- to help children to learn how to ask questions, exchange ideas and collaborate with others in order to clarify their thinking.
- to organise group work.
- to help children to understand their responsibilities in relation to the natural environment and animals.
- to arouse children's curiosity concerning natural phenomena.
- to provide examples of models of persons from the past and present who have distinguished themselves in science, how they solved problems in science and how they communicated their work.
- to make children aware of the different ways in which science is manifested :physical, natural, medicine, technology etc.
- to understand that different children experience science differently.
- to be capable to understand and use technology in the process of teaching science.
- to help children engage in experimentation.
- help children realise the changing nature of science and its inability to provide answers to anything.
- to help children develop a positive and critical attitude to science.

Primary Science at Pre-service Teacher training

Primary Science Teacher Training before October 1999

Up to a few years ago, teacher graduates following a B.Ed.(Hons) at the Faculty of Education, University of Malta, took one language as a main subject and Early and Middle Years (EMY) as a subsidiary subject. Science students had the option to either take up two sciences and focus on secondary education or else to take one science and combine it with EMY.

Early and Middle year's option trained student teachers in Primary education. As part of their course one credit was dedicated to Science Education. A credit is equivalent to 14 hours of lectures and to 50 hours of work.

The Faculty of Education was unhappy with the state of affairs in the case of teacher training at primary level. As a result the system was changed and B.Ed. (Hons) students were given the opportunity to decide whether they would like to focus on secondary or primary in their third year. The first B.Ed.(Hons) students with a primary specialisation graduated in 1998. The number of credits in Primary Science increased from one – which all students do in their second year to two, an addition of another credit in their fourth year.

The Primary specialisation was greatly successful and the Department of Primary within the Faculty of Education decided that it was time for a Primary B.Ed.(Hons) course, focusing only on primary education, to be created. This course started for the first time in October 1999.

Primary Science Training in the New B.Ed.(Hons) Primary Course

The new B.Ed.(Hons) primary course has the advantage of catering for those students who specifically decide to become primary school teachers. In the preceding B.Ed.(Hons) courses, many students were interested in secondary education and the core units on primary were considered as subsidiary.

The new B.Ed.(Hons) course is different in a number of aspects. These mainly are:

I. All credits in the course focus on Primary education
II. More credits can be dedicated to the various areas in primary education
III. Students can decide whether they would like to specialise in Early years (years1-3) or junior years.
IV. Students will also be given the opportunity to focus on one subject at primary level.

Training in Primary Science is included both in the core area and the specialisation part of the new Primary B.Ed. course:

The core Area

All students following the course, even if they do not choose science as their main area of specialisation will have to follow this part of the course. The core skills in the teaching of primary science are included in this

part of the course.

The number of credits involved is five. These are:

- **Teaching Primary Science (2 credits)**

The course looks at the aims and objectives of science at primary level and the skills, attitudes and content involved. Science investigations, problem solving and practical activities in the various aspects of teaching science to young children are discussed. The issue of how children learn science and methodology for promoting motivation and understanding are covered. The unit will also tackle various other aspects including language, fieldwork, alternative ideas, museums, outings, resources and the image of science and scientists are included.

- **Physical, Chemical and Biological processes in Primary Science (2 credits)**

This module considers the various aspects of science content covered in the primary years. The aim is to help students develop content competency together with pedagogical competencies in teaching these specific concepts. Whereas module 1 considered general aspects of teaching science, this module will target the teaching of particular science concepts. Sessions will generally run from covering science content and doing practical work, to discussing what experiments and investigations can be organised for children of different ages at primary level.

- **Primary Science in the Curriculum (1 credit) (Junior Years)**

The unit involves an analysis of the role of science in educational documents, from the Education Act to the official syllabi followed by both government and private schools. A curriculum analysis of the concepts, skills and attitudes presented in worksheets used in government schools are critically analysed and compared to those in present in other worksheets developed overseas. An exercise in curriculum development will then follow.

