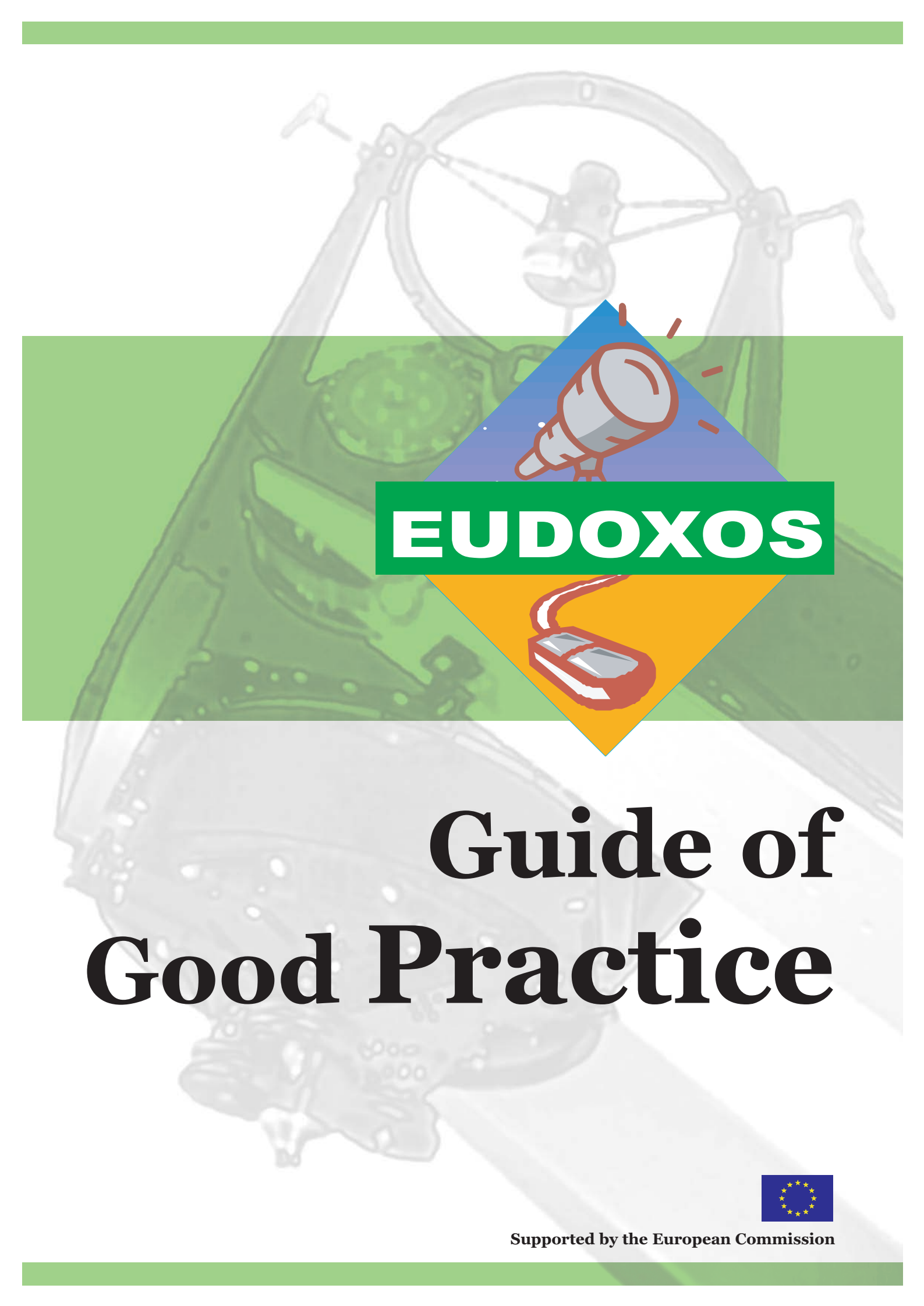


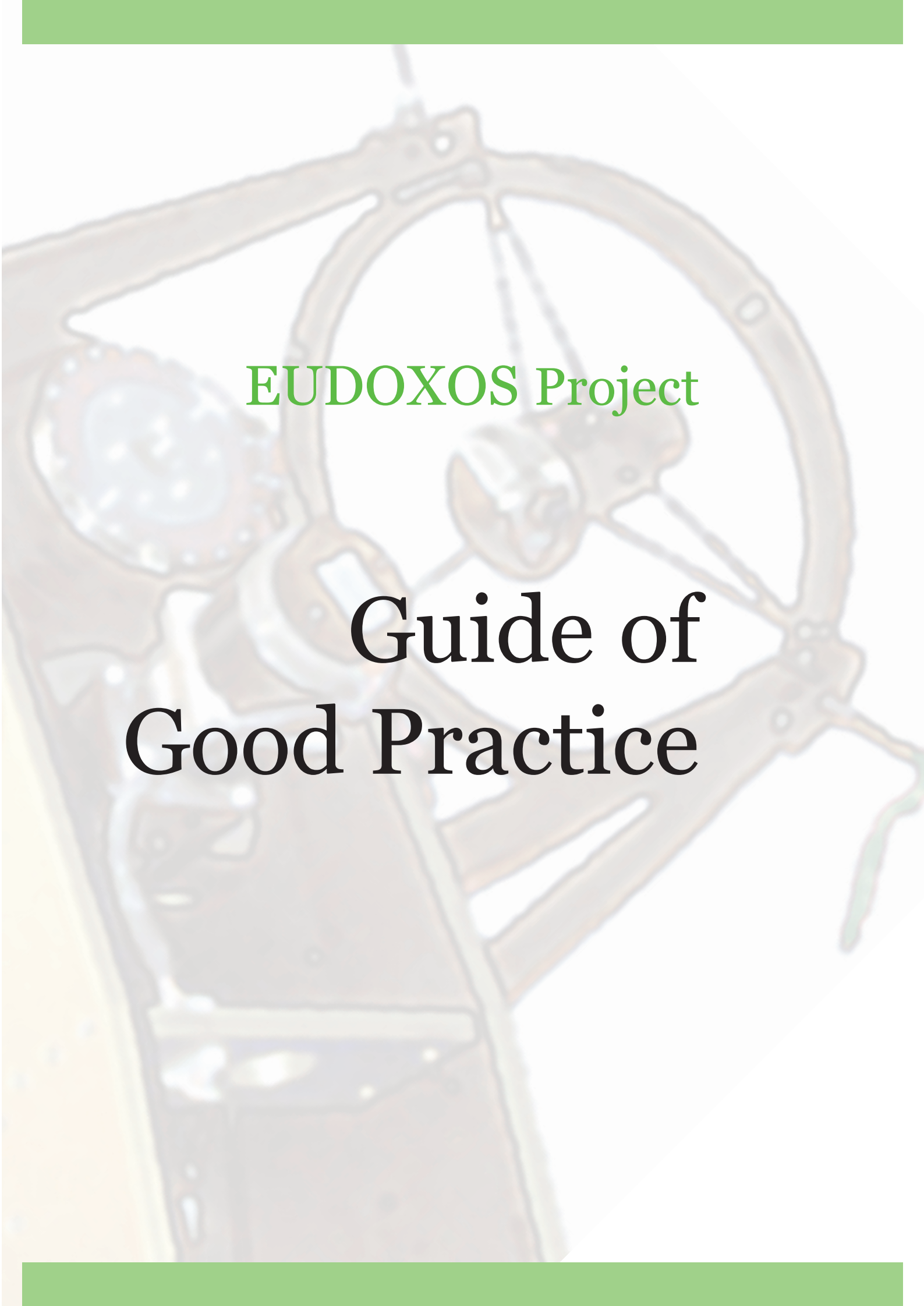


EUDOXOS

Guide of Good Practice



Supported by the European Commission



EUDOXOS Project

Guide of Good Practice

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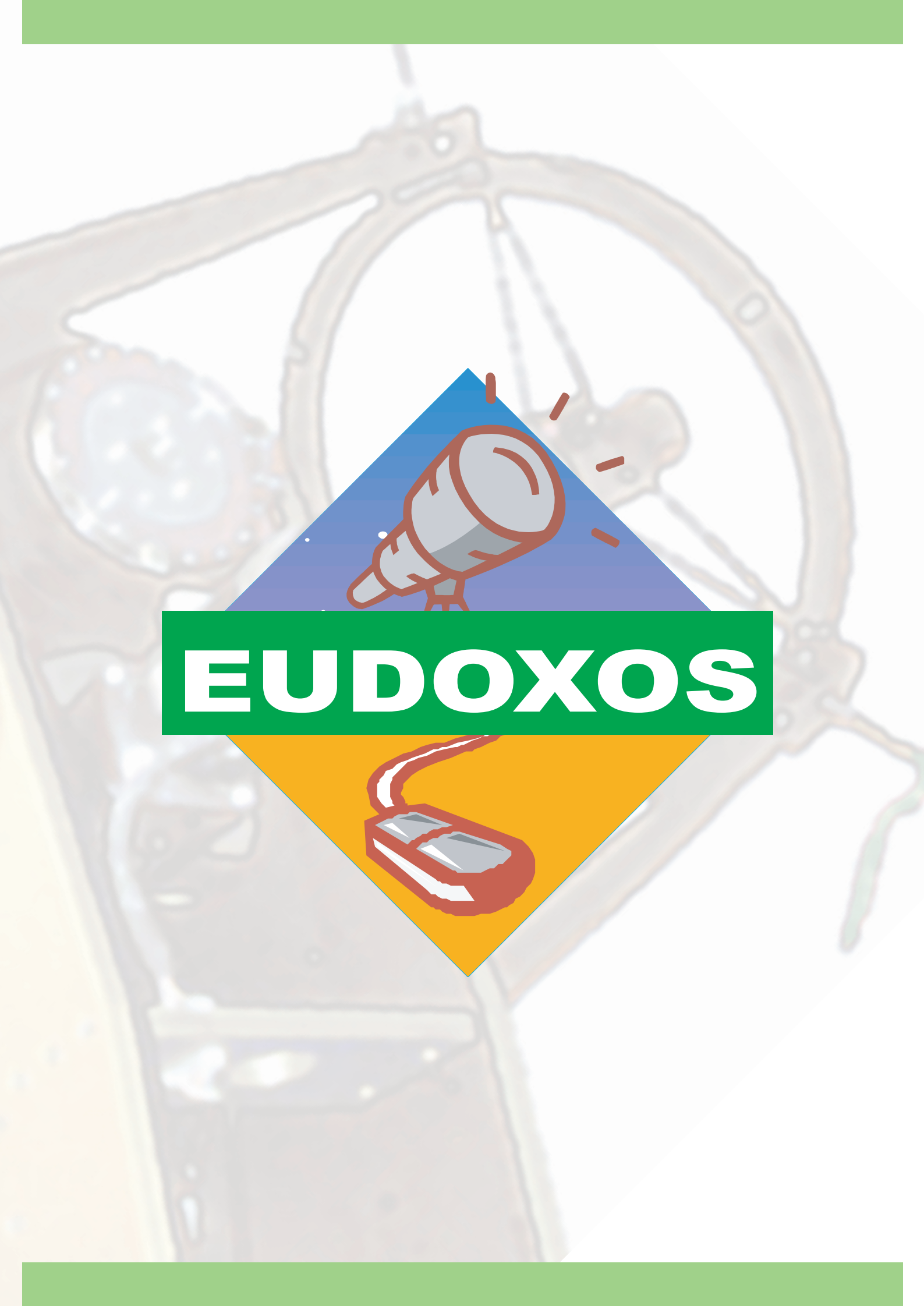
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Designing Tomorrow's Education

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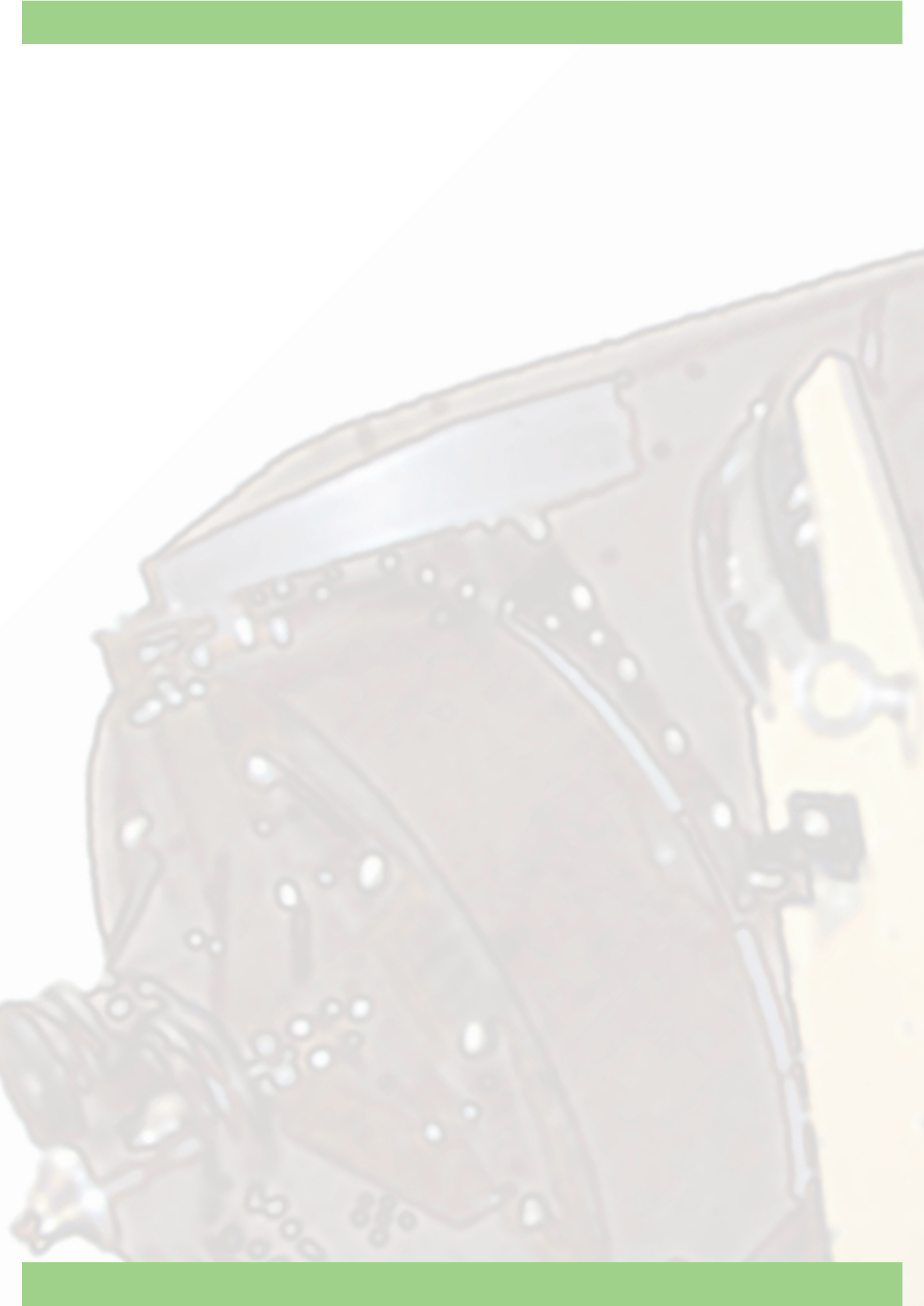
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EUDOXOS



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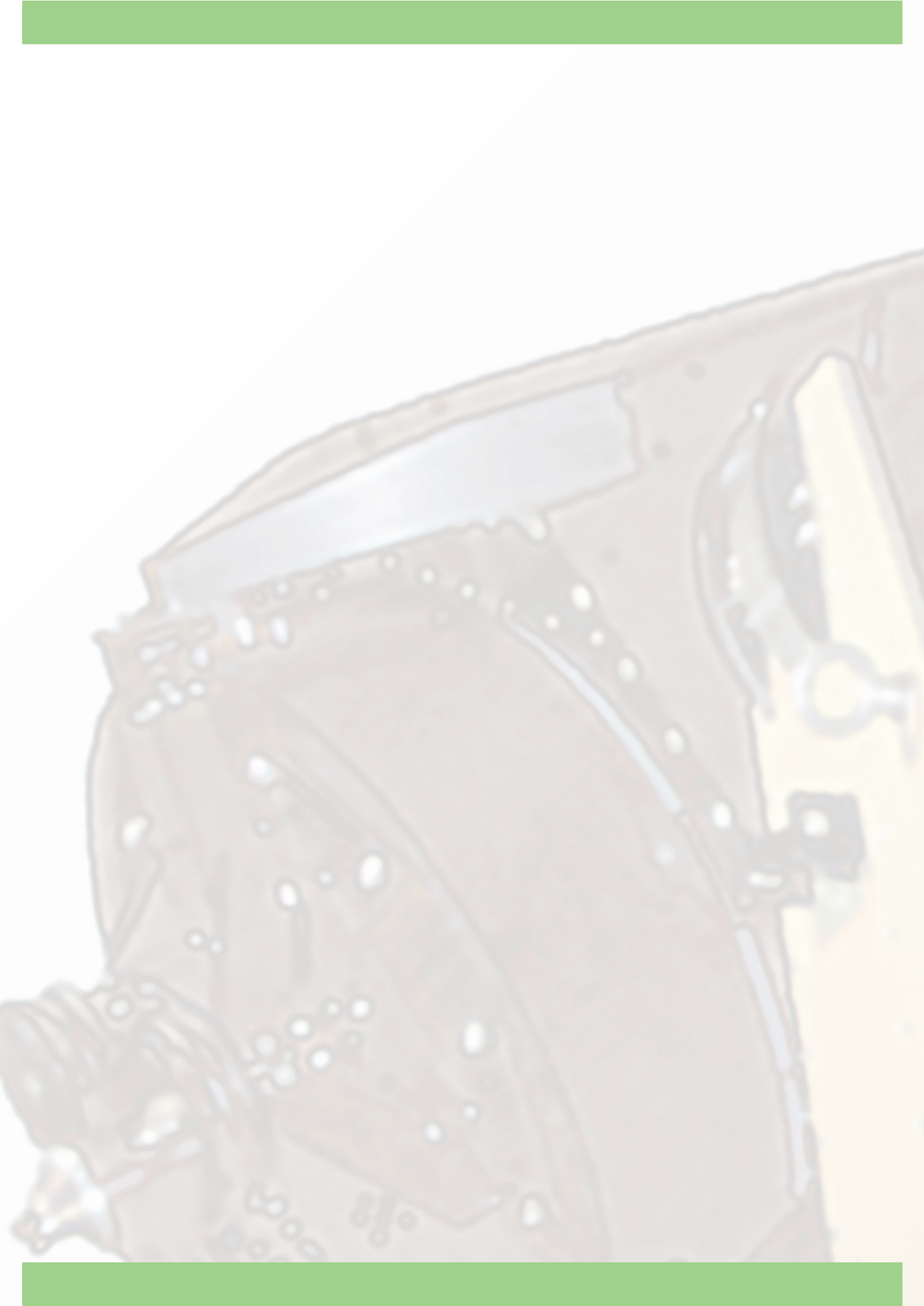
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For the Teacher

The Eudoxos project was implemented within the framework of the Action Preparatory and Innovative Actions - eLearning action plan DG EAC25/01. The eLearning initiative of the European Commission seeks to mobilise the educational and cultural communities as well as the economic and social players in Europe in order to speed up changes in the education and training systems for Europe's move to a knowledge-based society.

This Guide hopes to demonstrate to science teachers how eLearning can improve and enrich the quality of learning and teaching process in science and technology and thus to convince them that eLearning constitutes a cornerstone of the emerging educational environment. Within this environment, the role of teacher will change to a large extent. The teacher will be transformed from a content provider and “transmitter” to a mentor guiding and supporting learners through the process of knowledge acquisition. In addition, the Guide attempts to show the benefits that teachers and their students will profit from their interaction with science and scientists. The scientific field that constitutes the framework of the project is Astronomy. The teachers and their students will benefit from the use of scientific instruments such as the remotely controlled robotic telescopes as well as from the acquaintance with scientific concepts and ideas. Benefits will also be extracted from their communication and interaction with experts. They will experience for the first time in their life the scientific methodology.

This guide contains three main chapters. The first one deals with theoretical aspects such as what is eLearning and which are its characteristics, how the Internet has transformed learning and what the role of the educational software has been in this change, how new subjects in school promote the interdisciplinarity, which tends to be a demand for the school of today, and finally what the new role for teachers in the new era for schools is. The second chapter is devoted to the Eudoxos project. The goals and the objectives of the Eudoxos are presented as well as the main pedagogical and didactical approaches that dominated its run. In addition, it contains a description of its run when it was applied in the classroom. The innovative points of the Eudoxos project, the general impact it had on teachers and students, and some impressions the actors had from their participation to the project are introduced. The third chapter addresses the issue of the evaluation strategy of the Eudoxos project, its main objectives and the results from the qualitative analysis of the project. This chapter is a contribution of the University of Cadiz research group which performed the evaluation of the project. The Full Evaluation Report (including the full description of the methodology, the tools used as well the evaluation results for each school) is available at <http://www.ellinogermaniki.gr/ep/eudoxos> . As the Evaluation Report is focusing in advanced research issues in the field -something that goes beyond the scope of this Guide- it was decided only a summary of the extended evaluation report to be included in this Guide.



1

Implementing Innovations in the School Curriculum

1.1 Towards eEurope 2005

Powerful new technologies promise to transform education and training in ways previously unimaginable. Rapid advancements in educational technologies in the years ahead could enable new learning environments using simulations, visualizations, immersive environments, game playing, intelligent tutors and avatars, reusable building blocks of content, address distributed communities of learners, and many more. There are many challenges in the process of educational innovation that must be addressed in order to take advantage of these technologies to improve learning. Advanced technologies developed to meet other purposes must be translated into affordable tools for learners to use. Technical standards must be deployed to help guide the development of educational content that will be drawn from countless sources throughout the world. The technology community has to form stronger partnerships with the educational community. The educational institutions need to prepare for rapid technological change.

With the shift towards the knowledge society, the change of working conditions and the high-speed evolution of information and communication technologies, people's knowledge and skills need continuous updating. **Learning**, based on collaborative working, creativity, multidisciplinary, adaptiveness, intercultural communication and problem solving, has taken on an important role in everyday life. The learning process is becoming pervasive, both for individuals and organisations, in formal education, in the professional context and as part of leisure activities. Learning should be accessible to every citizen, independent of age, education, social status and tailored to his/her individual needs.

Member States responded positively to these challenges through the development of the ambitious **eEurope 2005: An Information Society for All Action Plan**. Most schools are now connected and work is underway to provide convenient access to the Internet and multimedia resources for teachers and students. The eEurope 2005 Action Plan aims that all schools and universities have Internet access for educational and research purposes over a broadband connection. Museums, libraries, archives and similar institutions that play key role in eLearning will be connected to broadband networks.

The principal objectives targeted by this effort are

- to improve the learning process, particularly the intertwined learning process between individuals and organisations, with consideration of pedagogic principles and the learning context,
- to increase the efficiency of learning for individuals and groups.

These objectives are expected to be realised mainly by

- supporting adaptive learning and collaborative learning,
- extending access to new learning opportunities, independently of time and place,
- facilitating transfer and sharing of knowledge.

The Eudoxos project could act as an excellent example of the effective and advantageous use of broadband services as it requires high speed transmission of significant amounts of data. In this way it is expected to support both the national initiatives as well as one of the main aims of the eEurope 2005 Action Plan, namely the widespread availability and use of broadband networks throughout the Union by 2005.

Additionally, as reflected in the eEurope 2005 Action plan “Developing a better understanding of the role of science in society and bringing science and scientific subjects closer to the citizen is expected to help increasing young people’s interest in science and scientific careers”. The Eudoxos project is building on this aim as it offers to young people the opportunity to use scientific instruments such as robotic telescopes in the framework of their normal school curriculum. Moreover, the Eudoxos project contributes to the access to and sharing of advanced tools, services and learning resources not only between schools but also among science museums and research centers. Finally, it supports the provision of key skills to the future citizens and scientists (collaborative work, creativity, adaptability, intercultural communication).

The main outcome of the EUDOXOS project is an ICT-based environment along with educational material to support science instruction at secondary school level. In the following paragraphs the main parameters that were taken into account during the development and the implementation process are presented.

1.2 Designing ICT-based educational applications

Taking a closer look on the courses internationally given, we observe that in practical teaching situations the methodology used in computer-assisted instruction is moving more and more into ICT-assisted knowledge construction, distributed expertise and collaborative learning. Hyper- and multimedia-based sources of knowledge have replaced in many cases traditional study books with electronic resources. ICT and networking can make the learning environment more open in terms of knowledge acquisition in all phases of education.

When teaching and learning is supported by virtual tools, it should be kept in mind that there is already a pedagogical concept incorporated within this environment determining the scale of pedagogical functions made available for the courses. Speaking in the context of the Internet, first it is the technology itself that determines the range of possibilities (e.g. dominance of texts due to bandwidth restrictions). Then, it is the environment which is based on the functionality of the technology that contains a certain design with a set of tools, functions, bars, fixed hierarchies and positions. Some kind of pedagogical limitations is again provided at the final stage of the pedagogical design of courses. Therefore, the variety of pedagogical functions is restricted to the tools which are offered by the pre-defined and standardised environment.

Wilson (*Wilson, 1996*) has described the relationship between the ideas of knowledge and the nature of the learning environment. His main ideas are presented in Table 1.1.

Table 1.1: *Relationship between the ideas of knowledge and the nature of the learning environment (Wilson, 1996)*

Metaphor about knowledge, knowing	Consequence for the learning environment
Knowledge is a quantity or packet of content waiting to be transmitted	Products that can be distributed via different methods, media.
Knowledge is a cognitive state as reflected in a person’s schema and procedural skills.	Combination of teaching strategies, goals and means to change the schemes of thought in the individual.
Knowledge is a person’s meanings constructed in interaction with one’s Environment.	The pupil acting and working in an environment with plenty of resources and stimuli.
Knowledge is enculturation or adoption of a group’s ways of seeing and acting.	Participation in the everyday life and activities of the community.

By analysing the concepts of environments and courses where information is provided on the Internet, all the aforementioned types of learning environment can be found. ICT is therefore not prone to support one particular type of learning environments. On the contrary, designing the ICT-based educational innovations, the technology will have to be introduced in such a way so as to create and support the desired learning environment. However, in practice we notice that the integration of virtual learning tools can also be derived from a pragmatical decision at the educational institution level. This can also be used as a step for introducing the evolutionary transition from traditional teaching environments towards settings related to ideas of social constructivism. The evolution of learning environment is a complicated process where the critical factor is often the institutions' cultural and historical situation with practical arrangements and not the learning theory (Bourdieu and Passeron, 1977).

As a consequence of this shift towards a student-centred approach, the building of “learning communities” and “collaboration” plays a crucial role in the instructional design of (social constructivist) learning environments.

Learning is an active process. Dewey (Dewey, 1916) foreshadowed the idea of active learning when he claimed that an individual learns through doing and engaging in authentic tasks. Learning as an active process has also been elaborated on by Bruner (Bruner, 1966; Bruner, 1986; Bruner, 1990). A central point to this idea is the concept that learning is a process where students explore and discover connections in order to create new ideas and notions. Learning takes place when the learner interacts with the content, materials, and other learners in the learning environment.

Exploring the experience of teaching in an online ICT-based environment, one needs to include a discussion about the interactive nature of learning as well as about the cooperative responsibilities that are implied by the use (and nature) of technology. The interplay between the learner and the instructional content is also a critical component of student's learning. A recapitulation and discussion follows in addition to an outline of how this interplay defines the evolving responsibility of the teachers in this environment.

Working with ICT in the classroom raises many barriers. The environment needs to be able to support the learner in ways that are encouraging by providing familiarity and security. The learner also needs to be productive in the environment and, therefore, needs to have tools at her/his disposal that will help her/him accomplish their tasks. Not only is organising group work a pedagogical measure that supports good learning but it is also a necessity. This stems from the fact that group work is the cornerstone of establishing the student-teacher relationship and defines the interaction among participants.

In their study about the evaluation of learning environments Britain and Liber (Britain and Liber, 1999) present two crucial issues regarding the work with Virtual Learning Environments (VLE)

- VLEs should provide opportunities to improve the quality and variety of teaching and learning that have not been achieved using current methods.
- VLEs should reduce the administrative burden on teachers, thus allowing them to manage their work load more efficiently and to be able to pay more attention to the educational needs of each student individually.

Taking into account these requirements, it is evident that the approach for analysing the process must reflect various other aspects apart from the discussion of pedagogical techniques within VLEs.

During the stage of planning, development and while educational activities are running, it is necessary to be stated that there are also a lot of other important aspects to be considered in this discussion about pedagogical techniques. In addition, teaching supported by ICT means a lot of organisational aspects that one has to consider. This statement is reinforced dynamically within intercultural settings and even more when the benefits of technologies are even applied in the context of local, regional, national or international collaboration.

When choosing to use educational software and material available on the web, the need to establish certain criteria for evaluation emerges. Several lists with criteria for evaluation have been developed. There is no checklist that seems to be exhaustive but the following criteria are frequently quoted:

Usability

Usability of multimedia material and web resources (Oliver et al., 1996) differs a lot from usability of conventional materials. Conventional materials require few operational skills on the part of the learner, while a web material, for instance, employ many different functions and features whose effectiveness or ineffectiveness is subject to evaluation. Usability can be measured in terms of access and retrieval speed, navigation, search facility, communication facility, user friendliness. Educational software web resources should be examined in order to

- 1) see the extent to which they can be easily and/or reliably accessed or if they are frequently overloaded or offline and
- 2) identify technical constraints, if any, which may limit usability.

In addition, the effectiveness of several facilities that influence usability should be considered. Such facilities include (a) the navigation tools, like menus, buttons, history lists, site maps and/or table of contents that should be both sufficient and easy to use, (b) the search tools, either in the form of a search engine or search categories, which help or hinder the user from effectively retrieving information in whatever form and (c) the communication tools that enable the user to get help, to communicate with peers and to interact with the web resource itself through games and tests. All these elements are said to enhance the resource's usability and increase its pedagogical value-added and user-friendliness.

Pedagogical Effectiveness

In addition to usability, pedagogical effectiveness in terms of pedagogical approach, interactivity, interdisciplinarity, learning outcomes should be examined. General pedagogical criteria are related to the objectives and the target audience. According to Smith (Smith, 1997), it is important that a resource states the subject area and the level of users it is addressed to, and takes into account the intended users' background, knowledge, goals and motivation for using the particular resource. In this way the resource (Edelson and Gordin, 1996), which is available to the user, becomes also accessible.

Apart from the general pedagogical criteria, the evaluation should focus on exploring the role of the learner and the role of the teacher within the resource separately. As for the role of the learner, students using the resource are expected to create knowledge databases, i.e., act as creators, constructors, carry out tasks and activities, i.e., act as doers, and undertake research and field studies, i.e., act as explorers/researchers. The quality of the instructional setting of the resource should therefore be assessed. According to Oliver et al. (Oliver et al., 1996), the role of the learner within an instructional setting greatly influences or enhances learning outcomes. If a resource acts like another information source and interacts to a limited extent with the user, then it contributes little to the user's learning.

In addition, the extent to which the resource includes or reinforces collaborative activities, which are said to be of great educational value for the students involved, should be measured. As Oliver et al (Oliver et al., 1996) point out, interactions and activities that enable group and teamwork should be included in the teaching-learning process. They are its essential ingredients. The communications' component of the web provides unique opportunities to enable forms of communicative and collaborative activities among networked learners. The value of group work cannot be stressed enough. Group work (Riel, 1998) provides a context for the externalization of thinking. It permits for the discussion of multiple perspectives and helps all participants realise that each person creates one of many perspectives on a topic or problem. Learning to see from the perspective of others helps create a more complex understanding of situations. More effective learning environments ensure that the resources are used within a social context with students working in groups, discussing the issues, reporting back, presenting findings, interviewing and debating the issues to ensure that students have the opportunity to articulate, negotiate and defend their knowledge. Knowledge construction is rarely done in isolation.

Measures and assessments of achievement and outcomes from instructional settings also play an important part in the teaching and learning process. It is suggested (Oliver et al., 1996) that assessment should not be a separate stage in a linear process of pre-test, instruction, post-test; rather assessment should be integrated, ongoing and seamless part of the learning environment. The enhanced interactive capabilities of the web provide the means for assessment of student learning to extend beyond conventional essays and examinations. More reliable assessments now take the form of evaluation measures such as portfolios, summary statistics of learners' paths through instructional material, diagnosis, and reflection and self-assessment.

Regarding the role of the teacher, it should be examined in order to see if the resource provides teachers with tools to develop own material, e.g. lesson plans, classroom activities, tests, etc., and if they can make good use of the existing material offered by the resource.

In addition to that, opportunities for communication with colleagues should be evaluated. It should be noted that a programme or a web-resource, which enables and supports communication greatly facilitates the development of a learning community (Riel, 1998). This learning community is a community of practice, a group of people who share common interest in a topic or area, a particular way of talking about their phenomena, tools and sense-making approaches for building their collaborative knowledge with a sense of common collective tasks. Communications technology provides promising opportunities for collaborative learning environments for teachers in which they can reflect on practice with colleagues, share expertise in a distributed knowledge framework, and build a common understanding of new instructional approaches, standards and curriculum. Communication with students is also important. The teacher should be able to provide coaching, feedback scaffolding, fading, modelling and so on, which are powerful enhancements to any learning situation.

Furthermore, interactivity is very important. Interactivity (Oliver et al., 1996) involves the forms of communication that a medium supports enabling dialogue between the learner and the instructor -not one-way transmission mode- and it is an important attribute of technology-supported environments. Print-based instructional materials have served well in the past in support of student-centred independent learning. In recent times, the move to computer-based learning environments has been taken to improve the perceived interactivity of the materials.

However, it should be noted that clicking on paths and navigating through a web instructional sequence is not representative of interactivity. Some strategies that have been used to create the essence of interactivity in web learning materials include the provision of model answers and e-mail communications. Other forms of interactivity include the creation of forms within documents by which learners can enter responses and receive programmed feedback.

The integration of web resources (Riel, 1998) should provide new forms of interaction very different from reading a text or watching a video or talking to a group. It should be an evolving social construction. It is this blend of projected reality with communication that makes it possible to create a sense of shared place with the potential for different forms of social exchanges.

Finally, interdisciplinarity influences a resource's pedagogical effectiveness. In other words, it should be examined the extent to which a resource provides information in different subject areas, integrates it efficiently by making meaningful links, includes activities which draw on knowledge and skills from various subject areas, and gives support for the development of interdisciplinary projects.

Content efficiency

The evaluation of content efficiency includes measuring information, structure, presentation and accuracy. For a start, information quality is an important criterion. More specifically, the breadth and depth of information, questions such as whether information is linked with other relevant online resources, if it is detailed and extensive, if it enriches the school curriculum and if various points of view are presented are relevant. Information should also be evaluated in relation to the educational objectives it serves and in terms of its appropriateness for the specified target audience.

In addition, the reliability of information has to be examined. Information (Smith, 1997) can be factual, original, opinion or simply links; it can have the form of a print document or it may be published on the web; whichever the case is, there should be evidence of authenticity and reliability, a reference of the authority responsible. Clues that provide such evidence are the credentials of the author or source of information. In addition, meta-information, i.e., information about information, can facilitate the reliability check. Harris (Harris, 1997) comments that there are two basic forms of meta-information, a) summary and b) evaluative meta-information. The first includes all the shortened forms of information, such as abstracts, content summaries or even tables of contents. The latter includes all the types that provide some judgment or analysis of content, i.e., recommendations, ratings, reviews and commentaries. These two types can be combined, providing us with a quick overview and some evaluation of the information reliability.

It is also important to know when the information was created and the date of the last update of the information included in a web-resource in order to check if it is still of value. Some work may be timeless; other work, however, has limited useful life because of advances in the discipline (psychological theory for example), or it is outdated very quickly (like technology news).

Apart from the quality of information, evaluation should focus on the structure of the resource. Assuming that a resource contains rich material and links with other on-line resources (Edelson and Gordin, 1996), these have to be properly organized in order to help the user locate the information it is of his/her interest. Organization (Oliver et al., 1996) of material in web resources can be linear, i.e., links simply act to connect nodes in a specified sequence and the learner follows an instructional sequence planned by the instructor. There is also the potential to create materials with varying degrees of linearity. Links may have a hierarchical structure, giving learners more freedom in the choice of path through the materials. The choice of information organization for materials in the web depends on the nature of the intended learning outcomes. For example, if the aim is to develop students' initial knowledge, namely facts, procedures and rules of discourse, linear linking is an appropriate hypermedia form. For higher levels of knowledge, developing an understanding of concepts and principles, the less structured hierarchical and referential linking is more appropriate. In such cases students are guided by such factors as their prior knowledge and readiness to assimilate new material. When building on an existing knowledge base, learners can benefit from the freedom to browse and explore, to inquire and seek responses to their own questions rather than following a pre-determined path of instruction.

Another critical aspect that determines content efficiency is the quality of presentation/design of the resource. The legibility of the texts and the technical and aesthetic quality of graphics, images, sound, video, and virtual reality elements are indicators of good presentation; according to (Oliver et al., 1996), these also increase the "readability" of the material presented and facilitate understanding.

Finally, content efficiency can be measured in terms of accuracy. The goal of the accuracy test (Harris, 1997; Smith, 1997) is to assure that the information included in a resource is actually correct: up to date, factual, detailed, exact and comprehensive and it is free of political, ideological biases.

1.3 Creation of learning communities

1.3.1 Rationale

Advocates of the use of ICTs in the classroom claim that universal access to the Internet mainly will

- expand the resources for teaching and learning in schools and classrooms,
- provide more challenging, authentic and higher-order learning experiences for students.

Technology can support learning in five ways (Bransford, Brown, and Cocking, 1999)

- **bring into the classroom activities that are based on real-world problems** and that involves students in finding their own problems, testing ideas, receiving feedback, and working collaboratively with other students or practitioners beyond the school classroom, provide tools

and scaffolds that enhance learning, support thinking and problem solving, model activities and guide practice, represent data in different ways, and are part of a coherent and systemic educational approach,

- **give students and teachers more opportunities, including those where students evaluate the quality of their own thinking and products**, for feedback, reflection, and revision,
- **give students and teachers the opportunity to interact with working scientists**, receive feedback from multiple sources including their peers and experienced cognitive tutors, and coach in areas where improvement is needed,
- **build local and global communities** where teachers, administrators, parents, students, practicing scientists, and other interested community people are included in order to expand the learning environment beyond the school walls, and
- **expand opportunities for teachers' education** which includes helping teachers to think differently about learners and learning, reduces the barriers between students and teachers as learners, creates new partnerships among students and parents, and expands communities of learners that support ongoing communication and professional development of teachers.

One of the most quoted reasons why ICT should be integrated into teaching is that it contributes to enhance the quality of teaching and learning. One aspiration is the more effective achievement of existing educational goals. Another aspiration is that ICT should act to liberate learners. The central issue (Somekh and Davis, 1997) is to empower pupil's autonomy over the pace and content of his/her own learning. Choosing to use ICTs in the classroom demands changes in the way the instruction is organised. Teachers' attitudinal changes concerning classroom practice play a fundamental role in realising the potential of ICTs in education. The shift from the old paradigm to the new (information-age) paradigm is best illustrated in Table 1.2 (Riel and Fulton, 1998).

Table 1.2: *The shift from the old paradigm to the new (information-age) paradigm (Riel and Fulton, 1998).*

Isolated class structure	Learning community
Homogeneous Grouping	Heterogeneous Grouping
Class Discipline	Community Organisation
Competition	Collaboration
Knowledge Delivery	Knowledge Instruction
Teacher Centred	Student Centred
Independent, individual work	Interdependent, teamwork
Expertise flows from 1-to-many	Expertise flows in many directions

The paradigm shift is from a teaching environment to a learning environment, where appropriate combinations of challenge and guidance, empowerment and support, self-direction and structure exist.

1.3.2 Collaborative learning

The use and application of ICT to the learning process allows the realisation of collaborative learning. Technology is used as a tool for learning, group work, communication and collaboration. The new technologies have made the so-called horizontal communication flow possible. Learners are able to

exchange information and experiences in real or not real time as well as to carry out common project work for both learning and operational purposes. More specifically, collaborative learning is the process of getting two or more students to work together to learn. Learners collaborate with each other and participate in heterogeneous groups which include a mixture of cultures, abilities, socio-economic status and age, a wealth of knowledge and perspectives.

Learners with different perspectives are brought together to produce shared understandings. Truly collaborative environments encourage all students to ask questions; define problems; take charge of the conversation when appropriate; participate in setting goals, standards, benchmarks, and assessments; communicate with experts outside the community. Each learner has a specific role and task but all learners collaborate to accomplish a joint goal or project. Learning occurs as the result of interaction with others. Considering the issues previously described, the objectives of the collaborative learning scenario may be stated as follows

- to learn collaboratively and autonomously according to group's own interests, needs, pace, etc,
- to share information and experiences,
- to reinforce the processes of knowledge construction by means of interaction with peers and thus its metacognitive, cognitive and social components,
- to update the course content and knowledge,
- to increase and diversify the feedback given to trainees (thanks to vertical and horizontal communication),
- to access diversified information and different opinions,
- to allow greater interaction between trainers and trainees,
- to encourage confident and continuing personal and professional use of ICT .

Choosing which learning methodology to employ depends on the learning objectives, the specific characteristics, the learners' needs, and on other factors related to technology and time. However, it should be noted that the aforementioned learning methodologies complement one the other and can be integrated. In this way any limitations of one method can be overcome by the other.

1.4 The significance of interdisciplinary activities

Recent calls for educational reform focus on the need for curricula emphasizing conceptual learning that is integrated across traditional subject areas. Interdisciplinary instruction links various content areas and is organized around questions, themes, problems, or projects rather than along traditional subject-matter boundaries. Such instruction is said to be responsive to children's curiosity and questions about real life and to result in productive learning and positive attitudes toward school and teachers. Classroom strategies for learning become more student-centred, with learning of content increasingly embedded in real-world contexts, separation between academic curriculum areas becomes less defined. Problem-oriented learning that is connected to real-world problems draws from many disciplines to find solutions. When a powerful idea or relevant problem is presented in a learning context, students are motivated to collaborate, explore the idea, and find solutions. In their quest, it becomes apparent that

- Communication skills are necessary.
- Historical perspective may provide clues to the exploration or solutions.
- Mathematical principles and skills can help in measuring, graphing, calculating, and analyzing the problem.
- Technology tools can assist in researching the problem, collecting and organizing information, and presenting results.

Learning through such interdisciplinary and student-directed learning activities was proved effective and long lasting. New learning environments must provide students with experiences in which they draw upon knowledge from several disciplines, apply a variety of strategies to get at the intended learning, and choose from a rich array of learning tools to examine, publish, illustrate, and communicate their results. Perhaps our greatest challenge in applying interdisciplinary learning exists at the sec-

ondary grade levels. Many high schools have yet to adjust their schedules, strategies, or educational philosophies to accommodate the need to connect learning to real-world contexts and problems.

Information technology cuts across all disciplines. It is a powerful aid to addressing real-world multi-disciplinary problems. The ability to access and store digitized information allows the student to research, collect, and share on a level hitherto unparalleled. Collaboration and consultation with other students and experts is fast becoming an everyday experience. Increasingly powerful computers provide students with real-world problem-solving tools. They help students overcome handicaps, choose among learning strategies, perceive and create new relationships among subjects, and demonstrate their knowledge in words, pictures, moving images, and sound. The experience of these changes allows us to preconceive the high school learning environment where disciplines cross-pollinate and students' learning is truly integrated.

1.5 A new role for the teachers

When talking about the use of ICT in the classroom, one should consider the specific conditions that can act as constraints in the diffusion and successful implementation of such an innovation. These conditions are related to the existing curriculum, managerial issues, range of resources available, level of competency and attitude of the teacher.

In fact, the teacher is a key player in the implementation of the innovation. At the centre of effective use of instructional technology is the teacher. For students to become comfortable and effective users of various technologies, teachers must be able to make wise, informed decisions about technology. All teachers should be confident in applying technology when and where appropriate.