Subject Specialisation Modules

Students are given the opportunity to choose one subject for specialisation. Science is included as one of these subject areas.

Eight credits make up this section of the course. These include:

- **Recent Developments in Primary Science (3 credits)**

The course covers recent areas of research interests in primary science. A part of the course will look at research about children's ideas in science and interventions tried out as part of the SPACE project is reviewed. Other aspects of primary science, like recent ideas on investigations, the teaching of moral values through science, children's image of science and scientists, social issues etc. will be reviewed. A reading pack covering the relevant issues will serve to promote discussion of these aspects and their impact on primary science in Malta.

- **Flora and Fauna of the Maltese Islands (2 credits)**

The aim of this module is to help primary science specials to gain familiarisation with the various species of flora and fauna present in the local environment. Their scientific classification, habitats and feeding conditions are considered in turn. The unit will also include an amount of fieldwork in a variety of areas in Malta. Species in danger of extinction are also discussed.

- **Developing I.T. Materials for Primary Science (1 credit)**

The credit first looks at how the computer can have a role in the teaching of science at primary level. A number of commercially produced C.D-ROM's are then reviewed and ways in which these can be used in teaching science concepts to young children discussed. The course then focuses on how activities for science can be designed for primary level. Data logging, its meaning and how it can be set up and used to carry out science investigations are finally tackled.

- **The Science Co-ordinator (2 credits)**

This module aims to develop science professional development skills of science specials. It will provide the opportunity to develop the necessary ability for providing support to fellow colleagues in schools and to organise in school professional development seminars. The role of the science co-ordinator is first discussed, with its implications, responsibilities and role. Reviews of professional development projects running overseas and locally are included. Students will have the opportunity to assist and participate in one of such projects (in collaboration with the science centre). The final part will include developing an in-service course for primary teachers.

At present (Spring 2001)

Kindergarten (age 3-6 years)
Primary school (age 6-11 years)
Secondary school: **low level**: age11-14 years
high level: age 14-19 years.
Each school level ends with an examination.
Up to now, **compulsory education begins at the age of 6 and finishes at the age of 15** (up to 2000, at the age of 14) and is equal for all students, while the secondary school high level is organised, mainly, in:
Licei
Classic studies, Science and Technical studies, Foreign languages, Socio-pedagogic studies, Art subjects, Conservatory…

Istituti Tecnici (Technical Institutes)
Industry, Business Management, Geometers, Agricultural studies, Nautical studies, Tourism, ...

Istituti Professionali (Vocational schools)
Tourism (hotel and restaurants) , Business, Agricultural studies, Nautical Profession, Optician
Mechanics, Electrician, ..

Secondary school like:

"**Liceo"** provides students with a sound cultural background (based on subjects) especially oriented to university studies (30 hours per week)

"**Istituto Tecnico**" (Technical Institute) provides students with a suitable theoretical and experimental background for technical professions in industries, in banks, for company secretary, for trading….

The first biennium is focused on theoretical disciplines while experimental work in Laboratories is widely practised in the last three years (35 hours per week)

"**Istituto Professionale" (**Vocational school) provides students with the minimum theoretical background needed and a noticeable experimental and hand practice to be immediately on the labor market (artisan, turner, optician….). Laboratory and practice are experienced since the first two years (40 hours per week).

School leaving "certification" allows admission to university.

Up to **2000**: University courses last four or five years and are focused on building of professional competences. Final examination provides with a University degree, named "laurea", having legal value needed for practice. Some professions (such as Engineer, Architect or Doctor) require a further "Esame di Stato", State examination, before practicing.

Teacher's Training.