As quoted in (McCombs, 2000), Fullan stresses that the more powerful technology becomes the more indispensable good teachers are. From Fullan's point of view, teachers who are pedagogical design experts and facilitators of learning are needed. Technology may change some of the traditional teacher roles but it will also require them to engage more powerful roles - roles that include not only using technology appropriately that opens new pathways to learning not previously available but also require teachers to find ways to build on meaning, purpose, connections and relationships to the larger world and community outside the school building.

The role of the teacher in the new technology-rich instructional paradigm involves the following

- becoming the creator of an effective external learning environment that stimulates the environment within the classroom,
- mentoring and counselling to ensure that learners are encouraged to pursue their learning in an appropriate and meaningful direction using approaches best suited to them as individuals,
- facilitating students' inquiry, guiding student work and offering individual help (Suthers et al., 1997),
- coaching, observing students, offering hints and reminders, providing feedback, scaffolding and fading, modelling (Oliver et al., 1996).

However, there are a number of teacher-related factors that should be carefully considered so that appropriate support and professional development opportunities are provided. These teacher-related factors that can act as barriers include the following

- Established patterns and limited exposure to new models. According to Collis (Collis, 1996), teachers may have developed patterns and styles of teaching and students interaction that fit their own circumstances and can be managed. Previous practice provides them security. Many prefer replicating traditional chalk and talk instruction and "safe", teacher-led and controlled learning activities. Changing what they think as appropriate pedagogy for the learners, themselves and their subject area may be difficult. This can be even harder when teachers act in isolation from one another and are not exposed to innovative models of learning.
- Accessing technology for lesson preparation but also for instructional purposes plays a significant

role. The availability and operability of technologies influences the extent to which they are used.

- Teachers' workload and lack of flexibility in time and in the curriculum are also considerable constraints.
- The school's culture.

Drawing from various interpretations, Stoll and Fink (Stoll and Fink, 1996) define school culture as follows; various formal and informal elements, the beliefs that colleagues share, the dominant values and the school vision as well as the organisational rules and policies that regulate the life of the school. We should not forget that the teacher is part of a whole, is a member of an organisation with which he/she interacts. If a teacher works in isolation from peers, without collegial support and in a stagnant environment, he/she is likely to be influenced by it and remain static. On the other hand, an organisational culture that is characterised by teacher collegiality and formal or informal collaborative work, both supports and facilitates the development of the organisation's members. Teachers working in an environment where they feel safe, give and receive support from their peers and/or from the head, exchange ideas and innovative practices and share the same values, are likely to respond positively to an innovation and embrace it.

What teachers need in order to respond to their new role are skills in ICT which can be classified into a range of competences. These competences act as a useful framework for teacher professional development and should be perceived as integrated elements of a teacher's professional role and activities. The National Council of Educational Technology's guide lists seven elements

- positive attitudes to ICT,
- understanding of the educational potential of ICT,
- ability to use ICT effectively in the curriculum,
- ability to manage ICT use in the classroom,
- ability to evaluate ICT use,
- ability to ensure differentiation and progression,
- technical capability to use an appropriate range of ICT resources and to update these skills.

In order to develop these skills and overcome the barriers mentioned above, teachers need

- sufficient professional development opportunities in order to (1) learn how technology works and how it is integrated into the curriculum, (2) develop new skills, and (3) change attitudes, and
- support both on pedagogical and on technological issues in order to sustain the use of new technologies in the instruction and to help teachers respond to the demands of their new multifaceted role.

However, changing roles and adopting a new model of instruction which involves the use of ICT is a lengthy process. Teachers go through certain phases before they fully adopt and commit themselves to using ICTs for instructional purposes.

Riel and Fulton (Riel and Fulton, 1998) adopt the stages that describe teacher's change in relation to technology intensive environments or projects, i.e., the entry level, the adoption level, the adaptation level and the appropriation level, identified by ACOT (Apple Classrooms of Tomorrow research project) researchers.

- Entry level: much frustration and anxiety, with a focus on replicating traditional instruction and learning activities.
- Adoption level: beginning to move from concern with connecting the computers to using them, but with much of the attention on how they can support established instructional formats and teacher presented lectures and presentations.
- Adaptation level: greater focus on ways student involvement may change, and teaching style may differ (e.g. giving students more responsibility, encouraging students to use and create activity modules similar to those the teachers are creating).
- Appropriation level: new instructional patterns start to emerge building around interdisciplinary project based approaches, more reflection on teaching and recognizing the need for alternate models of assessment and classroom structuring.

Only when teachers adopt innovation and commit themselves to using technology for instructional purposes, can we ensure that students will be prepared for the challenges they will face in the future. Simply providing sufficient access to technology for teaching and learning is not enough. The preparation of new teachers should be improved, including their knowledge of how to use technology for effective teaching and learning; the quantity, quality and coherence of technology-focused activities aimed at the professional development of teachers should be increased; and the instructional support available to teachers who use technology should be improved.

1.6 The EUDOXOS Project: Implementing innovations in the school curriculum

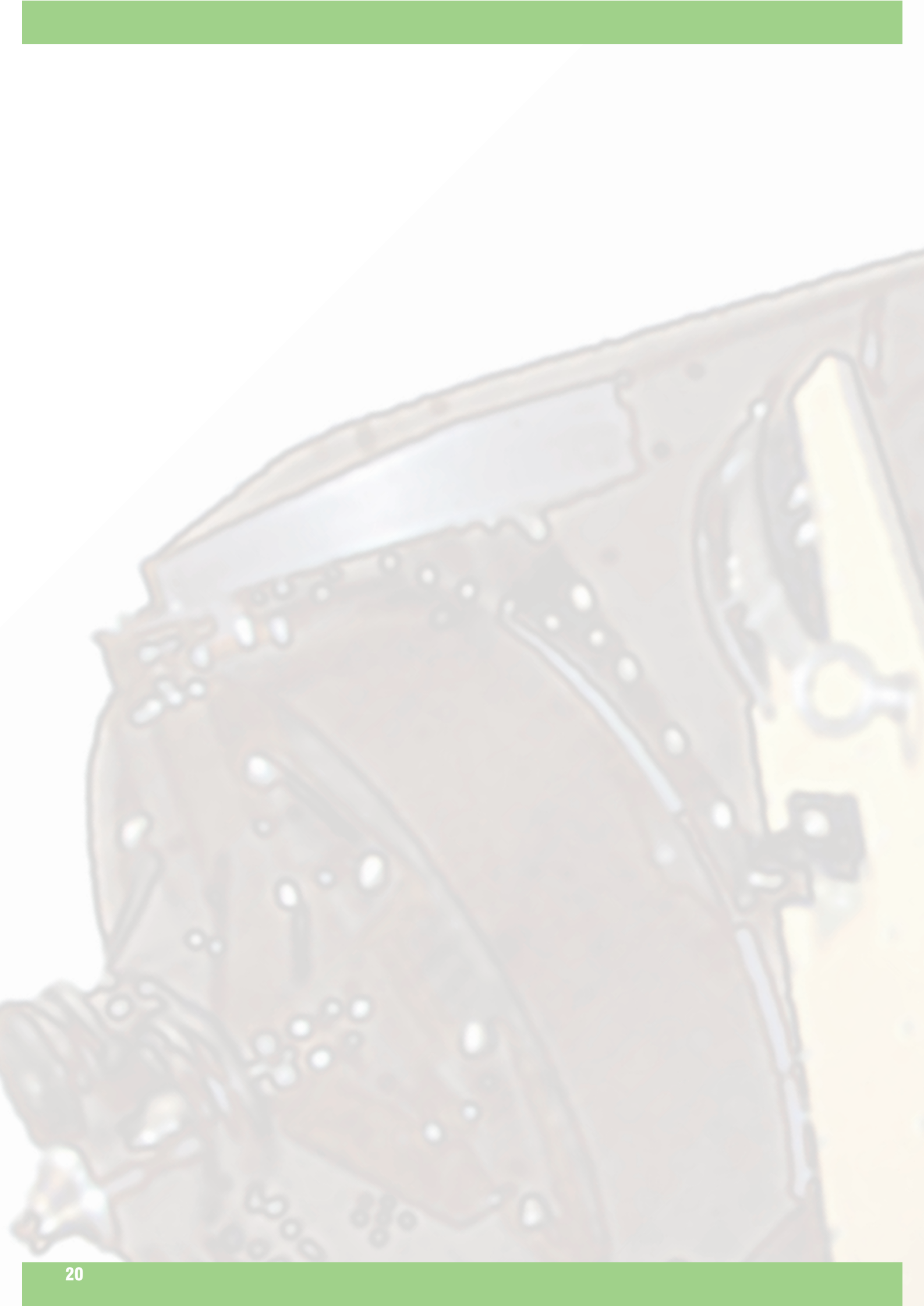
One of the main goals of the EUDOXOS project was to study the applicability of the existing and emerging technologies in the school sector. This was realised by providing a platform that allowed students and teachers to navigate remotely controlled telescopes in the framework of their normal school curriculum. The aim was to demonstrate in practical terms how eLearning can improve and enrich the quality of the learning and teaching process in science and technology.

The pedagogical framework (Eudoxos' Implementation Guide, 2003) which was developed during the first months of the project's life cycle includes all the necessary adjustments to the normal school curriculum, support and training for the teachers, the design of lesson plans for the project's implementation in the classroom and the development of additional educational material (conventional and electronic).

Within this given context, the pedagogical approach consisted of providing an adequate frame for improving teaching and learning in school education. Lesson plans and methods were enhanced and adapted according to the national curricula of each participating country.

However, as a second step it is necessary to keep in mind that technologies provide new educational potentials which are still not sufficiently reflected in school curricula. Besides improvements achieved with the given technologies, new pedagogical (constructionist) approaches for science teaching are also supported which allow learner-centred approaches to be implemented such as project-based or problem-based learning (setting up own experiments and performing observations etc.). Consequently, national curricula will need to be adapted by taking into account the new possibilities given by innovative applications such as the EUDOXOS project. Considering the cultural differences in European school education (curricula, pedagogy and learning approaches), this task will need to be performed at a national level.

There are various aspects of how information technology is used in education: as a platform for the development and delivery of products for teaching and learning and as a tool for the organisation of the learning contents and resources as well. This covers relevant aspects about environments and courses which cannot be analysed separately due to their inter-dependency. The question arises as to whether open and flexible learning environments built on information technology, as provided by the EUDOXOS project, will lead us to qualitatively better, more effective and more efficient education and how these new educational models have to be brought about. This was analysed during the project. The evaluation provides new insights into practises and adequate approaches for the remote telescope application in school education.



2

The EUDOXOS project

2.1 Project's Description

The EUDOXOS project aimed at using the possibilities the Internet offers in order to transform the traditional classroom into a place of discovery and exploration. The project studied the applicability of the emerging technology in the high school sector and provided a platform that allows the students to use the robotic telescopes of the EUDOXOS National Observatory of Education and Research in the framework of their school curriculum. The EUDOXOS project presented ways on how eLearning can improve and enrich the quality of the learning and teaching process in science and technology and thus should constitute an element of a new educational environment.

The sky is a vast and unique laboratory of science, always in operation, accessible to everybody at all times, where all sorts of interesting physical phenomena take place most of which is impossible to reproduce in any scientific laboratory. The project took advantage of the natural tendency of children and youngsters to pursue pleasure and research in their activities and the fact that the observation of the sky always fascinated mankind and motivated the studies of nature and the physical laws. Furthermore, the project provides students, even from remote schools with elementary technological infrastructure, the possibility of using a technologically advanced research instrument, to comprehend scientific issues.

The aim of the EUDOXOS project was to utilize the “Andreas Michalitsianos” (AM) telescope, a 60cm Cassegrain type remotely controlled robotic telescope with large-format CCD camera (Figure 2.1) and the “Apolon” solar telescope, in order to develop the adequate framework to teach science subjects to high school students in the basis of an interdisciplinary approach. The robotic telescopes are installed in the National Observatory of Education EUDOXOS on the Ainos mountain of Kefallinia Island (Ionian Sea), Greece. These scientific instruments have been developed with funds from the Greek Government. The EUDOXOS project is a collaboration of the Institute of Nuclear Physics at the National Centre for Science Research “Demokritos”, Ellinogermaniki Agogi, the Greek Naval Academy, The Pedagogical Institute and the Prefecture of Kefallinia and Ithaki. It is used for educational and research purposes as a working example for Distance Learning and Research (Solomos et al., 2002).

The robotic telescopes were installed in August 2001 and they are operational since then. One is able to remotely request a specific observation schedule and subsequently receive the resulting photographs via the Internet, to be used for educational purposes or for scientific analysis. OTE, the Greek Telecommunications Organization is currently collaborating with Ellinogermaniki Agogi and Research Foundation of Kefalonia in order to create an advanced communication system (including satellite link through DVB-RCS platform utilization) for the EUDOXOS observatory.

A User friendly Interface has been developed to be an adding tool that bridges science teaching and technology. This educational software supports teachers and students in an innovative learning environment while at the same time is compatible with graphics and analysis software components, so that students can easily investigate trends and patterns of the data they collect by using the telescope. The EUDOXOS platform gives students around Europe the opportunity to use remotely controlled telescopes in a real-time, hands-on, interactive environment. In this way it enables students to increase their knowledge on astronomy, astrophysics, mathematics and other science subjects and improve their computer literacy while strengthening their critical thinking skills. Students are able to graphically view all quantities under study and the data correlations through diagram on the computer screen.

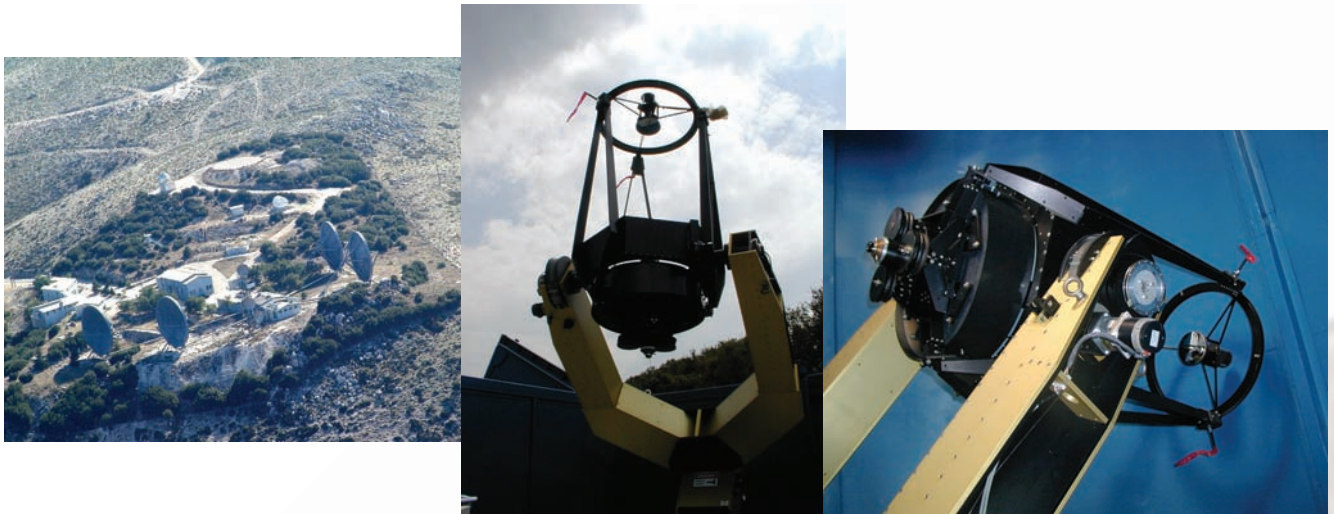


Figure 2.1: *The Andreas Michalitsianos robotic telescope on location (National Observatory of Education EUDOXOS, Ainos mountain, Kefallinia island, Greece).*

2.2 Added Value

Although the EUDOXOS project is using a front-end technological device, the aim is not to test this technology but to focus on the results and changes on the qualitative upgrade that it can produce in the teaching procedure. The EUDOXOS project challenges the most difficult objective of **the development of a better understanding of the opportunities, which are associated with e-learning methods, contents and resources and their impact in education in terms of organisation and management**. The partnership believes that the new systems and educational tools have to start from the user. They have to be so transparent that the user can understand them and be in control of what she or he is doing.

Recent studies¹ normally describe science lessons by means of negative indicators. Students behave passively and their learning outcome is mostly not seen as a basis for the acquisition of new knowledge and for further activities in the area (Baumert et al., 1997). Students seem to not possess skills proposed by “scientific literacy” to become reasonable and responsible acting citizens (Fischer, 1993), meaning in short they are far away from presenting, discussing and criticising science related topics of society. The EUDOXOS project contributes in changing the present situation by implementing the following innovations

- **Teaching science through the use of an advanced scientific instrument:** The new technology offers to the participating students and teachers a unique possibility to use a scientific instrument remotely. The students are able to observe the sun, the planets, the stars, the galaxies on line. In this way their classroom is transformed into a scientific laboratory. The partnership believes that students can come to view the astronomical observations as a craft that rewards dedication and precision but simultaneously encourages a spirit of creativity, exuberance, humour, stylishness and personal expression.
- **Reinforcing interdisciplinary approaches:** The main link usually missing in the learning process is that students do not learn sufficiently through experience but through a systemic model based approach, which should be the culmination of learning efforts and not the initiation. A particularly disturbing phenomenon, that is common knowledge among educators, is that students fail to see the interconnections between closely linked phenomena or fail to understand the links of their knowledge to everyday applications. Therefore, in recent years, there is a clear focus on interdisciplinary education. This approach supports that educational experiences should be authentic and encourage students to become active learners, discover and construct knowledge. Authentic educational experiences are those that reflect real life, which is multifaceted rather than

¹ The TIMSS Videotape classroom study, National Centre for Education Statistics, US department of Education.

divided into neat subject-matter packages. The Educational context of the EUDOXOS project is not transmitted in a theoretical way but rather in a biomatic way in the form of a real life experience. Observing the sky and using a telescope is a highly interdisciplinary subject and its implications give topics for discussion in Astronomy, Cosmology, Physics, Chemistry, Mathematics, Mechanics and clearly expanding the learning resources for students. Additionally, teachers are faced with a real challenge. Having specialised in an academic discipline may cause frustration to them when it comes to creating interdisciplinary, cross-curricular activities. Such activities demand considerable knowledge in many areas, something they may lack. Collaboration with their colleagues may help them overcome this challenge, develop positive attitudes to interdisciplinary learning and gradually adopt it and make it part of their teaching practice.

- **Promoting behaviour and process oriented learning:** After the familiarization of the students with the use of the telescope, projects were assigned to them. They were let free to approach the phenomena and the astronomical objects (sun, planets, stars, galaxies, etc) they wanted to study. The students were requested to develop real problem solving practices, letting themselves free to handle situations and study them. By using the telescope and the user interface to compose their own scientific inquiring strategy, the partnership demonstrated that students are able to engage in more meaningful and motivating science-inquiry activities. In this way these assigned projects promoted creativity through new forms of content combining highly visual and interactive media with the use of innovative ways of design, delivery, access and navigation. The versatility of the tool and results was one of the most compelling factors of the project. The students were encouraged to present and further develop their results in settings that go beyond the school boundaries. Finally, the partnership believes that the students who participated to the project will not see the advanced electronic equipment like the telescope and other similar measuring devices as black boxes, but as something that can “take apart and built again”.

2.3 The EUDOXOS pedagogical approach and the Project's objectives

The EUDOXOS pedagogical approach cross cuts the traditional boundary between the classroom, home, scientific laboratories and research institutions as distinct learning environments. It aims at involving the users (students, teachers) in extended episodes of playful learning. Learning involving a fun element can be more effective (Quinn). According to Lepper and Cordova (Lepper and Cordova, 1992) learning embedded in a motivating setting (such as an observatory) improves the learning outcomes. One implication of this model is that students should be assigned activities that reflect the application of the content knowledge as it is practised outside the classroom. The goal is to induce the learner into a “culture of practice” which makes the knowledge meaningful. Within this general framework, the new technology application of the Eudoxos project supports the pedagogical method of autonomous self-directing learning and allows for a self-directed acquisition of skills to meet users individual communication and learning needs. The self-learning method is supported by elements of entertainment (play and learn) in order to enhance learning by using the new communication technologies to transfer the magic of an observatory into the classroom. Both students’ and teachers’ support was supplied through an on-line manual that acted as an on-line tutor. The on-line tutor served as the guide to the students’ work. Methodologically it is based on the learning scenarios and the lesson plans that have been developed in order to support the project’s application.

The applied methodology ensured the active participation of all partners by proceeding in the following way. A prototype version of the web platform was initially developed according to the guidelines of the pedagogical experts. Teachers were also involved in this stage providing significant input from their teaching experience. During a test run (first cycle of school-centred work), the web platform was tested and evaluated in real conditions. The final run (second cycle of school-centred work) followed the evaluation of the test run. The improvements and the appropriate modifications were made and the final version of the platform was used in the final run in the second year of the project. These cycles of school-centred work were not only meant for evaluation purposes (technological and pedagogical) but also aimed to involve teachers and students in giving direction to the project and its technological and pedagogical results. The aim was to help both teachers and students reach beyond “cliches” to the areas in which they could make the most valuable contributions, and potentially increase their role in the project. To assure maximal usability of the new tool and realistic evaluation of the pedagogical

effects, the developed software add-on used a heavily student-centred approach. In this framework, the project's implementation served the following objectives:

- **The enhancement of a constructionist approach in science teaching.** Usually pre-designed experiments are used in science teaching. Within the framework of the project, students acquired the skills to use the telescopes in order to set up their own experiments and observations which they conducted autonomously. In this way the procedure of scientific inquiry is fully realised: formulation of hypothesis, experiment design, selection of time and sky area, implementation, analysis of data, verification or rejection of hypothesis, evaluation and generalisation are the steps that allow for a deeper understanding of the scientific method. The partnership believes that the proposed approach acted as a qualitative upgrade to everyday teaching for several reasons:

Motivation: Students felt a sense of personal investment in a scientific investigation as they actively participated in the research procedure and added their own ideas to their observations.

Developing critical attitude: Too often students accept the readings of scientific instruments without question. When students got involved in the project's activities they appreciated the power and limitations of an experiment and, as a result, they developed a healthy scepticism about the readings and acquired a more subtle understanding of the nature of scientific information and knowledge.

Making connections to underlying concepts: In the framework of the project's application to the school communities, students were asked to design their own projects. During this procedure students figured out what to measure and how to measure. In this process they developed a deeper understanding of the scientific concepts underlying the investigation.

Understanding the relationship between science and technology: Students who participated in the project gained hands-on experience in how technology and engineering can both serve and inspire scientific investigation and vice versa.

- **The development of new learning tools and educational environments.** The EUDOXOS project gave the opportunity to students around Europe to use remotely controlled telescopes in a real-time, hands-on, interactive environment. This has enabled the students to increase their knowledge of astronomy, astrophysics, mathematics and other science subjects; improved their computer literacy; and strengthened their critical thinking skills. The partnership developed a User friendly Interface as an adding tool that bridges science teaching and technology. The aim was to develop a better theoretical framework on how different types of tools, like the e-tool of the EUDOXOS project and the learning environments, support different types of thinking, reasoning and understanding.
- **The development of a pedagogical framework that allows for successful application of advanced technology in science teaching.** The project developed an innovative educational approach which guides students through the learning process in science by using real-time astronomical observations as possible subjects of both formal and informal scientific investigation.
- **The development of a concrete evaluation scheme of the educational and technological aspects.**
Most electronic tools (software, CD-ROMs, Internet sites) used in education have never been concretely evaluated. The EUDOXOS consortium stated from the very beginning that the evaluation of the pedagogical impact of the tools was a very important aspect. The didactic approach of the project was evaluated according to an academic valid scheme based on well-defined methodologies. The aim was to develop a better theoretical framework on how different types of tools and instruments support different types of thinking, reasoning and understanding. The evaluation of the didactic approach was performed in three aspects: evaluation of student's learning, evaluation of the underlying pedagogical framework and ethnographical evaluation.

2.4 The use of ICT in the framework of the EUDOXOS Project

The EUDOXOS project made full use of the capabilities the web offers. In order to stimulate students' interaction a web-based platform was developed. Designing the web platform, proper weight was given on its educational concept. It was a tool for students, a distributed learning environment, facilitating the learning process. It included facilities to make astronomical observations, to analyze the astronomical images and to communicate with the astronomers. The educational use of technology was clearly one of the most important aspects of the project. It has to be stressed though that technology is not considered as a substitute of the conventional teaching but rather as an add-on that has to justify its introduction through the qualitative upgrade it offers to everyday school practice. The web-centred technology used in the EUDOXOS project had three main components, a) the EUDOXOS platform, through which students and teachers had access to the telescopes and to the data, b) Bulletin Boards for exchange of ideas and data between the working groups as well as for communication with the experts and finally c) extended videoconferencing sessions for the enhancement of the social parameter of the communication.

The EUDOXOS platform

Using the EUDOXOS User Interface, students had access to data from all schools. The code for supporting the recovery of the data from the database in order to be used from teachers and students was developed in ASP/HTML programming language with the use of VB scripts. An SQL database has been developed to store the collected data for future use. The development of the interface was based in JavaScript and HTML, whereas advanced software tools (e.g. Macromedia Generator, Macromedia Flash) were used for the presentation of the astronomical data. The aim was the final outcome to be a fast processing tool, free from complex procedures, giving students the opportunity to easily access the data on demand.

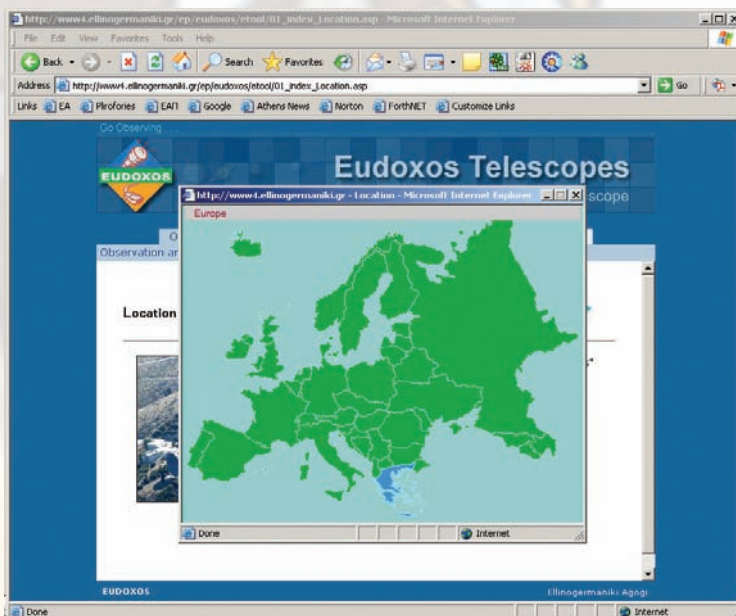


Figure 2.2: 1st STEP: Select the location for the observation. The user has the possibility to select among the available telescopes through the EUDOXOS platform

Through a very simplified procedure the student is able to perform an observation or to submit a request. For example: the EUDOXOS Observatory has currently two telescopes in use, a conventional and a solar one. So the user has the possibility to choose the telescope according to the needs of the observation (Figure 2.3). Additionally, the user has to check the weather conditions in the area (the observatory includes a robotic meteorological station which controls the dome where the telescopes are housed - still an observation could fail due to clouds for that reason the interface provides on-line access to satellite views of the area), Figure 2.4.

The **scheduler mechanism** makes optimal use of the available resources (individual sites will be able to make themselves available or remove themselves according to their needs). Additionally, it considers weather and technical status as attributes in order to make real-time adjustments to the sched-

ule when appropriate and necessary, adding a routing capability to the scheduler. The activities to be scheduled are those users' requests that have been approved by a review mechanism. The scheduling system is also used to filter infeasible requests - those for which there are no available telescope - early in the review process. The consortium based on the experience of the TIE project, (Rathod et al., 2003) has develop a method of cost-sensitive constraint satisfaction (CSCS) that incorporates the costs of constraint checking into the constraint reasoning process (Sansare, 2002). This method allows for the scheduler to be sensitive to the cost of evaluating alternatives (testing constraints). Constraints that are expensive or difficult to test are treated as having an additional cost that must be minimized. The goal is to develop a constraint satisfaction method that minimizes the total cost of constraint checking. The number of constraint checks is commonly used as an evaluation metric for the time performance of constraint methods, but to our knowledge, there is no previous research that allows constraints to have varying costs, or that treats the cost of constraint checks as an explicit optimisation criterion.

The **Upload Mechanism** supports users for presenting their work on the web and it manages the system's resources.

The EUDOXOS platform uses a **multimedia database system (Library)** for storing and retrieving the multimedia knowledge data that consists mainly of text and images. Examples of resources include projects, lesson plans, educational material for teachers, images. As each resource comes into existence, its components are encapsulated in XML and are further annotated with appropriate metadata protocol, to permit queries for future use. The database will store and manipulate the following knowledge data types

- The images of the astronomical objects.
- The mapping information between images of real objects and knowledge data scenarios.
- The knowledge data scenarios of the e-learning experiment.
- The multimedia objects (text, audio, images, video) composing the knowledge data scenarios.



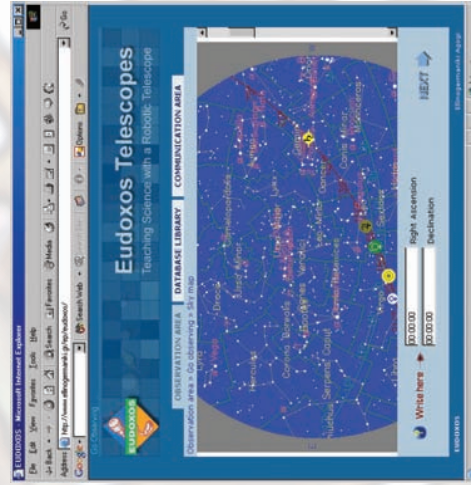
Figure 2.3: The user has the possibility to select among the available telescopes at the participating observatories. The EUDOXOS observatory has two telescopes in use, one conventional one (60cm) and a solar one for day-observations.

When the user issues a query, the EUDOXOS query agent expands the query according to the relationships expressed in the back-end ontology. All queries in the conjunction would be issued to the XML database. In summary, the EUDOXOS Resources Database provides an interface to a collection of ontologies and query agents that together make relevant resources retrievable.

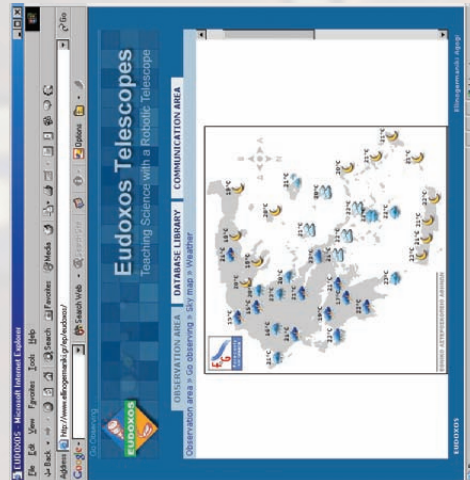
Following the “open systems” philosophy, the EUDOXOS Database will allow for maximum access and use by the educational and scientific community by embracing technologies which promote interoperability, such as XML, and RDF. The EUDOXOS platform is built on open web standards, facilitating use by new users and integration of new telescopes.



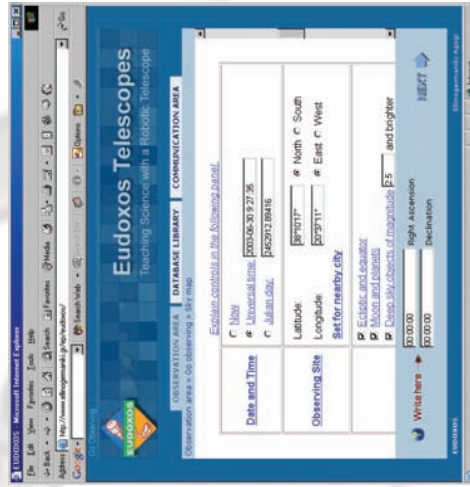
Select the astronomical object you want to observe.



Point the area of the sky you want to observe.



Check the weather conditions in location of the telescope.



Submit your request.

Figure 2.4: The steps the user has to follow after choosing the telescope. First the user has to check the weather conditions in the location of the telescope, then either has to select a specific object in the sky or to point the area of the sky he/she wants to observe. Finally, the user is filling - in an observation form by including necessary parameters for the observation (filters, time, etc)

Bulletin Boards

Asynchronous computer mediated communication has reached a state of maturity. Synchronous ways of communication actually dominate the field, as they are more direct, fast and satisfactory for the participating parts. However, the use of Bulletin Boards cannot be considered as dated since it has a lot of advantages and pedagogical benefits. Opportunities still exist for innovative ways to integrate conferencing and the web. The structure of a really useful Bulletin Board must be hierarchical containing important information essential for the following up and the contribution to a dialogue. There are three pieces of information that should be always available: attribution (who said what), sequence (in what order) and relationship (to whom). This much seems common sense and most systems (but not all) have this information. Because an interchange in a web conference may well take place over a period of weeks, it is important that this information is easily visualized and accessible to anyone interested in it. A learner returning to a conversation some days later, or catching up on new messages, needs this detail in order to respond and contribute to the discussion.

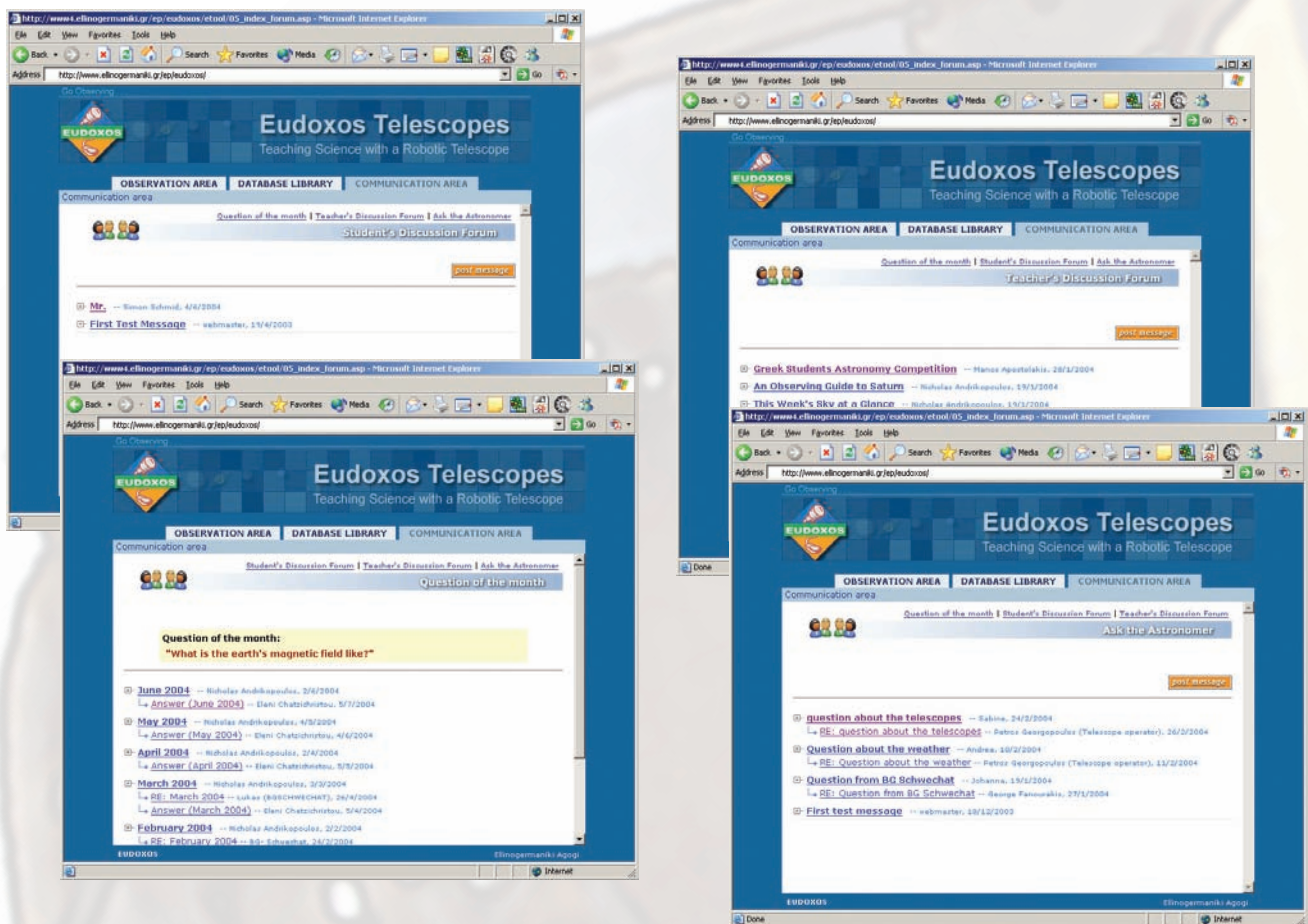


Figure 2.5: *The Eudoxos forums. A live dialogue, questions and answers were presented on the projects' web site*

Students and teachers participating in EUDOXOS project had the chance to use four different Bulletin Boards. Except from the students' and teachers' Bulletin Boards, it was considered very useful to create one for the presentation and the discussion of the "Question of the Month" and one for the communication between the students and the astronomers entitled "Ask the Astronomer". The later was used to enhance the communication acting as a stimulus for further discussions and exploration. In order to assess the impact of the use of these tools, different parameters were adopted, such as the number of messages, the "reaction time" to the questions, the different answers, etc. More than 150 messages were presented on the Bulletin Boards with a mean reaction time of 20 hours which is considered quite good taking into account that students were involved in the project during their normal school curriculum once or twice per week. The main outcome of the data coming from the use of the Bulletin Boards is that students were visiting them regularly, even afternoon or night hours.

Videoconferences

Within a distance learning project where the main players have never met, stimulating dialogue consists a serious challenge if the web is to serve as an educational medium. A video conferencing session could support this process and act as a stimuli for the creation of a virtual learning community. EUDOXOS project's activities provided a lot of opportunities for discussions, exchange of knowledge and culture, and even for the creation of "friendships". Students showed a great interest in videoconferences and during the life cycle of the project they became more familiarized with the procedure and created relationships with their virtual classmates. 16 videoconferencing sessions were realised, 5 of them between the schools and the astronomers team at the EUDOXOS observatory.



Figure 2.6: Moments from the Videoconferencing



2.5 Introducing the Project into the classroom

In the analytical description of the activities that took place during the run of the EUDOXOS project, we will mark out the positive as well as the problematic or negative aspects so as to let the reader who are potential appliers of the general idea of the EUDOXOS or of similar type projects- learn what they have to adopt and what to avoid in order to implement successfully similar activities. The information and experience acquired from the test run was used for the implementation of the activities of the final run. May the experience from the final run prove to be useful to those who will continue the project or will try to introduce eLearning practices and innovative subjects in the everyday school curriculum.

2.5.1 Proposed lesson plans

In the framework of the Eudoxos project a series of lesson plans has been developed to be implemented in classroom during the first two cycles of the school-centered work. The lesson plans are in accordance with the science curriculum of the participating schools and are designed to utilize the experimental capabilities of the robotic telescopes. The aim is to implement these lesson scenarios for the familiarization of the students with the idea of scientific investigation in order to reach the last stage of the work in the school environment. At the final cycle of the school-centered work students and teachers will have the opportunity to design and perform their own scenarios for observations.

A specialized structure for the Eudoxos lesson plans have been developed for the needs of the project. Each lesson plan consists of two main parts.

The first part of the lesson plan gives general information concerning the lesson. It is based on the curriculum and provides details for the implementation in classroom. In this part information about the

time duration, the vocabulary, the tools, and the materials necessary for the observation are given. The educational aims of the each lesson activity are specified and categorized in general and more specific didactical objectives. Finally, the usual student's misconceptions on the teaching subject are presented to teachers in order for them to be prepared and plan an effective teaching session.

The second part of the lesson plans provides information about the pure educational phase of the lesson. This is the part where ideas to stimulate students are proposed and the observational activities are described. Discussion, observation and analysis of the data are proposed as well, while the expected conclusions that should be the outcome of the lesson are listed. In order to assist consolidation, a series of exercises and questions and further activities are proposed.

Four lesson plans have been developed so far, namely:

1. Measuring the size of Saturn's Rings.
2. Measuring the height of the Lunar Craters.
3. Measurement of the Solar Rotation.
4. Determination of Asteroids Rotation Periods.

General Structure of the Lesson's Plan

I. General Information

Duration

Vocabulary

Tools and Materials

Aims and Objectives

Student's Misconceptions

II. Educational Phase

Stimulation

Experimental Activities

Observation - Discussion

Consolidation

Measuring the size of Saturn's Rings

I. General Information

This lesson plan provides information and material concerning observational (experimental) study of Saturn's rings using the Andreas Michalitsianos Robotic Telescope or preferably the Apollon telescope. Specific observational and experimental activities are presented and several questions, exercises and tasks are proposed to assist consolidation of acquired knowledge.

Duration

Classroom lesson	:	1x45 min
Observational Activities	:	2x45 min

Vocabulary

Saturn, Saturn rings, satellites, Cassini division.

Tools and Materials

Andreas Michalitsianos Telescope (TAM) or Apollon telescope, PC with internet connection, Paper sheet, Pencil, Ruler.

Aims and Objectives

The students should

- be able to plan and carry out astronomical observations,
- be able to understand the exact correspondence between lengths in the focal plane of the telescope and angles in the sky,
- be able to compute the maximum angle in the sky from which the incoming light is focussed within the area of one picture at the detector,
- be able to use compute the size of Saturn's ring,
- be able to understand the scientific methodology.

II. Educational Phase

Stimulation

1x45 min

Presentation of selected photos and/or videos of the Saturn's rings

- Short discussion on the Saturn's atmosphere.
- Draw up a list on the blackboard with the proposed methods of measuring of the size of Saturn's rings.
- Explain the optics behind the operation of the telescope.
- Explain the concept of focussing a parallel light beam by a lens or mirror.
- Explain why the position of the focus in the focal plane (where the CCD is located) determines the direction of the (point-like) astronomical source in the sky (along which the light is coming to us).

Experimental Activities

First phase (1x45 min)

The students using the Eudoxos User Interface must

- select the Andreas Michalitsianos Robotic Telescope or the Apollon telescope,
- check the meteorological status for the site of the Kefallinia Island,
- determine a reasonable exposure time (*see: <http://knidos.snd.edu.gr/telescope/E-Exposur.html>*),
- fill in the Saturn name or the celestial coordinates of the Saturn (and the corresponding time) and submit their request(s).

Figure 2.7: The Saturn's Rings



Second phase (1x45 min)

The students using the Eudoxos user interface must

- study and understand the method employed to measure sizes,
- determine the actual distance of Saturn from Earth at observation time,
- take the Saturn's images from the Database Library,
- estimate the size of Saturn's ring using the proposed image-processing software (*using the "sky map" tool or "cart du ciel" tool*).

Observation - Discussion

Discussion of the theoretical issues arising from the observational (experimental) activities.

This is facilitated with the assistance of the website's theory tutorial and links

- Theory and observation (experiment) comparison.
- Comparison with the Galileo's anagram.
- Short discussion on the satellite system of Saturn.

Consolidation

Questions, exercises and tasks aiming at consolidation of the acquired knowledge.

Exercises

- Attempt to measure the size of the Cassini division, problems, comments.
- Measure the Saturn's radius.
- Measure the diameter of other planets.
- Discuss the factors determining the accuracy of the method.