1) Kindergarten and Primary school.
Up to 1998, kindergarten and primary school teachers were formed in special secondary school (Istituto Magistrale).
The law concerning University teachers training, approved in Parliament in 1990, has met a lot of difficulties for its application; at long last, University courses for teaching in kindergarten and primary school became operating since autumn 1998.
So, now (spring 2001) **graduation** (University course lasting four years), **is requested for teaching children (age 3-11 years).**
Humanities and scientific subjects are taught together with professional ones as Pedagogy, Psychology, Sociology etc.
Stages should be carried out for an amount of 400 hours (in 4 years).
In Italy, dissertation is compulsory for each graduation course and, usually, takes a lot of time.

2) Secondary school.
Up to 1999: students willing to teach in secondary school were requested to be graduated in disciplines; University disciplinary courses last 4 or 5 years (for instance, Physics and Mathematics last 4 years, Biology and Chemistry last 5 years), but they do not receive professional (pedagogical) training.
Now, teaching in secondary school (age 12-19 years) requires professional training in a post-graduation school, lasting two years, for an amount of 1000 hours.
Stages in classrooms and laboratory activities are very important for teaching practice. For instance, in the University of Genoa a 25% of the total amount will be devoted to stage and 20% to laboratory.

In July 1998, the Italian Ministry of Education gave general provisions, published in the Official Gazette (3 July 1998).

As far as the professional dissertation is concerned, the Cabinet decree orders: Section 2, paragraph 8:

“The examination for getting the degree (at the end of the graduation course) or for specializing (at the end of post-graduated school) consists in a discussion of a written report concerning activities carried out during the stage and in the laboratory, behind a board of examiners. The board includes either University professors and teachers belonging to the schools having cooperated with the activities of the graduation course or with the ones of the post-graduation school.”.Furthermore: Paragraph 6:

ìI each university the didactic regulations: .....omissis

e) can provide that the report, whose reference is at paragraph 8, is to be completed by a suitable thesis work; ...omissisî.

So, being each University self-governing, a specific thesis might complete the professional dissertation or not, depending on decision of that University.

University of Genoa has decided that, as far as post-graduation school is concerned, the discussion of a written report is enough for judging educational competences achieved by the student. Subject competences are provided by graduation disciplinary courses; the thesis work, being in Italy very important, especially in scientific disciplines (6 months are the minimum, sometimes 2 years are requested, when a research thesis is carried out), provides high professional competences (on a subject, of course).

Important aspects. Stage and tutor.

i) it represent the first contact with the classroom and its problems such as learning, communication, relationships with teacher(s) and his colleagues, with the head of the Institute and with pupils/students’ families;

ii) the final report is based partly on the stage activities and partly on laboratory activities (see above the Cabinet decree).

The stage is performed under the responsibility of a tutor, which is a teacher, charged with a less working time in school.

His task is very delicate, being a link between two public institutions, school and University, each jealous of its autonomy. Tutors are chosen through an open competition, by a jury, composed of delegates both of school authorities and of University, who will evaluate the curricula of candidates.

While in post-graduation school, the stage is equally shared during the two years, in the University course for kindergarten and primary school teachers, the stage has an increasing importance: some people think that it should begin in the second year, as in the first year students should become aware of their choice and a premature introduction in school activities could be not useful for teacher students and for classrooms.

But a **reform has been approved and some changes are going** now while other ones will occur since September 2001. As previously said, in school year 2000-2001, compulsory education has been prolonged up to the age of 15. The reform concerning school cycles foresees:

(2001, February 7)

- disappearing of secondary school low level. Primary school and secondary school low level will be joined in an **inclusive cycle of seven years** (up to September 2001, of 8 year, 5 for primary school, 3 for secondary school low level).
- in the first biennium, subjects will not be distinct.
- Teachings will become gradually differentiated since the third year. In the last biennium seven different teachings are foreseen.

About **graduation** the reform states:

- first level graduation (after a three year university course)
- second level graduation (after further two year university courses)
- third level graduation (after two or three year university courses).