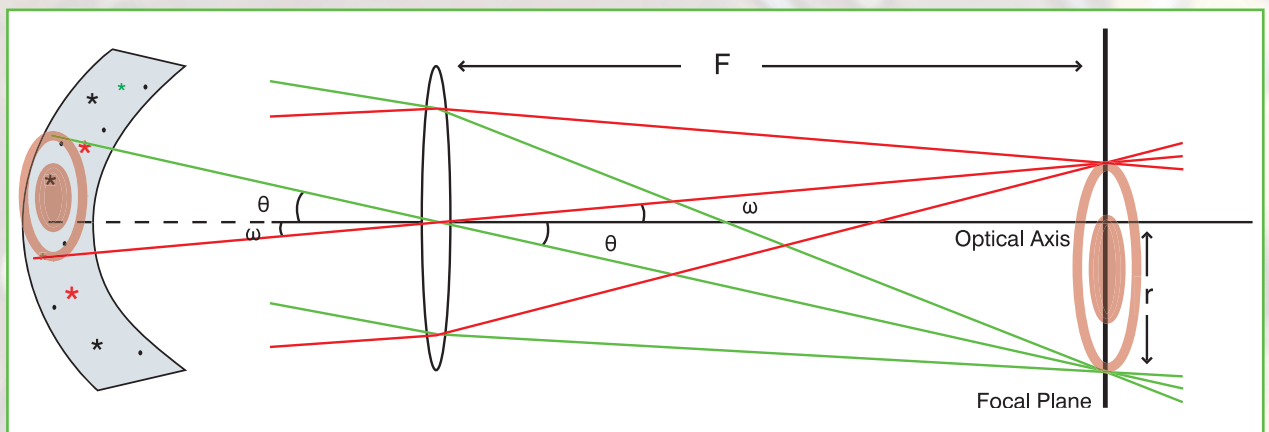


Figure 2.8: Measuring the size of Saturn's Rings

Measuring the height of the Lunar Craters

I. General Information

This lesson plan provides information and material concerning observational (experimental) study of the lunar craters using the Andreas Michalitsianos Robotic Telescope or preferably the Apollon Telescope with a Lunar camera. Specific observational and experimental activities are presented and several questions, exercises and tasks are proposed to assist consolidation of acquired knowledge.

Duration

Classroom lesson	:	1x45 min
Observational Activities	:	2x45 min

Vocabulary

Lunar craters, Meteorites, Solar ray, Shadow, Moon radius, Moon phases.

Tools and Materials:

Apollon or Andreas Michalitsianos Telescope, PC with internet connection, Paper sheet, Pencil, Ruler.

Aims and Objectives

The students should

- be able to prepare and make astronomical observations,
- be able to use celestial coordinates,
- be able to measure the moon radius and the lunar craters radius,
- be able to estimate the height of the lunar craters,
- be able to understand the scientific methodology.

Student's Misconceptions

Shape of the earth, day-night cycle, phases of the moon.

II. Educational Phase

Stimulation

1x45 min

- Presentation of selected photos and/or videos of the Moon's surface.
- Short discussion on the Moon's surface and crater formation mechanisms.
- Draw up a list on the blackboard with the proposed methods of measuring of the height of the lunar craters.

Figure 2.9: The Shape of the Moon



Experimental Activities

First phase (1x45 min)

The students using the Eudoxos User Interface must

- select the Apollon or Andreas Michalitsianos Telescope (Lunar camera),
- check the meteorological status for the site of the Kefallonia Island,
- fill in the celestial coordinates of the Moon and the proper time of observation or (better) just select the moon and submit their request(s).

Second phase (1x45 min)

The students using the Eudoxos User Interface must

- take the Moon's image from the Database Library,
- study and understand the analysis method followed in the theory,
- estimate the height of the lunar craters using the proposed software for the analysis of

the image(s).

Observation - Discussion

Discussion of the theoretical issues arising from the observational (experimental) activities. This is facilitated with the assistance of the website's theory tutorial and links

- Theory and observation (experiment) comparison.
- Comparison with the Eratosthenes experiment, observe similarities and differences.

Consolidation

Questions, exercises and tasks aiming at consolidation of the acquired knowledge.

Exercises

- Estimate the height of a tree measuring the shadow of the tree.
- Make craters by throwing small marbles on flour.

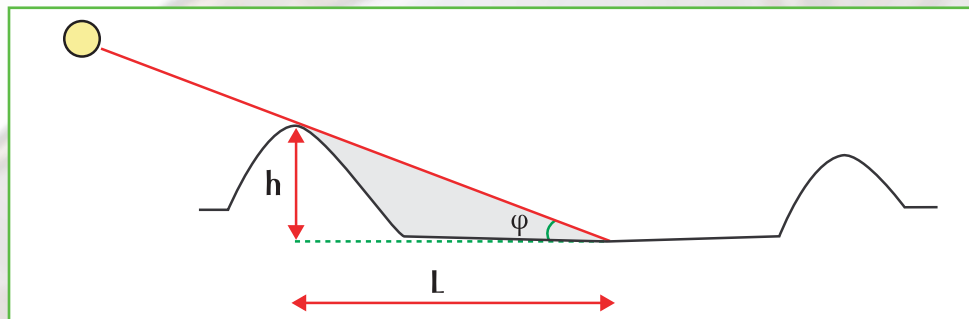


Figure 2.10: Estimating the height of a crater

Measurement of the Solar Rotation

I. General Information

This lesson plan provides information and material concerning an observational (experimental) study of the solar surface in order to find characteristic features (solar spots) whose apparent motion is due to Solar Rotation. By taken sequential images of the solar surface, using the Apollon Robotic Telescope (HTA), and estimating the display of the spots, the solar rotation can be detected. Then by converting that displacement to an angle (using the spherical grid) the sun period of rotation can be measured. Specific observational and experimental activities are presented and several questions, exercises and tasks are proposed to assist consolidation of acquired knowledge.

Duration

Classroom lesson : 1x45 min
Observational Activities : 2x45 min

Vocabulary

Sunspots, rotation orbit, differential rotation, solid body, period, gravity.

Tools and Materials:

Apollon Solar Telescope, PC with Internet connection, Paper printout, Pencil, "Spherical" grid.

Aims and Objectives

The students should

- be able to compare and contrast the differences between orbital and circular motion,
- learn safety rules for observing the Sun,
- understand that the apparent motion of the solar spots accross the solar disk is an indication of rotation,
- be able to acquire an appreciation for basic astronomy and astrophysics through the exposure in such topics as these embedded in this lesson.

Student's Misconceptions

Day-night cycle, seasons, geocentric system, sun nature.

II. Educational Phase

Stimulation

1x45 min

- Presentation of selected photos and/or videos of the Sun.
- Presentation of the first solar telescopes.
- Short discussion on the Sun's surface (photosphere) - origin of solar light emission - origin of dark spots.
- Draw up a list on the blackboard with various proposed methods of measuring of the solar rotation period.

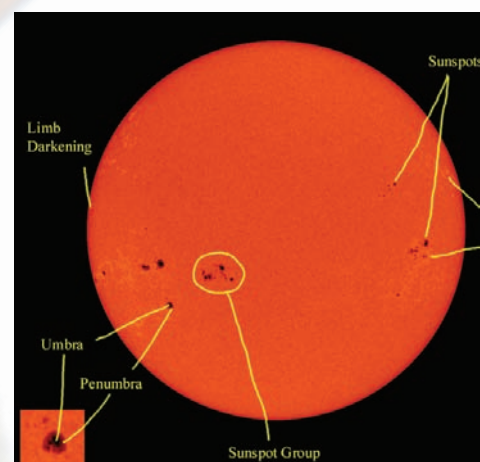
Experimental Activities

First phase (1x45 min)

The students using the Eudoxos user interface should

- select the Apollon Telescope, select the "Sun" as object of interest in the observing request form,

Figure 2.11: The Solar activity



- check the meteorological status for the site of the Kefallinia Island,
- fill in the celestial coordinates of the Sun and the time and submit their request(s),
- decide the number of exposures to be ordered.

Second phase (1x45 min)

The students using the Eudoxos user interface must

- take the Sun's images from the Gallery, display and print them using the proposed image-processing software,
- estimate the Solar Rotation Period by measuring the angular displacement of a certain spot in a given time interval (with the aid of the "spherical grid").

Observation - Discussion

Discussion of the theoretical issues arising from the observational (experimental) activities. This is facilitated with the assistance of the website's theory tutorial and links

- Theory and observation (experiment) comparison.
- Short discussion on the center of the universe in ancient times Ptolemaic versus Aristarchian/Copernican system.

Consolidation

Questions, exercises and tasks aiming at consolidation of the acquired knowledge (Refer to the relevant Worksheet).

Exercises

- Make a solar telescope using simple materials (like pinhole on a box).
- Make the daily solar orbit using a simple solar telescope to center the sun and measure its angular height from the horizon and azimuth of the telescope from the local meridian, at different times.

Questions

1. How do the stars evolve?
2. Approximately, how long is the main sequence lifetime of the sun?
3. Why do sunspots appear dark?

Figure 2.12:
*Observing the sunspots
during a five days time*



Determination of Asteroids Rotation Periods

I. General Information

This lesson plan provides information and material concerning observational (experimental) study of the Asteroids rotation period, using the Andreas Michalitsianos Robotic Telescope. Specific observational and experimental activities are presented and several questions, exercises and tasks are proposed to assist consolidation of acquired knowledge.

Duration

Classroom lesson : 1x45 min
Observational Activities : 2x45 min

Vocabulary

Order and names of the planets, asteroid belt, position of the asteroid belt, light curve, solid bodies, rotation, period, reflectivity.

Tools and Materials

Andreas Michalitsianos Telescope, PC with internet connection, Paper sheet, Pencil, Ruler.

Aims and Objectives

The students should

- be able to understand the origin of the constant rotation of an asteroid along its axis (conservation of angular momentum),
- be able to understand the origin of the asteroid motion around the sun (Newton's universal attraction law),
- be able to recognize a periodicity within a set of data,
- be able to compare and contrast the differences between orbital rotation and self rotation,
- be able to make astronomical imaging observations and extract Photometric data from their CCD frames,
- be able to learn how to complete and apply the method of finding the period by plotting the asteroid light curve,
- be able to understand the scientific methodology.

Student's Misconceptions

Composite motion, angular velocity.

II. Educational Phase

Stimulation

1x45 min

- Presentation of selected photos and/or videos of Asteroids.
- Short discussion on the Asteroids' surface and the reflection of the incident sun light.
- Short discussion on the Asteroids' self rotation and the relative positions of Earth, Sun and Asteroids. Also on the path of light from sun to earth through the asteroid.
- Draw up a list on the blackboard with the proposed methods of measuring of the Asteroids rotation period.

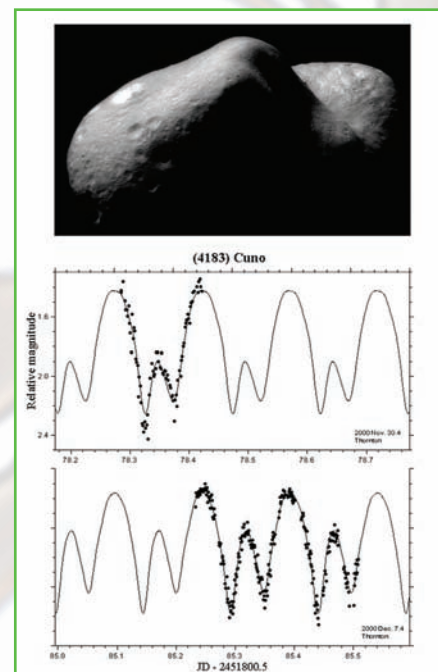


Figure 2.13:
The asteroid 433 Eros and
the photometric light curves
from asteroid 4183 Cuno

Experimental Activities

First phase (1x45 min)

The students using the Eudoxos user interface must

- decide which asteroid to observe,
- find the coordinates of the object at a known (future) time using “cart du ciel” software,
- select the Andreas Michalitsianos Telescope,
- check the meteorological status for the site of the Kefallonia Island,
- fill in the celestial coordinates of the selected Asteroids the appropriate times and the number of sequential CCD frames desired and submit their request(s).

Second phase (1x45 min)

The students using the Eudoxos user interface must

- collect the Asteroids’ images from the Database Library,
- display each CCD frame using the proposed image-processing software,
- extract photometric information (brightness measurements) of the asteroid for each frame
- plot the asteroid light curve,
- estimate the asteroids rotation period.

Observation - Discussion

Discussion of the theoretical issues arising from the observational (experimental) activities.

This is facilitated with the assistance of the website’s theory tutorial and links

- Theory and observation (experiment) comparison.
- Comparison with the orbital period and the period of the self rotation.
- Discussion on the origin of the asteroid belt.
- what determines of brightness difference between the maximum and minimum of the light curve?

Consolidation

Questions, exercises and tasks aiming at consolidation of the acquired knowledge.

Exercises

- Determine the two maxima (or minima) on asteroids light curve.
- Estimate the Asteroids rotation angular speed. What other data is needed?
- How the light curve would look like, if the surface was a perfect sphere?

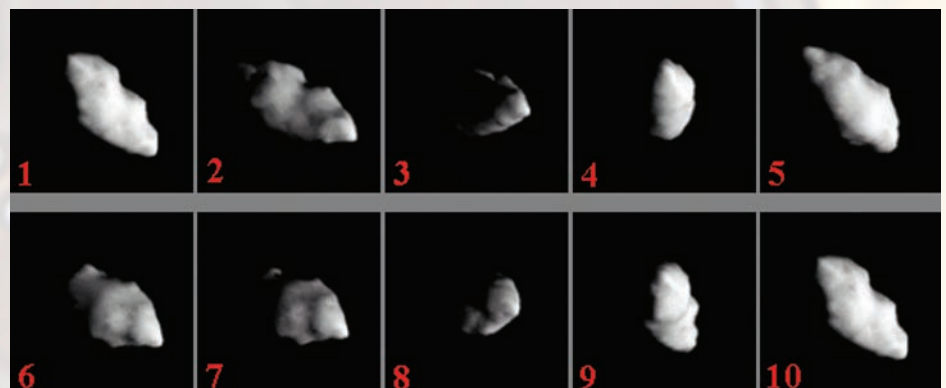


Figure 2.14: A sequence of views from Earth of asteroid Geographos that demonstrates how the cross-section varies with time.

2.5.2 Participating schools

The EUDOXOS project was implemented in the following schools:

Austria: “Bundesgymnasium und Bundesrealgymnasium Schwechat”

The group of Austrian students that participated in EUDOXOS were from the “Bundesgymnasium und Bundesrealgymnasium Schwechat” Secondary School.

A total number of 16 students between 16 and 17 years old participated in the project. They were students on Arts-based courses but were chosen among other students at the school to participate in the EUDOXOS project as their education was closely connected with the use of computers and ICTs.



Figure 2.15: Bundesgymnasium und Bundesrealgymnasium Schwechat



Figure 2.16: Students from Austria

This group were part of a class in the school called “the notebook class” and were characterised by carrying out their schoolwork via the daily use of a laptop computer.

They were students who were familiar with the use of computers and Internet which was a tool constantly available in the classroom.

This fact meant that they were accustomed to using the resources they would have to utilize for the EUDOXOS lessons on a daily basis. The Austrian teacher took on a major challenge to make this decision taking into account that although the use of new technologies was no obstacle for his students, the physics content would be complicated for them.

As we will be able to analyse more deeply in later sections, this school participated by following the programme offered by the EUDOXOS experts, implementing the programme in four lessons, overcoming the problems with physics and maths calculations and thereby making the learning of a new subject, i.e., astronomy, a reality.

Greece: Ellinogermaniki Agogi (EA)

The Greek representative of the EUDOXOS project was “Ellinogermaniki Agogi”, a private school that offers all stages of education from Primary to Upper Secondary. The group of 17 students from this school that participated in the project were students between 15 and 16 years old. Implementing the project in this specific context, it appears that two key characteristic elements of these students had a profound influence on the process.

Firstly, their depth of experience in the use of ICT which provided a solid base for the implementation of the majority of the activities within the lesson framework of the project and for undertaking the complementary activities designed by the experts.

Figure 2.17: *Ellinogermaniki Agogi*



Secondly, the other fundamental characteristic of this group of students that defined the process of implementation was their experience of group work.



Figure 2.18: *Working in groups*



Figure 2.19: *Students on the PCs*

Italy: G.B. Pininfarina

This Italian school is located in Moncareli, close to Turin. G.B. Pininfarina Industrial Technical State Institute has a total number of 1400 students (in more than 50 classes and 20 areas for specialised classes) who are educated to obtain a diploma in various technical disciplines related to mechanics, electronics and telecommunications, computer sciences and media sciences. It is therefore an educational institution specialised in the teaching of science, and where highly specific subjects are taught.

The two groups of 25 young people who attended the “Media Sciences” course participated in the EUDOXOS project. Their ages ranged from 17 to 18 years old. They were in their penultimate or their final year of the five years of training offered at the school. The EUDOXOS project lessons were introduced into their curriculum via their physics studies, more specifically in the subject called “Optics” (which within the annual programme lasts approximately 6 weeks). Therefore, the students had an excellent background in the concepts and activities that they would have to face as a result of being involved in EUDOXOS project. This supposes an implementation process without any major problems but, as we will see, there were some specific difficulties.



Figure 2.20: *G. B. Pininfarina School*

Spain: Centro Publico Rural “Campina de Tarifa”

The “Campina de Tarifa” Rural State School consists of three units in three small villages (Bolonía, Tahivilla and La Zarzuela) in Tarifa, in the Campo de Gibraltar area. Around 200 students attend the school which covers the stages of Infant up to the first cycle of Secondary, i.e., between 4 and 13 years old. The school offers basic education in accordance with Spanish educational law and the academic level of the students is normal (according to the headmaster's report). The group of students that worked on the EUDOXOS project was a mixed level class of students in the first and second years of the first cycle of Secondary education (12 and 13 years old). The students worked using an active methodology and carrying out theoretical and practical multidisciplinary activities. The rural context of the school played an essential role.



Figure 2.21: Campina de Tarifa Rural State School

This school faced a serious problem: the academic level necessary to undertake these tasks was too high for the Spanish students. Far from rejecting the opportunity to participate in the EUDOXOS project, the school decided to meet the objectives of the European project by adapting the lessons and making them as flexible as possible in order to guarantee that the Spanish students would benefit from the content and material offered. The pedagogical team of the University of Cadiz offered the school as much help as was necessary so that the school could obtain the photos from the telescope which were available in the database and accessed through the web page.

2.5.2 Classroom activities

Following the scientific methodology, students had to select the astronomical object that they wanted to observe. Furthermore, they had to check the weather conditions in the area of the Observatory, to select telescope and at the end to fill in and submit their request.

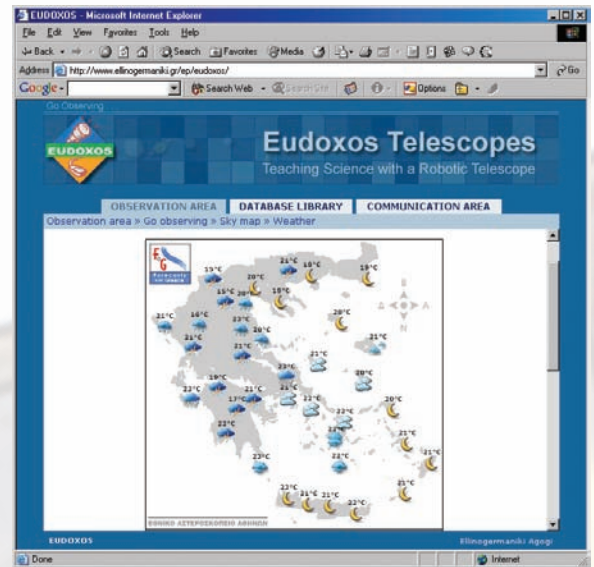
For the determination of the celestial coordinates, students used the **Sky Map Section** of the EUDOXOS platform. In this section they could observe a simulated view of the sky in real time, choose their object of interest and find out the celestial coordinates of that astronomical object. These were the absolute parameters for the effective pointing of the telescope to that particular object.



Figure 2.22: Sky map above the Eudoxos Observatory

In order to check the actual (at present) and to foresee (in the near future) weather conditions in the area of the telescope (Mountain Ainos, Kefallinia Island, Greece), students used the **Weather Section** of the EUDOXOS platform. In the same section additional web pages about weather forecasts and satellite images were available to the students.

Figure 2.23: Weather map



In the **Telescopes Section**, they selected a telescope for their astronomical observations. They could select the Telescope Andreas Michalitsianos for night observations or the Apollon Telescope for solar observation.

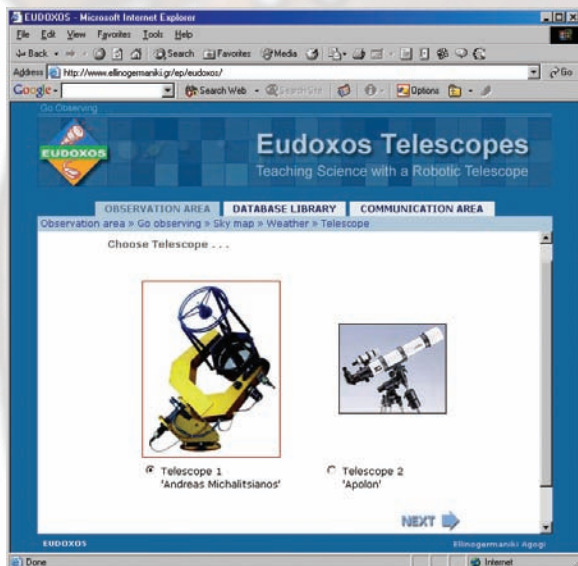


Figure 2.24: Choice of telescope

In order to submit their requests, students had to fill in the **submission form** in the Submission Section. The complete form with all the necessary information about the requested observation was submitted to the EUDOXOS Observatory in Kefallinia via the Internet and was scheduled for inclusion in a night's program of operations.

Eudoxos Telescopes
Teaching Science with a Robotic Telescope

OBSERVATION AREA | DATABASE LIBRARY | COMMUNICATION AREA

Observation area > Go observing > Sky map > Weather > Telescope > Requests

Enter observation requests

School:

Student group:

Password:

Project Title:

Observer(s):

Required Fields

Celestial Object:

Figure 2.25: Submit a request for an astronomical observation

The **Database Library Section** was one of the most useful tools for the students. In this section the images taken by the telescopes were presented.

Students could select not only their proposed images but each one of the database in order to implement the lesson plan that they had selected. It has already been mentioned that a specialized structure for the EUDOXOS lesson plans has been developed for the needs of the project. After a theoretical explanation of the fundamental concepts necessary for later geometrical, optical, and mathematical problem-solving, the practical work started and it was eminently scientific. The steps to be followed included observing and collecting data obtained from the telescope in the form of images (preparing the observations and using the appropriate coordinates) which were to be later analysed in order to reach conclusions and solve the initial questions via a report.

Eudoxos Telescopes
Teaching Science with a Robotic Telescope

OBSERVATION AREA | DATABASE LIBRARY | COMMUNICATION AREA

Database library

EUDOXOS > Database library

All Schools VIEW

Pending Requests: (4)

Completed Requests: (30) ✓

Canceled Requests: (29)

Total Requests: (63)

Completed Requests submitted by All Schools

A/A	Title	Date	School
1.	Transit of Venus...	8/6/2004	Ellinogermaniki Agogi
2.	Sun and Venus	8/6/2004	Ellinogermaniki Agogi
3.	M57 Ring Nebula in Lyra (PN)	12/5/2004	Marasleio - B6
4.	M13 Globular Star Cluster in Hercules	12/5/2004	Marasleio - 3
5.	M51 Spiral Galaxy (NGC 5194) Type Sc in Cancer Venetian	12/5/2004	Marasleio - 3

Eudoxos Telescopes
Teaching Science with a Robotic Telescope

OBSERVATION AREA | DATABASE LIBRARY | COMMUNICATION AREA

Database library

EUDOXOS > Database library > Information for current request

Go Back

Sun and Venus

School: Ellinogermaniki Agogi

Student group: 6th Group

Observer: D.S.

Date: 8/6/2004

Fits file(s)*: [W3616000.fits](#)

* To view the fits files:
Right Click - Save Target As...
Open the files with "Raw Data Viewer"
(http://www.astro.wisc.edu/~dphillip/rdw/)

Figure 2.26: Eudoxos Database Library



Figure 2.27: Educational conference in Tirol, Austria

“Ask the astronomer” Bulletin Board: The most visited part of the project’s website

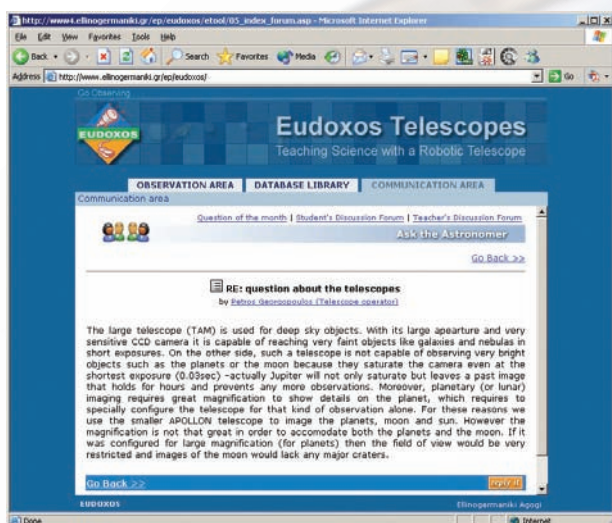


Figure 2.28: Ask the astronomer

Within the framework of the EUDOXOS project, students which had questions in the field of astronomy could ask experts and astronomers in order to understand the complexity of the universe. Using the specific Bulletin Board, students asked questions and received answers from the experts. 62 messages were presented in this session (out of 150 messages presented in all Bulletin Boards) as questions to the astronomers’ team. These questions covered both issues discussed in the framework of the proposed activities and in addition the students’ more advanced ideas for projects (kinds of filters to be used, exposure time, availability of specific objects, trajectories of different objects). Clearly during the transit of Mercury (Test Run) and the transit of Venus (June 2004), a peak was noticed to this Bulletin Board.

“Question of the Month” Bulletin Board

Among the four different Bulletin Boards, there was only one in which experts or astronomers posed the questions. This is the “Question of the Month”. The goal of this specific Bulletin Board was to bring teachers and students closer to more complex issues in Astronomy. During the first ten days of each month, starting January of 2004, an expert or astronomer wrote the “Question of the Month”. The correct answer was offered after a month by an expert or astronomer, not necessarily the corresponding inquirer. In the meantime, students and teachers had the time and the opportunity to give their own answers.

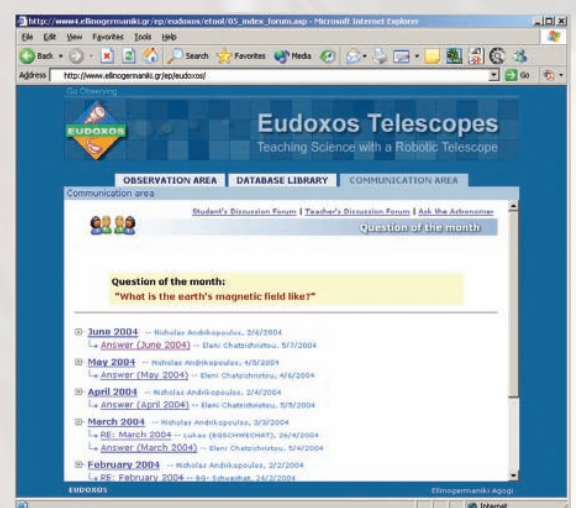


Figure 2.29: Question of the Month

Additional Activities

One of the project's greatest potential was the adaptability to different educational contexts and the flexibility of the activities that were suggested. The general idea of the project was to motivate and inspire students to work with other innovative and creative materials. One of the most successful examples was the construction of a MINDSTORMS LEGO model (1/50) of the real robotic telescope. The students used the CAD drawings of the real telescope and by using a specific version of the AUTO-CAD (designed for constructions of LEGO bricks) recreate an excellent working model of the telescope. The model was then connected to the PC and it was guided through the EUDOXOS platform for demonstration purposes. When students were submitting a request they had the possibility to see what is the exact motion they have request the telescope to perform.

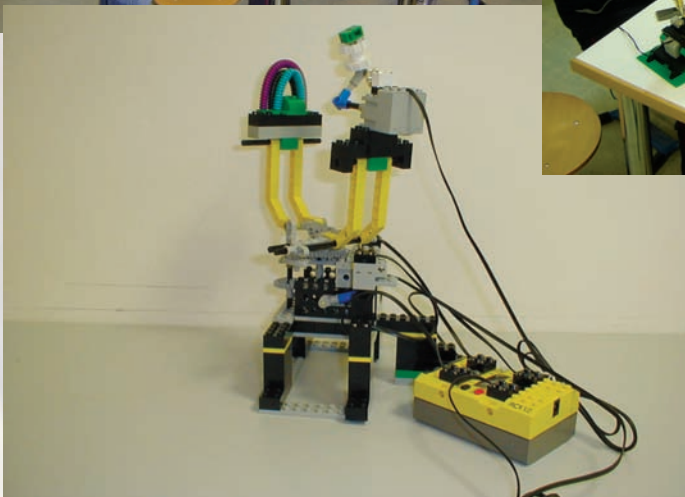
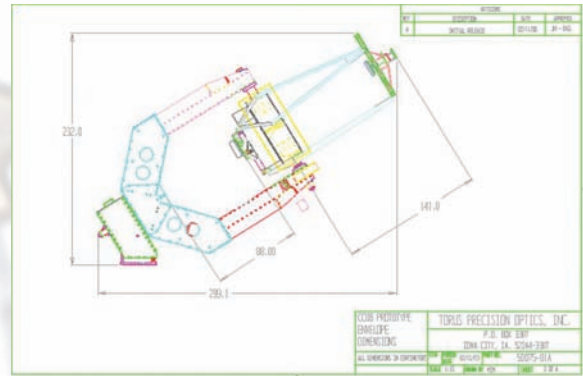


Figure 2.30:
Construction of a model telescope
using Lego pieces

Students' Contests

The EUDOXOS platform allowed students in different places to remotely control the telescopes and make observations anytime and anyplace, even from their home PC. In this way students acted as amateur astronomers and make their own observations of the astronomical objects and phenomena. They were able to search into the sky, learn about different physical and astronomical phenomena and at the same time have fun with this. In the framework of the EUDOXOS project special events (contests, open days in the observatory) were organised in order to attract the students and teachers interest and raise its awareness concerning astronomy and science in general. In the framework of the project's activities a photography competition was organised. The students were asked to take pictures of the sky or different astronomical phenomena. In the following the students had to submit their photo.

The best photos were published on the project's website and the winners of the competition profited of a visit to the EUDOXOS National Observatory to make their observations in situ and to attend the "Astronomy Night" event which was organised at the end of the project.

Additionally, all users will be informed for specific events taking place (e.g. Mars in the closest distance from Earth, Mercury passing in front of the Sun). Users will be able to schedule observations in order to have the possibility to get the best images of such phenomena.

Observation Weeks

Since the beginning of 2004 three Observation Weeks were organized. This was a very good chance to familiarize students from other schools - not participating to the project - with the EUDOXOS platform and its approach. There was one Observation Week per month during which the students from more schools around Europe had to submit their observation request. This helped them to plan ahead and focus on their experimental work and subsequent analysis of the imaging data. We did not, of course, succeed always to predict a cloudless week, but the situation was quite improved by selecting specific weeks with clear sky according to the weather forecast which was made available to the experts' team from the Greek Meteorological Organization.

The Observation Weeks served one more purpose: to attract the attention of other interested schools and help them having a successful astronomical observation. There was a specific banner created on the first page of the EUDOXOS web site, advertising the particular Observation Week of every month, which was flashing, calling for attention and inviting applications for participation in the observation plans. Additionally, about 500 registration forms were distributed to science teachers in the framework of the 10th National Conference of the Greek Physicists which has taken place at the end of January 2004.

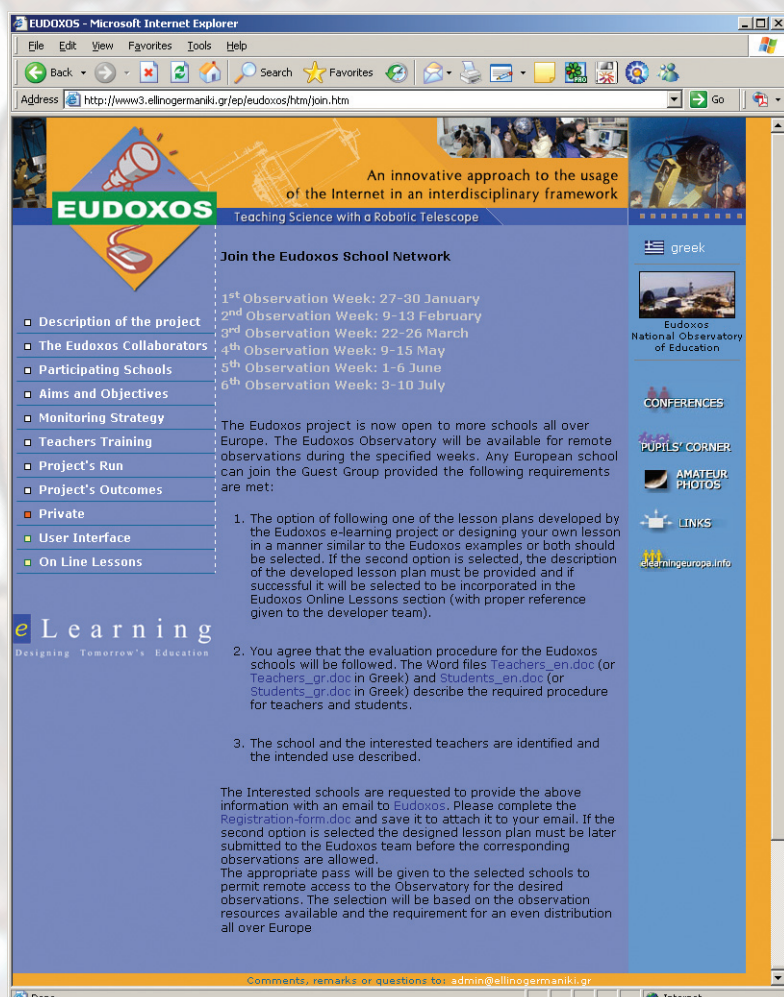


Figure 2.31:
Invitation to Observation Weeks



Eudoxos Project

Teaching Science with a Robotic Telescope

Registration Request Form

After completing this form please save it and attach it to you email to Eudoxos.

School data

School name: _____

Teacher(s)' name(s): _____

Address: _____

Postcode: _____ **Country:** _____

Phone: _____ **Fax:** _____

Email: _____

Web address: _____

Class: _____

Number of Students: _____

Internet connection: ☐ PSTN 56Kbps ☐ ISDN 64Kbps
 ☐ ISDN 128Kbps Other: _____

Do you agree to follow the Eudoxos evaluation procedure? : ☐ Yes ☐ No

Which option do you intend to follow? : _____

Please give an outline of the intended use of the Eudoxos Observatory:

Figure 2.32: The consortium has used many different means to attract the interest of the educational community. The organization of the Observation Weeks was a very good example since it brought 34 more schools to the EUDOXOS school community. Teachers and their students had the chance to use the telescopes to perform their own measurements and to design their own projects.

The idea of the Observation Weeks was quite successful and will be maintained in the following running periods of the EUDOXOS project. In total 34 European schools submitted requests to the EUDOXOS telescopes during the period of Observation Weeks. In this way a large network of schools connected with the telescopes was set up. Students and teachers from these schools had the chance to use all the facilities of the EUDOXOS platform (image library, on-line lessons, Bulletin Boards) and to interact with the students and the teachers who participated in the project. The aim of the consortium is to support this community of schools to actively participate to the EUDOXOS activities after the end of the project, by a series of activities (educational visits to the site, organization of contests, email notifications of interesting events, etc.)

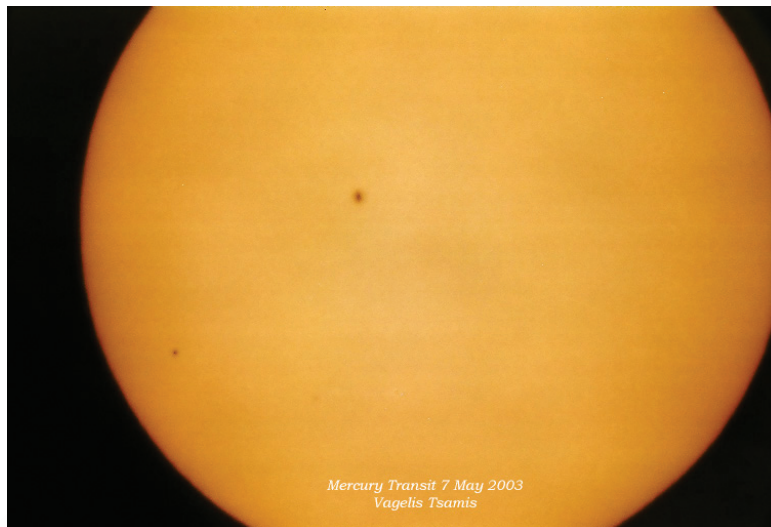


Figure 2.33: The transit of Mercury in front of the Sun as it was captured by a student using the Apollon solar telescope of the EUDOXOS observatory. This photo won the “Photo of the Month” competition among the students of the EUDOXOS project.

The Astronomical Night

In the framework of the EUDOXOS project, a major closing event was held at Kefallinia Island, Greece, on 4th to 6th of July 2004 with the participation of all partners of the project, i.e., academics, experts and schools. Additionally, many more experts from the international educational community participated. Talks were given by more than 30 distinguished academics and experts about the eLearning and ICT in education. All the participants of the closing event had the opportunity to enjoy a special Astronomical Night at the EUDOXOS Observatory (Mountain Ainos, Kefallinia Island, Greece). Talks were given by the astronomers of the National Observatory of Education in order to introduce the participants in science and astronomy and also to explain them the main steps of the scientific methodology. Using the telescopes of the EUDOXOS Observatory and several amateur telescopes, the participants made a lot of observations and experienced the infinity of the universe.



Figure 2.34: Astronomical night, Ainos Mountain, Kefalonia Island, Greece

2.6 Short and long term benefits for the users

There are several benefits for the users involved in the EUDOXOS project:

Operation from multiple locations around the world. The EUDOXOS platform was used from multiple locations around the world which has a number of advantages

- Observing conditions at any one site become less of a factor and less of an impediment to a successful observing experience.
- The ability to observe at different latitudes opens up much larger parts of the sky to the observer.
- The ability to observe from different longitudes makes night-time observations possible from classrooms during their school day.
- Telescopes can be assigned based on observing requirements such as duration of observation, visibility of the target body, required angular resolution, type of observation (image, spectra, photometry).
- Coordinated observations among observatories can provide long baseline temporal coverage.

A significant add-on to the current status will be the ability to select observing sites in an automated fashion based on user-supplied requirements. This permits an elevated level of coordination, which can be particularly useful when used to adapt to real-time requirements (e.g. weather or technical difficulties).

Unification of the existing tools and on-line materials. A common user interface based on the already in use EUDOXOS platform could act as an educational portal in the field of astronomy. The open architecture of the EUDOXOS platform allows for easy adaptations and additions. This ensures that every observatory in the network will feel comfortable and familiar to the end user. The site contains materials and information, such as access to data and tools, teacher resources (e.g. professional development materials, lesson plans), student-centred materials (e.g. data library, communication area, student's magazines), applications for observing time and collaborative activities.

The EUDOXOS project adds its contribution to the development of a new generation of citizens who are scientifically literate and thus better prepared to function in a world that is increasingly influenced by science and technology. The project's ambition is on one hand to inspire and motivate young people to pursue careers in science, but also to engage the young participants in sharing the experience of exploration and discovery. It envisions to enhance awareness and understanding of the scientific and technological advances of our times, and to link them to the history and evolution of the human mind and society (scientific, historical and cultural basis for modern astronomy).

Using the EUDOXOS platform **students and teachers** were able to directly apply the theories learned and taught in the classroom to real, interactive research. They personally experienced the procedures involved in an authentic research project and thereby gained a far better understanding of science and engineering. It is hoped that the EUDOXOS platform will provide more students and teachers with a valuable and unique perspective as they become adults and embark on careers as business persons, lawyers, judges, politicians, and others who will lead society through the 21st century on a solid foundation of knowledge, new technology, and the cultural diversity of the new world economy.

Additionally, the EUDOXOS project **raised the wider public's interest and awareness on science.** As reflected in many surveys realized in the recent years there is a falling interest on behalf of the wider public concerning science, even if individuals in general have a positive perception of science. The main reason behind this attitude is the lack of attractiveness of science matters as well as the lack of relevance to the everyday life. The EUDOXOS project allowed to individuals for a different insight in a scientific sector, as astronomy. Using the platform individuals will be able to make their own astronomical observations without even having a telescope. In this way they will be able to observe and thus better understand specific astronomical events. As a result science will be brought closer to the individuals. In the partnership's vision the way individuals will experience science through the

EUDOXOS platform is expected to have a lasting positive impact on the general public attitude towards astronomy and science in general. Concluding the EUDOXOS approach could impact three main application areas:

▪ **Formal Education: An Experimental Laboratory for All**

One of the main purposes of the application is to improve science (physics, astronomy, mathematics, computer) instruction. It is indeed ideally suited to help young people (and in particular women) learn to use the Internet and computers in a scientific environment and is designed to promote independent and creative activity. The participating classes were able either to control the telescopes “live” over the Internet or the students prepared and “ordered” their own observations via the Internet and had the robotic telescopes perform them at the next possible date. The images which are finally delivered were calibrated and analyzed by the students using simple image-processing software, offered the service.

Elementary and Secondary Education: School teachers could develop creative, hands-on interactive astronomy lessons over the internet using our network's robotic telescopes, to meet the needs of school curricula. These would be suitable for small-group collaborations and would include automated image acquisition service and/or observatory control as required to complete the lessons, plus the use of material on the project's web site.

University Education: The developed application could be used to improve the quality of science instruction at the university level, while offering to the students the opportunity to realize their own projects and to gain experience in carrying out independent scientific research. Astronomy (or other closely related fields) students and faculty can use our service for teaching practical astronomy laboratory techniques and research astronomy courses (that is, a minimum of related theoretical background is required). Essentially (due to the nature of telescopes) optical observational techniques can be taught.

▪ **Informal Education: Self-Directed Interactive Astronomy for All**

The proposed application could offer to users all over the world the unique opportunity to control professional astronomical observatories in real-time for self-directed astronomy studies or personal enjoyment. Using the Internet, private users can gain full control of our virtual observatory, commanding its robotic telescopes and cameras to capture images of the sun, moon, planets, galaxies and other deep sky celestial objects in real-time much like a professional astronomer. Images can also be obtained using automated requests, without having to control the telescopes directly, which is a convenient way to acquire multiple images during late night hours. In this way, the requested data will be taken on the next clear evening/day and returned via email. The private users will have to first sign-up with our service for a fee (per hour or per night) in order to control the various (one or more) telescopes, or in order to request specific object images. Once they have purchased the credits, they will be able to book observing time or make specific image requests. Upon agreement, there will also be provision for refunding if the requested observing cannot be performed on time (e.g. due to instrument problems or unfavourable weather conditions).

▪ **Acquisition of Professional Scientific Data**

Scientifically, the robotic telescopes will open totally new horizons and possibilities for obtaining critical scientific data that could not be obtained otherwise. Indeed, because they can obtain measurements automatically, it will become possible to perform time-intensive projects which otherwise would require enormous efforts from the professional astronomy community, both in terms of personnel and money.

3

Monitoring and Assessment of the Project's Activities

3.1 Framework of the Evaluation

Teaching for Understanding: What is really most important in education?

Educational research describes teaching as a complex activity which is characteristically simultaneous, multidimensional and unpredictable (Darling-Hammond, 2001). In the classroom contradictory objectives and multiple tasks are negotiated at a very fast rate; changes are continually made, and obstacles or unforeseen opportunities appear. Every hour and every day teachers have to reflect on and take decisions to create a safe environment and encourage learning pressurised by the need for academic performance and the need to satisfy each individual student and the demands of the group. Realities such as these contradict the bureaucratic view of teaching as a task directed at a limited number of aims and simple, predetermined objectives; organised into a sequence of activities and uniform lessons for all the students in a particular class or in different classes or countries.