Nevertheless, as the reform will operate next autumn, now (spring 2001) the situation is quite confuse. It is not clear if teacher’s training will require a second level graduation or a third level.
Anyway the whole reform (for compulsory education, secondary school and graduation) might be cancelled: if in May 13 the general election will cause a political change, this might bring it all up for discussion again.
This state of uncertainty is quite detrimental to school climate; young people are confuse in taking suitable decisions for their future; so teacher

Appendix IV. Some delayed answers to the initial questions **Nektarios Tsagliotis**

1.a. A comparison of initial science teacher education (primary)

1-What the systems of education and training for the primary Science Teacher are used

We do not have enough information about Italy and no information about Malta. If we are supposed to produce a comparative study about initial teacher education in Europe we definitely need to focus on primary science teachers education in specific, within a broader framework of primary teacher education in general. We need more participants from other countries, since our sub-network has only 5 members, whereas the average appears to be 8-9. That means we need to attract more people or discuss ways to obtain valid information from other European countries. Of course, there are questions about the number of countries and the parameters we will decide to look into depth. All these are issues of discussion for further action for the following year. Thus we could have a sub-network meeting in the ESERA 2001 conference to discuss such issues.

2-What the objectives of Primary Science Teaching are - should be

Primary science teaching should aim to:

- help children become aware of their own ideas and to have access to those of others (peers, teacher and other sources) to set against them
- help children apply ideas (their own and others) to a problem or situation and test the usefulness of the ideas in particular cases
- help children reflect critically on how ideas have been used and tested and to find more effective ways of doing these things

Good primary science teaching should:

- provide opportunities for children to investigate problems and events from which useful ideas can be developed
- provide opportunities for children to think of alternative explanations or solutions and test them fairly
- introduce ready-made ideas in such a manner that they are regarded as alternatives worth considering, not as right answers
- provide opportunities for children to share in groups a task or problem where they are responsible for the ideas and the ways of testing them
- invite children to explain the thinking which led to a solution or idea being put forward in terms of how the idea came to their mind, how it led them to make a prediction and how the prediction was tested
- accept the ideas and explanations of children, which are consistent with their limited experience and ways of processing evidence, even though these may require refinement later in the light of wider experience and knowledge (conceptual change approaches in teaching and learning science).

Reference: **HARLEN, W.** (1993) Teaching and Learning Primary Science, (2nd ed.), London: Paul Chapman Publishing.

3-What Skills a Primary Science Teacher should have

I agree with most of the points you raise, but right now I do not have something better to suggest.

4-How these affect Primary Science Teacher Education

Primary science teachers' education should be consistent with the role they will have to play in primary science classrooms as teacher-researchers who are able to control promote and develop their practice. Thus teacher education should:

- address teachers' (existing) knowledge and beliefs about teaching and learning, learners and the subject matter (i.e. science)
- provide teachers with sustained opportunities to deepen and expand their knowledge of subject matter (and its didactics and pedagogy)
- treat teachers as learners in a manner consistent with the program's vision of how teachers should treat children as learners
- ground teachers' learning and reflection in classroom practice
- offer the means, ample time and support for reflection, collaboration and the establishment of an idea of continuous learning and education.

Reference: Murphy, H. & Russell T. (1998) Epistemology and context in learning to teach science. In Fraser, B.J. & Tobin, K.G. (1998) International Handbook of Science Education, Dordrecht: Kluwer Academic Publishers (pp. 643-666).

5-How the current system of Primary Science Teacher Education may cope with the demands form 4

There appear to be three prominent features in the development of European science teacher education programs, which are:

- growing attention to the development of student teachers' subject matter knowledge and pedagogical content knowledge
- increasing use of conceptual change approaches, especially the use of techniques of reflection and growing emphasis on the social dimensions of learning
- integrating (university) theory and (classroom) practice and developing analogies between teacher education and student education.

Reference: De Jong, O., Korthagen, F. & Wubbels. T. (1998) Research on science teacher education in Europe: Teacher thinking and conceptual change. In Fraser, B.J. & Tobin, K.G. (1998) International Handbook of Science Education, Dordrecht: Kluwer Academic Publishers (pp. 745-758).