Therefore, any teaching plan that does not take into account the complexity of the school environment is not consistent with reality and does not respond to the necessities, interests and situations that arise in every educational situation:

“Probably, whenever we bring together 25 to 30 people of the same age, whatever age that might be, we find major differences in development, levels of knowledge, types of personality, expectations, interests, etc. and, precisely because of that, one of the most significant characteristics of teaching is that of having to create a “complex” and “diverse” environment; and therefore one of the conditions that any teaching strategy should meet, if it wants to be effective, is the ability to adapt itself to this complexity and diversity.” (Porlan, 1996)

It is absolutely necessary to adapt every project, plan, activity, etc., to the real situation in each context. There are various pieces of research (Good and Brophy, 1997) highlighting that the best teaching is that which is adapted to each situation, to the educational aims and planned outcomes, to the students and the lessons.

There is no point in an educational approach based on the transmission of knowledge, i.e., teachers give academic lectures or use textbooks and students memorise content. On the contrary, the process of teaching and learning must go hand in hand with the social construction of knowledge on the part of the students. The following table lays out the main aspects that define the two major theoretical approaches to the process of teaching and learning: Transmission of Information versus Social Construction of Knowledge.

Table 3.1: Teaching and learning as transmission of information versus social construction of knowledge (Good and Brophy, 1997)

Transmission View	Social Construction View
Knowledge as fixed body of information transmitted from teacher or text to students. Texts or teacher as authoritative source of expert knowledge to which students refer.	Knowledge as developing interpretations co-constructed through discussion. Authority for constructed knowledge resides in the arguments and evidence cited in its support by students as well as by texts or teacher; everyone has expertise to contribute.
Teacher is responsible for managing students' learning by providing information and leading students through activities and assignments.	Teacher and students share responsibility for initiating and guiding learning efforts. Teacher acts as a discussion leader who poses questions, seeks clarifications, promotes dialogue, helps group recognize areas of consensus and of continuing disagreement.
Teacher explains, checks for understanding, and judges correctness of students/responses. Students memorize or replicate what has been explained or modelled.	Students strive to make sense of new input by relating it to their prior knowledge and by collaborating in dialogue with others to co-construct shared understandings.
Discourse emphasizes drill and recitation in response to convergent questions; focus is on eliciting correct answers.	Discourse emphasizes reflective discussion of networks of connected knowledge; questions are more divergent but designed to develop understanding of the powerful ideas that anchor these networks; focus is on eliciting students' thinking.
Activities emphasize replication of models or applications that require the following of step-by-step algorithms. Students work mostly alone, practising what has been transmitted to them in order to prepare them to compete for rewards by reproducing it on demand.	Activities emphasize application to authentic issues and problems that require higher-order thinking. Students collaborate by acting as a learning community that constructs shared understandings through sustained dialogue.

“As educators, we want students not just to retain information but to develop deep understandings and reflect thoughtfully about what they are learning. We want them to become scientific inquirers, critical thinkers, systematic problem-solvers, and value-based decision makers. If these lofty goals are to be accomplished, we need to teach with emphasis on higher-order thinking about the implications of what is learned.” (Good and Brophy, 1997)

A curriculum that is consistent with the Social Construction of Knowledge approach has to be open and flexible in order to make it possible for all students to learn, and in addition has to respect different learning rates.

In this framework the EUDOXOS project could be approached as a Telecollaborative Curriculum Project (TCP) (Angulo Rasco, 2003). A TCP is a project for students in which understanding, knowledge construction and collaborative learning are promoted.

- **Understanding** is the ability to think and act flexibly with what one knows. Understanding can be appreciated (appraisal) and developed via the performance of understanding: activities and

practice that give students the opportunity to understand and learn.

- **Knowledge construction** means that the students have to use arguments and evidence, ask and answer questions. Knowledge construction promotes dialogue, emphasizes reflective discussion, etc.
- **Collaborative learning** means tele-working with other groups of students or partners sharing experiences, ideas, results, doubts, etc.

The TCP must

- be flexible in terms of the structure to be adapted to countries and schools,
- be a learning tool that motivates and challenges the students,
- be a pedagogical tool for the teachers,
- focus on the students' work and collaboration,
- focus on the process much more than on the "results",
- combine information from the Net, information from other sources and field research information, and
- subordinate the technology to the pedagogical material.

Evaluation and Assessment: Why is Testing not the best way to evaluate the Project?

Evaluation in education can be understood in two distinct ways: with a broad view of the concept or with a narrow view. In Anglo-Saxon countries a distinction is usually made between evaluation and assessment. These terms correspond to the two views of evaluation as quoted in (Angulo Rasco, 1995).

Broad view of Evaluation refers to the process through which we come to know and evaluate the quality of "the service" (or the project) and the role of the various components in delivering the service.

Narrow view of Evaluation refers to the process through which we establish "quality" only by means of the impact of "the service" on individuals or groups of individuals, restricting the understanding of quality of educational service to its effect on students. In addition, the narrow view of evaluation underlies some everyday words such as "exams" and "tests", and other more technical ones such as public exams, educational quality indicators, performance measurement, testing systems, etc.

Within *the narrow view of evaluation* (assessment) there is a general and commonly-used concept: "tests". Tests represent the essence of scientific measurement in psychology and education. Followers of this narrow view of evaluation wrongly believe and defend the fact that its use shows up students' learning clearly and thoroughly, which allows discrimination between students on the basis of merit.

However, various things are usually forgotten. Firstly, it is forgotten that a test is a measurement tool that collects very specific information about an individual or a group of individuals. But it is not the only tool that we have at our disposal. It could be that we limit ourselves to the narrow view (assessment) with tests being the fundamental tools, but not even in this case are they the only ones. If on the other hand we feel more inclined towards the *broad view*, tests are one of the many tools that we can use and are not even the most important.

Secondly, tests as tools are only a sample or selection of questions or situations (called items) taken from one area of content or interest (Madaus, 1988b). The psychometrician has to make sure that it is representative of the field in general. In technical terms, this is called the validity of the test.

However, tests can only tell us whether the student has answered correctly or incorrectly, without showing the underlying causes of these answers (correct and incorrect). That is to say, tests do not help us understand the educational reasons why the marks are high or low, nor how to solve or improve the problems or difficulties that may be detected (Berlak, 1992; Broadfoot, 1983; Broadfoot, 1984; Broadfoot, 1986; Broadfoot et al., 1990; Gipps 1994).

This tool is regarded as being certain, thorough and scientific, in the sense that it allows mental states, intelligence, learning or certain characteristics of social interaction (Berlak, 1992; Madaus, 1988a).

However, this characterisation is questionable for various reasons

- it is clear that tests measure those meanings, concepts and experiences that society believe to be valuable, standardized and homogenous without taking into account that learning, achievement and attainment are concepts that take on different historical, social and political meanings; and thus tests are not universal and unchanging truths.
- the psychometric approach has held a fragmented view of learning and knowledge practically since the beginning, but it has been particularly influenced by the area of conductive psychology (since the 1950s). This fragmentation can be seen in the tests in the separation between the cognitive, affective and connective areas and in their decontextualisation. Decontextualised teaching lacks meaning for the students, distorting and obscuring the richness and complexity of the learning process.

“The importance of the content does not lie in facts and routine skills, but in the understanding of concepts and relationships, that is what gives meaning and usefulness to facts and skills.”
(Darling-Hammond, 2001)

By putting evaluation and tests on the same level, we limit the amount we can capitalise on the significance, richness and complexity of the former. Therefore, deciding about the future of an individual or a group of individuals, about the performance or professionalism of a teacher, about the state or quality of a system, about teaching and learning experiences, or the future direction of education policy, basing ourselves on the marks obtained in certain tests, however, numerous they may be, is a questionable and educationally- and politically-irresponsible exercise.

We can conclude that the adoption of the narrow view of evaluation or the technique of tests as the theoretical framework for the evaluation of a project (of some innovative teaching and learning experiments), seriously mars the knowledge about and perception of the quality of such a project, reducing the process to pure information collection using tools which are technically and educationally limited.

In this case, it seems to be assumed that quality depends purely on the “results” measured in student performance. This implies that the quality of teaching and the quality of the educational centres is determined by the success rates of the students.

Finally, it is important to add here that evaluation methods have a decisive influence on teaching. For example, the use of standardised tests, as often happens in the United States (Darling-Hammond, 2001), has a powerful influence when it comes to determining what to teach, how to teach, what the students study, how they study and also what they learn. The use of this method of evaluation results in a classroom emphasizing on memorisation of isolated facts and vocabulary, and ensuring that the students pass their exams.

Consequently, they never develop the ability to use the knowledge and skills in new situations, connect ideas from different subjects or fields, etc. Particularly, they have not arrived at the development of understanding: the knowledge they have acquired is inert, it cannot be remembered, transformed or applied in a significant way to new situations or problems.

On the other hand, when the evaluation methods take a global view of the whole process of teaching and learning and concentrate on understanding what goes on in the classroom, (and do not check what the students know about the content laid-out in the curriculum), more enriching and dynamic educational processes are allowed to develop. The aim of this form of evaluation is the analysis of educational practice and the ability to take steps towards improvement in the future. This approach encourages active learning (projects, discussions, research, etc..) which allows students to develop complex thought processes. They will be capable of remembering and applying what they have learnt, and make connections between what they already know and new content by relating it to their experience.

Global, Qualitative Evaluation: What do we want to evaluate and how?

The evaluation that we suggest is concerned with analysing the influence of the various components of the teaching and learning process (curriculum, methodology, organisation of the centre or of the classroom, teachers and students) in educational quality.

Evaluation processes are converted into research processes in the classroom. This research should be based on the following principles (Porlan and Martin, 1996):

- a) Research done by students: as a way of creating rules, attitudes, skills and knowledge in the classroom.
- b) Research done by teachers: as a way of adopting reflective practices and continuing professional development.
- c) Curricula which are open and experimental as a way of establishing the correct balance between the planning and the evaluation of teaching.

The innovation of the EUDOXOS project, in the specific case, is the achievement of learning about natural sciences through the use of a telescope via the Internet and the promotion of telecollaborative learning.

The value of an innovation does not depend on the quantity that the students learn but on more factors: the design of the innovation, its implementation, consideration of the contexts (schools) in which it will be applied, the understanding of the innovation by the agents, etc. An innovation, therefore, includes everything.

Authentic Assessment as the basis of Student Evaluation

The broad view of evaluation demands that the most important aspect of the evaluation is student learning. Having this in mind, and as an alternative to Testing, some years ago the concept of Authentic Assessment (Torrance, 1995) was added to the field of learning evaluation. Authentic Assessment means that students are exposed to tasks which are designed to confront them with situations which are more practical, realistic, and challenging than those offered by traditional tests (Torrance, 1995).

There are two basic elements that define the kind of tasks which are included in the Authentic Assessment approach: the production of knowledge and disciplined investigation:

Production of knowledge means that students have to produce, more than reproduce, knowledge and express it in different forms: speeches, performances, compositions, problem-solving, etc.

Disciplined investigation assumes the use of previous knowledge (substantive or conceptual and procedural), deep understanding (of a problem or situation) and the integration of knowledge (interpretation of information, formulation of ideas and comments which require the re-organisation, synthesis and coherent re-structuring of knowledge in a different way).

With regard to the specific evaluation strategies and tools, Authentic Assessment highlights the following

- the strategies and tools used in global, qualitative evaluation should be sensitive to social and educational phenomena, the ethos of the school and the needs of those directly involved,
- tools and strategies should not artificially separate the cognitive, affective, connective, interactive and situational aspects of learning,
- they should also allow the various social groups involved to freely express their opinions, criticisms, uncertainties and problems,
- instead of forcing teaching to adapt itself to the structural and technical requirements of certain forms of evaluation, as happened with tests (to be precise, tests of criteria and minimum competence), evaluation must be subordinate to the natural complexity of learning, school-based knowledge, the process of teaching and the curriculum. (Angulo Rasco, 1995).

3.2 The main aim of the evaluation

The main aim of the evaluation of the project was to understand the processes of change that take place in the various participating schools, caused by the use of the EUDOXOS educational material (both electronic and conventional) within the lesson plan framework.

3.3 Procedural Principles

During the evaluation process, those that play an important role in the teaching and learning process in the classroom must actively participate, the teachers and students were involved. They were the most appropriate to provide information and evaluate the implementation of the project; given that they are directly involved. Their opinions, comments, recommendations, difficulties encountered, etc., with respect to the implementation of the lessons and the use of the telescope, were a rich source of information in trying to understand the processes of change in each different context.

In order to provide a contrast with the information and evaluation given by students and teachers, the evaluators were external and thus they analysed from outside what is going on inside classrooms. This triangle of information from different sources gave internal validity and coherence to the evaluation process.

3.4 Evaluation strategies and tools

The proposed evaluation strategies and tools match the characteristics required by global, qualitative evaluation. Fundamentally, teachers and students were responsible for registering and analysing the information for the evaluation. The proposed tools for them were the following

- a. Teachers' Diaries
- b. Students' Portfolios

3.5 Teachers' Diaries

The teacher becomes a fundamental mediator between educational theory and practice. The teacher analyses, interprets and takes decisions about the teaching and learning process. The teacher is an active agent of everything that happens in the classroom taking on a role as regulator and controller of educational events.

The teacher diagnoses problems, formulates hypotheses and experiments, evaluates these hypotheses, chooses and selects materials, designs the activities, etc. He or she is, definitely, a researcher in the classroom.

In the framework of the EUDOXOS project, the Teacher's Diary was a tool for the collection and analysis of information that allows the teacher to analyse thoroughly and systematically what happens in his or her classroom. Additionally, it allows reflecting on the teaching and learning processes to put into action and carry out a critical analysis of his or her daily work in the classroom. The ideas, contributions and views that a teacher could collect with a tool like this Teacher's Diary seem to us to be extremely valuable. The evaluation that the teachers could make of the day to day implementation of the project was of great use in judging the impact of the EUDOXOS Project

The purpose of the Teacher's Diary from our point of the view was that of an evaluation tool with which teachers will become aware of the things that happen in the classroom when integrating the teaching and learning process with the lessons and the telescope that the EUDOXOS project proposes. Teachers developed this tool, in three main phases, related to each of the phases of the implementation of the Framework and of the Telescope.

1st Phase: Before the implementation of the project

It was important that teachers gave their initial points of view about the project before putting the lessons and the on line work into practice. This initial evaluation allowed us to discover how the process of implementation of the project changes preconceptions and previously-held ideas about learning

possibilities etc. All of these ideas helped us to better understand the influence of the project in each school.

2nd Phase: During the implementation of the project

This phase of evaluation by the teachers was of vital importance. When the lessons started in class, it was fundamental to try to collect information about the teaching and learning processes that were being undertaken, the reactions of the students to the content, etc.

3rd Phase: After the implementation of the project

After the implementation, it was necessary for the teachers to analyse in a general way all the work that had been done. It was important to have an evaluation of all that has gone on in order to gauge the influence of the project, taking into account to what extent the EUDOXOS project met original expectations, the most important aspects during its implementation, etc.

3.6 Students' Portfolios

Reason for and usefulness of the Portfolios: Evaluation through files of work.

Students that learn content by understanding it do not only learn the content itself but also appreciate the reason for learning it and retain it so that they can use it again when necessary. The Student's Portfolio constitutes a fundamental tool with which each student monitors his/her learning process systematically and thoroughly, and becomes aware of the usefulness of the content in which students are working on. It will help (or try to help) students to develop the ability to evaluate their own learning process and work. Similarly, their opinions with respect to the multiple elements that form part of the whole (content, activities, methodology, way of working, space and time management) will take on a considerable importance in the global evaluation of the teaching and learning process of the group. In addition, teachers will have a rich source of information about where the students were at the beginning, what steps they have taken, what processes they have followed, where they have arrived, what aspects have interested them most, what difficulties they have found, etc.

Physical Characteristics of the Portfolios: How they should be created and used.

A Portfolio is a file in which each student keeps a record of the activities undertaken within the framework of the project. The portfolios for the EUDOXOS project are divided into three main parts, which correspond to the three main phases of implementing the project in the classroom:

- 1st Part : Before the Implementation of the Project
- 2nd Part: During the Implementation of the Project
- 3rd Part: After the Implementation of the Project

Students responded to the questions posed in the first and third parts. During the second part which is the implementation part, students collected materials used in class activities (texts, images, notes, etc.). Additionally, they gathered together activities already done, reflections on the knowledge acquired, strategies, ways of working (with the Internet, in groups, individually, etc.), interests, feelings that the activity provoked, difficulties experienced, solutions for the difficulties, etc.

For the evaluation research, pictures were very interesting and additional information was very useful. The students took photos of the moments in their daily schools life, e.g. working with the e-tool in the computer, the teachers' explanations of any activities, etc. Each student expressed his/her ideas in relation to the situations represented in his/her photos.

3.7 Achievements and elements of good practice

The implementation of an eLearning project involves different educational institutions in the development of teaching and learning programmes in which the Internet and the New Technologies take on a central role.

New tools and resources are made available to European schools in order to improve the education of students, improve educational processes and try to ensure their development via innovative and comprehensive strategies.

But this is not an easy task and in addition a multitude of factors are at play in each programme. These factors interact to create a complex kaleidoscope of situations which go to make up classroom life and affect the teaching-learning process. To analyse the development of the teaching-learning process, it is necessary to take into account the reality of each school and all aspects that are involved in each one.

The value of a new innovation does not just depend on the quantity that the students learn, but on more factors: the design of the innovation, its implementation, the consideration of the contexts (schools) in which it will be applied, the understanding of the innovation by the agents, and so on.

For this reason, the use of an evaluation focus in accordance with this concept of teaching was proposed. The evaluation of how teaching and learning took place in the participating schools is not an easy task. The richness of these projects requires a multidimensional and global evaluation methodology that responds to this complexity.

The evaluation proposal arose as a result of negotiations with the various partners and with the aim of understanding the process of implementation experienced by the teachers and students.

Putting the evaluation proposal into practice has been a complex process characterised by adaptation to the circumstances and experiences arising throughout the implementation of the project. As a result, some aspects have been remodelled in order to respond appropriately to the desire to carry out a complete, rich and significant evaluation and to achieve the objective of understanding how the EUDOXOS project's approach influenced the science learning of those students involved. These changes mainly affected the qualitative information collection strategies initially proposed. The Teacher's Diary and the Student's Portfolio underwent modifications that allowed the evaluators to obtain the necessary data and at the same time to release the teachers and students from the dedication and effort that such tools require.

The need to undertake a continuous process of collecting information required a great effort from the side of the students and teachers who agreed to collaborate with the evaluators. This task was from time to time quite complicated due to major obstacles.

The first challenge to overcome was to face the educational evaluation as a tool capable of measuring knowledge acquired and not as an instrument used to understand the multiple factors at play in the classroom. Quantitative data collected with valid and reliable resources is useful but it can fragment reality and, thus, reality will be restricted. The evaluators decided to use this type of data because of its ability to offer direct, clear, and representative analysis, and, thus, to convert it into just one of the many sources of information that would allow to obtain a richer and more contrastable analysis of what occurred in each school.

Another problem to be overcome was the need to introduce the qualitative information collection strategies to the students and teachers. The evaluators asked for their collaboration through the use of two tools that required dedication and ability to reflect on classroom practice during the implementation of the EUDOXOS lesson plans. In addition, throughout the past two years, they have maintained contact via e-mail with the teachers involved in the project.

A lack of time, lack of experience and the language problem were all arguments used by teachers to justify the brevity of some of their evaluation reports. To overcome this, the evaluators adapted the evaluation strategies and they embarked on more direct evaluation activities, asking students and teachers for more detailed and accurate information. Despite this adjustment, they tried to uphold the principles that underpinned the original evaluation proposal by making the proposed tools as flexible as possible in order to obtain high quality information.

Teachers and students responded better to this type of initiative and evaluators obtained more specific and richer material. The questionnaire of open questions became the resource mostly used. With this resource, evaluators were able to break down the barriers of distance and language. For example, they were able to obtain observations and interpretations from some teachers and from the Italian students

before the beginning of the implementation of the project.

The evaluation report presented here is an attempt to capture and understand the complexity of the educational processes that took place during the implementation of the project in the different participating schools. As a result, the evaluators have considered various aspects of the educational reality such as: the methodology, the role of the teacher, the role of the student, the EUDOXOS platform, the characteristics of the project, its adaptability to the different contexts and the difficulties faced during the implementation process.

The EUDOXOS methodology

EUDOXOS project offered four pre-designed lesson plans to the participating schools. These were explained to the teachers. Later, these lessons were revised taking into account the teachers' comments at a workshop held in Athens in March 2003, before putting them into practice in the classroom. Each of the lessons was based on a physical cosmic phenomenon which was able to be observed via a telescope. What could have been just one more academic activity was turned into a real scientific problem by setting tasks that gave the students practical challenges with a real application.

The lessons followed a predetermined logic that was made available via the web page. After a theoretical explanation of the fundamental concepts necessary for the later geometrical, optical and mathematical problem-solving, the practical work begun and was eminently scientific. The steps to be followed included observing and collecting data obtained from the telescope in the form of images (preparing the observations and using the appropriate coordinates) which were to be later analysed in order to reach conclusions and solve the initial questions via a report. One of the Italian teachers outlined briefly the basic sequence of actions undertaken:

Introduction - teacher (traditional lesson)

Mathematical formulation (a model on an Excel worksheet) - teacher and students (each student on individual work)

Design the observation and submit the request - student (groups or individual)

Data analysis - student, in groups

Report - students (individual groups)

(Evaluation workshop questionnaire. Italian teacher)

The EUDOXOS lesson plans were characterised by the development of innovative and comprehensive didactic planning. As a project within a framework of an e-learning programme, the use of tools such as the Internet to improve teaching and learning was fundamental. The web was converted into a medium to access knowledge and as a source of information and communication. The computer was a resource daily used in the classroom and a basic support for carrying out activities and writing reports.

The EUDOXOS project gave a central role to these innovative strategies in the teaching and learning of astronomy, but the teachers did not abandon their traditional methods of explaining content and doing activities with their students. Blackboard presentations and teachers' support during student computer work were complementary to and enriched by these new tools.

These resources, without a doubt, brought about an improvement in the quality of information sources used in the classroom. The teachers confirmed that the students showed a lot of interest in studying using images that they themselves had obtained using the Internet and the remote control telescope. This way of constructing new knowledge seemed more interesting because the content was not presented in an isolated or decontextualised way but stemmed from real experiences and was therefore full of significance that allowed it to be better understood. The students had the opportunity to discover the purpose of the mathematical calculations that they had to undertake and to understand that the results were applicable, thereby acquiring meaningfulness.

"It is a great difference to see pictures of planets in books or to have the possibility to request pictures from the telescope." (Teacher from Austria)

"I think it is interesting experience because it is an alternative method compared with the traditional learning systems." (Student 3, Italy)



Figure 3.1: Austrian students using their laptops



Figure 3.2: Greek students Observing the Moon

With the use of the ICT, the EUDOXOS project managed to bring different worlds and people closer together. The learning process takes on a new dimension when there is the opportunity to connect knowledge centres which are apparently unconnected. The groups of scientists that work in their research centres and laboratories create new knowledge which could later become part of school subject matter. However, students are unaware of the ins and outs of the life of a researcher and the processes that they use to access new concepts, ideas and media. The EUDOXOS project innovated in allowing them to work, collaborate, debate and learn together; exchanging valuable information rich in content. The teacher and the ICT became the mediators of this union which powerfully motivated students and encouraged their interaction with science and its methods of research and interpretation of everything around us.

“I think that it was always great to look at the answers of the astronomer and everything else we could do there.” (Student 10, Austria)

“The students expected to work with an astronomer and their expectations were fulfilled (...) they liked to have a direct communication with an astronomer, to get pictures from a telescope, to ask the astronomer.” (Teacher from Austria)

Thanks to their participation in the project, teachers and students are now aware of having achieved another major objective. This objective arises from the handling of advanced technologies which will undoubtedly open new doors in classroom learning: Internet allows traditional barriers of time and space to be broken down and scientific work to be converted into an attractive, everyday task, perfectly integrated into the everyday life of the school.

The telescope located in Kefallinia Island, Greece, was in their hands and they could work with the material that the telescope offered in the classroom or at home, reconstructing the concept of a science laboratory and making it more flexible.

“The use of the telescope in different places will give more chances to achieve good photographs.” (Student 14, Italy)

ICTs and collaborative learning

With regard to ICTs, the use of the EUDOXOS project website (www.ellinogermaniki.gr/ep/EUDOXOS) was the principal technical support for the implementation of the project. This site included general information about the project, four lessons from the “Implementation Guide”, examples of the images that the telescope offers and, of course, the “EUDOXOS Observatory” where photos could be requested from one of the telescopes (Andreas Michalitsianos and Apollon) by completing a simple form and introducing the respective coordinates. In general terms, the website was evaluated very pos-

itively by teachers and students from the four countries. Its straightforward and clear structure facilitated the students' requests for images and other web-based research. The implementation of the project was determined in practice in the majority of the schools by the use of the EUDOXOS project website. This fact caused participating students to have a special attraction to the project to such an extent that it could be said that the ICT made a particular contribution to maintaining the motivation and interest of the students.

"It was an interesting and innovative educational tool in order to learn and as well to teach science in our school. I used the possibilities of the elearning in order to challenge the students' interest in science." (Teacher from Greece)

"I really like your page! It's unique and interesting." (Student 10, Austria)

In addition to the EUDOXOS website, other resources were used such as computer programmes (word processors, Power Point presentations, and Excel spreadsheets), Internet (in general, to carry out information searches to support the lesson content) and computer systems for video conferences, amongst other things. All these technologies seem to have been integrated in a natural way into the daily work in the classroom at least in relation to the implementation of the EUDOXOS project.

Collaborative learning is the other important methodological dimension, applicable both to the teacher (in the preparation and delivery of the lessons) and to the student (in carrying out the activities set). In both cases, the different activities undertaken in groups seem to have involved negotiation of and consensus on the concepts being studied which apparently provoked the ideal context for the social construction of knowledge.

The answering of questions or the solving of mathematical problems laid out in the "Implementation Guide" was carried out on most occasions in groups. These procedures consisted of considering the different options or possibilities, analysing their implications, discussing and arguing over the answers, and taking decisions.

If the combination of ICTs and group work constitutes one of the common key elements of all the participating schools that facilitate the understanding of the teaching-learning process, it is important to highlight that this combination took on a different form in each context. Depending on the circumstances of each school, more time and space was devoted to the lessons, the website or group work in an attempt to match the specific needs of the students, the teachers' teaching methods and the different learning paces.

The teacher: mediator and guide in the process

Teachers were partners in the EUDOXOS project and also the driving force behind it. Their work as mediators in the learning process was fundamental, showing that the appropriate use of ICTs and their progressive integration into the life of the classroom is in their hands. Teachers involved in this eLearning programme had to make the effort to look at the lessons, negotiate them with the experts, integrate them into the classroom, and adapt them to the needs, interests and work culture of their students. In this way, the construction of knowledge was ensured to take place appropriately on a daily basis.

The majority of teachers participating in the EUDOXOS project were physicists or natural scientists. From their reports, we can conclude that their involvement in this initiative was a response to the search for new ways to teach physics in order to improve the quality of the learning processes in which their students were involved. We thus discovered a double motive: to maximise their teaching abilities with the use of new strategies and teaching resources, and to increase the interest and knowledge of their students with respect to science and physics via the study of astronomy. The analysis of one of the participating teachers showed his expectations for the project before the implementation of the lessons. He listed all the possibilities he thought his involvement in the project could offer. Beyond the conceptual content that the EUDOXOS project offered, we are able to discover a multitude of objectives to be achieved in the classroom when putting the project lessons included in the "Implementation Guide" into practice. The use of new technologies, the importance of participating in a process of real

scientific investigation, etc. are some of the aspects to be highlighted.

“The project seems to be a good opportunity to have an interesting approach to sciences and to the scientific method. It gives the possibility to use mathematical concepts in practical physics problems, check the importance of physical quantities size, challenge in a real project planning and design, carry out a data analysis, get acquaintance with e-learning procedures, use information technology instruments, improve awareness about the web and its means.” (Teacher from Italy)

The teachers expected students to react positively to this new content, resources and activities. They openly stated that students, in general, worked with a great deal of motivation (motivation for the content, the use of the Internet, the use of real astronomical images, etc.), but we have to highlight that the teachers also felt very attracted by the lessons throughout the teaching-learning process. One of the reasons that justified this attraction was the multidisciplinary character of the teaching programme presented by the EUDOXOS project. The teachers believed that this was very valuable for the development of their work, and for the multidimensional and global development of their students. The activities allowed teachers to offer their students work that was not only related to physics but also to maths, English, technology and even mythology and history (as was the case of the Spanish students who investigated the origin of the names of some planets and constellations in their “Dictionary of Astronomy”). In addition, this allowed students to understand the complexity and richness of scientific activity and the need to work with a plethora of subjects and concepts in order to understand any research process.

Teachers played an extremely important role in the effective delivery of the lessons. Each of them had to make the activities their own in order to achieve their successful and harmonious integration into their students' curriculum. To do this it was necessary to adapt timing, space, content and activities. Their reports confirm that they undertook a task that required continuous attention to the progress of their students in order to guarantee that they were assimilating the content well.

Next table shows one of the plans presented by the teachers:

Activity	Actors	Methodology	Tools
Presentation	Teachers - students	Traditional lesson; Laboratory explanation; Duration: 2 hours	Blackboard; slides; PC animations; approach to User Interface
Design and submission	Students (teachers as supporters)	Work in groups (2-3 students per PC) Duration: 4 hours	PC; User Interface; www
Analysis and report	Students (teachers as supporters)	Work in groups (1-2 students per PC) Duration: 4-6 hours	PC with user interface and MS-Office programs

Teachers stated that they begun each lesson with a formal oral presentation of the theory (following the traditional model of teaching science) in order to orientate students. These presentations allowed each student to assimilate a theoretical basis for later work with the e-tool and the computer-based activities designed by the project's expert team.

An example of this is the case of the Greek teacher. In the case of the lesson about the moon, the prior explanation of the subject matter to be worked on and the use of an atlas of the moon allowed students to get an overview of the part of the moon from which they would obtain the images via the EUDOXOS Observatory and recognise the exact crater for which they were calculating the dimensions.

“The lesson plan about moon craters was processed in detail. The sun lesson plan was cut in order to fit student's abilities. It is relatively heavy for the majority of the students (except the ones that have a very strong personal interest in Astronomy) and there is a danger of loosing their general interest of the lesson.” (Teacher from Greece)

Additionally, the teachers became guides and mediators of learning. The orientation and support role of teachers turned them into a bridge between the scientific community and the Secondary students. This link fostered an increase in the student's interest in and curiosity about the world of researchers and science which to them seemed distant and strange and for which they would not normally, particularly at this age, show much interest.



Figure 3.3: One of the teachers explaining the material to his students

Academic and learning results

All the work carried out by experts, teachers and students was fruitful. Although some obstacles arose in the teaching-learning process and in the whole e-learning initiative (the language, technical problems, etc), the overall assessment by teachers was very positive. The academic results are the indicator that reflects this satisfaction most easily and that mostly clearly gives us an idea of the level of effectiveness of EUDOXOS approach in science learning of the participating students. This information, which came from the assessments made by each teacher using various criteria (reports from each student, as in the case of Italy, quality of the activities undertaken, participation in debate and brainstorming sessions, etc.), shows graphically the level of conceptual and academic knowledge acquisition achieved by students.

25% failed (no interest, difficulties in mathematics and in PC use)

65% almost all achieved

10% more than expected (report in English, deep research at home on the web and/or on books)

(Teacher from Italy)

This data obtained from the Italian school could be applied to the rest of the educational institutions. The rest of the teachers, despite not offering us quantitative data on the results obtained, gave us enough information to be able to state that the majority of students learnt the content worked on and participated actively in the tasks undertaken.

“More or less students understood the content but there were some equations which need to be more analytical or to avoid them. I think that students attained the main aim of the EUDOXOS project that was the understanding of the scientific methodology.” (Teacher from Greece)

“Yes, the students understood all the contents - my students had only great problems to understand some mathematical calculations.” (Teacher from Austria)

“The majority of students have worked on the activities suggested in each unit and have handed in the tasks required on time and of high quality. However, the problems that they encountered and the errors they made have been resolved thanks to the continuous evaluation process and collaboration with classmates.” (Teacher from Spain)

The level of participation of the students and their level of construction of knowledge suggests that their work was of optimum level. The teachers also undertook an assessment of the percentage of students that had not met the required levels. Amongst the factors involved in this, they highlighted various aspects.

However, as a counterbalance to this, we have to highlight a fact of great interest to teachers and physics experts involved in the EUDOXOS project. In addition to the good academic results, we have to mention the achievements which are equally positive, encouraging and of extraordinary value to the development of the students. The EUDOXOS project allowed students to develop skills and abilities that cannot be measured via exams, but which can be seen and analysed in the daily work of each school. The teachers expressed their satisfaction with their students' ability to read and write in a foreign language, i.e., English. They considered it important that their students had been able to understand that English is the language of science and that it is necessary to learn it.

“I saw that the learnt to send requests to the astronomer without my help - they also learnt, to discuss some astronomical aspects with an astronomer in English - so they saw, that the language of the scientists is English and they learnt to express their arguments in English.” (Teacher from Austria)

Teachers discovered that their students had developed another series of skills which were important for maximising their ability to study. The work undertaken on the project required them to handle the Internet as just one more source to search for and select information. They handled files from different computer programmes easily, were able to organise and interpret (with their teachers' help) images and data, and produced individual reports that reflected their learning process. They also reasoned effectively with the scientists via the forum available on the project web page.

Another initiative that we highlight and consider to be extremely valuable for the academic, social and professional development of the students was the opportunity that the Austrian and Italian students had to participate in conferences and seminars about their learning process in the EUDOXOS project.

The students and their learning experience with EUDOXOS

“Sometimes our traditional laboratory experience have lost part of their interest for students (instruments look very old, the connection between theory and experiment even when is clear, is not very interesting, students cannot find out the practical importance of some subject in mathematics or physics). Probably the use of a telescope, the direct involving in planning and carrying out the experiment, the feeling to be a main actor in the experiment, could wake up students interests.” (Teacher from Italy)

The students in the four participating schools were at the centre of everything undertaken within the project. The lessons were designed with them in mind, the forum was opened for them to be able to discuss the activities and the implementation process, and the evaluation also centred on them. The main objective of EUDOXOS project was to increase their interest in science, using a new and innovative educational programme involving new and innovative material and tools.

We had the opportunity to discover the expectations that some students had for the project before they started work on the tasks in the different lessons. By using open questionnaires, we were able to obtain information that would allow us to judge how far their expectations had been met. In their answers we were able to observe a great interest in and curiosity about the possibility of finding out about the universe, the solar system and the stars. Obtaining sky photos taken directly became their main motiva-

tion, exceeding their satisfaction at being able to handle a high-precision telescope in a real observatory by remote control. Some students stated that they did not expect anything of the project at the beginning and were waiting to see what would happen.

“It is a real good idea to make it possible for normal schools to get new pictures of the mars and other planets.” (Student 11, Austria)

Once involved in the implementation of the lessons, the students' expectations started to be met and became a basic element of motivation for their participation in the activities. Some of them showed initial resistance when they discovered that the material was not included in the curriculum and as a result had to be optional. The teachers confirmed that this group of students was not very large.



Figure 3.4: Learning astronomy

Direct communication with the experts involved in the EUDOXOS project via the project's Bulletin Boards was one of the activities for which students were mostly interested. The opportunity to speak to the experts directly, based on an exchange in the forum (in the sections “Ask the Astronomer” and “Question of the Month”), made a great impression on the students and attracted them until the end of the project. The students participated actively in answering the questions set by the scientists and contributed their own ideas and theories on these small monthly challenges.

“They liked to have a direct communication with an astronomer, to get pictures from a telescope, to ask the astronomer.” (Teacher from Greece)

One of the students stated that they had learnt to combine maths and physics. This comment is palpable proof of how students were able to work in a multidisciplinary way using different branches of knowledge in a globalized way, giving more meaning and coherence to each activity and therefore facilitating the learning process in different subject matters.

Some of the students highlighted the importance of using different tools and strategies which changed their views about traditional science lessons. Some students showed their satisfaction of being able to leave aside the well-known and traditional tasks of choosing and studying theoretical concepts in textbooks and specialist manuals.

But this interpretation was not superficial or limited to recognising the use of the computer and Internet as new learning media. They were able to recognise that they had taken on responsibilities in undertaking an interactive project. Despite the guidance of the teacher, the quality of the photos obtained depended on their work and dedication, and therefore so did the end result of each exercise and lesson. They were aware that in the EUDOXOS project their work was not limited to listening to the explanation of the teacher but that they played a fundamentally active role in their own learning process.

The students stated that the relative freedom they enjoyed during their studies with the EUDOXOS project was relevant to their learning. Within certain constraints imposed by the teacher and the lessons, students were able to choose, what to observe, what parameters to send and how to measure and analyse the images obtained. They had to organise their work in an autonomous and independent way and, despite the complications with the mathematical calculations, the students that were most deeply involved felt at the centre of their own learning process. This new way of working and this sense of autonomy and independence were the key to the improvement of the process of knowledge construction in each classroom. However, some teachers stressed the danger that such novelty could entail. According to them, some students were losing interest in the EUDOXOS project's activities as the lessons advanced. One demotivation factor was that many of the students found the mathematical operations that they had undertake too complicated. Some students became disillusioned and gave up on the activities.

Another achievement that students stated that they made (and their teachers confirmed this) was the understanding of how real scientists work. They believed they were able to understand the processes involved in any scientific research since they were immersed in one such process. The use of real images and data, taken directly from the natural world with the mishaps and obstacles that they had to face (such as meteorological problems, the slowness at times of the processing and obtaining images, small technical problems, etc.), allowed them to understand the daily work of a scientific researcher.

"They feel as amateur astronomers. They had many problems in order to make their observations so they understood the difficulties those have the researchers in their work." (Teacher from Greece)

We believe that the students in general learned from their participation in the EUDOXOS project, enjoyed it and appreciated the experience of working like real astronomers with real and tangible tools, and not with cold, decontextualised and abstract resources. For this reason, they overcame their difficulties and worked putting themselves in the shoes of the researcher, taking control of their own process of development.

4

Conclusions and Next Steps

4.1 General conclusions

The EUDOXOS project demonstrated an innovative approach that crosscuts the boundaries between schools, research centers and observatories and involves users in extended episodes of playful learning. The EUDOXOS project looked upon informal science education as an opportunity to transcend from traditional classroom based teaching, to a “feel and interact” user experience, allowing for learning “anytime, anywhere”. These pedagogical concepts and learning practices addressed by the implementation of **a set of demonstrators** (lesson plans), employing advanced and highly interactive visualization technologies and also personalised ubiquitous learning paradigms in order to enhance the effectiveness and quality of the teaching and learning process. The consortium believes that in addition to enriching the repertoire of learning opportunities, the blending introduced by **the EUDOXOS project will help to meet the challenge of “science for all”, i.e., providing science education opportunities tailored to diverse and heterogeneous populations of future citizens. These populations vary both in their interest in learning science and in their abilities to learn science.**

The EUDOXOS platform acted as a **window into live scientific experiments and phenomena**, ongoing research, and the personalities and stories of working scientists across the world. In this way science education can act as the mediator among people in different countries reducing at the same time prejudices and stereotypes and increasing social cohesion. The direct interaction with science or the doing of science reflect a fundamental pedagogy of the EUDOXOS project to provide learners with personal and direct experiences which can build upon in their own ways. Users will experience the phenomena presented in their own terms, freely choosing what to attend to and interact with, depending on their prior knowledge, interest and expertise. It is important also to point out that in the science museums and science centres the exhibits and the related phenomena are embedded in rich real world contexts where visitors can see and directly experience the real world's connections of these phenomena.

Problems encountered and possible solutions

Experience from the application of the educational activities in schools the last years indicates that the expansion of the usage of the robotic telescopes could be rather problematic mainly for two reasons, availability of the telescope and time consuming data transfer.

For such an application high bandwidth connection is necessary. The transfer of images from the telescope is a very demanding task and needs a very fast and very reliable connection line between the school and the telescope. The pedagogical value of the application can be minimized or even lost completely when the connection to the telescope fails. In many cases teachers experienced significant difficulties trying to get connected with the telescope during their lesson. Although this is a reality that all users of the Internet are experiencing from time to time, the consequences of such an experience while implementing an innovation in the classroom could be very negative for both students and teachers. The initial enthusiasm is lost, the high expectations are becoming obsolete, educational objectives are not met. During the EUDOXOS project's implementation teachers experienced such cases, mainly at the Test Run phase. Both the pedagogical and technical experts had explained and given specific guidelines for backup scenarios to teachers during the teachers' training process. But it is an issue that the potential user of the EUDOXOS platform has to know when he/she is implementing the application in

his/her lesson.

The utilization of broadband communication channel (both wired and wireless) will improve significantly the communication between the telescopes and the remotely located users. It will allow very fast and efficient transfer of data that will permit on-line observations. The EUDOXOS case could support the exploitation of the broadband networks across as it demonstrates the effective usage of the new generation of high speed transmission services.

Currently RFK and EA are collaborating with the Greek Telecommunication Organization (OTE) in order to create an advanced communication system (including satellite link 2Mbps through DVB-RCS platform utilization) for the EUDOXOS observatory. A DVB-RCS terminal will be used in-situ to allow very fast connection between the Observatory and EA, where the EUDOXOS platform is physically located.

Additionally, during the operation, the telescopes at the EUDOXOS observatory reported several vulnerabilities mainly in the field of the denial (failed requests) of service. This fact has occurred due to three basic reasons:

- Weather conditions (70%).
- Requests expand the capabilities of the system (e.g. large amount of data) (20%).
- Telescope not in operation due to maintenance activities (10%).

One of the apparently negative aspects of the astronomical research is the possibility that the weather will be cloudy not allowing for observations. Astronomers have spent many fruitless nights on the mountains waiting for the weather conditions to improve so as to perform a particular series of observations. This is one of the reasons mount Ainos in Kefallinia was selected, since the frequency of clear skies is quite good there. Nevertheless, this can happen, especially during winter and spring, and creates disappointment and frustration to the prospect observer. It was inevitable then that this happened during the first phase of the project's run and caused negative feelings to the students. However, this was used as one more learning experience for them, namely that, the scientists do not always succeed in their experimental endeavors and quite often they have to try more and again.

During the EUDOXOS project's implementation teachers experienced such problems many times. Again the impact to the teaching and learning process was significant. The use of only two telescopes located at the same observatory does not allow for high flexibility in this issue. The addition of more telescopes around Europe could give new possibilities for further expansion. In this case a scheduler mechanism could be an effective solution for this problem. It could make optimal use of the available resources (supporting also the future expansion of the network by adding new observatories that will be available upon request according to the observers' needs). Additionally, it could consider the weather and technical status as attributes, in order to make real-time adjustments to the schedule when appropriate and necessary, adding a routing capability to the scheduler. The activities to be scheduled are those taken from the users' requests that have been approved by a review mechanism. The scheduling system is also used to filter infeasible requests - those for which there are no available telescopes - early in the review process. The consortium based on the experience of the TIE project, is already developing a method of cost-sensitive constraint satisfaction (CSCS) that incorporates the costs of constraint checking into the constraint reasoning process. This method allows for the scheduler to be sensitive to the cost of evaluating alternatives (testing constraints). Constraints that are expensive or difficult to test are treated as having an additional cost that must be minimized. The goal is to develop a constraint satisfaction method that minimizes the total cost of constraint checking. The number of constraint checks is commonly used as an evaluation metric for the time performance of constraint methods, but to our knowledge, there is no previous research that allows constraints to have varying costs, or that treats the cost of constraint checks as an explicit optimisation criterion.

4.2 Using Robotic Telescopes for educational purposes: An emerging market

Except from the EUDOXOS initiative, there are other similar approaches across the world. In the recent past there have been significant initiatives in the USA, Japan and in Europe, aiming to use telescopes for educational purposes at high school and university level. The major issue under investigation in the framework of these initiatives is to study the applicability of the emerging technology in the school and university sector and to demonstrate in practical terms **how eLearning can improve and enrich the quality of the learning and teaching process in science and technology**. Additionally, the specific initiatives contribute significantly to increase accessibility to unique resources as the sky is a vast and unique laboratory of science, always in operation, accessible at all times from everybody from everywhere, where all sorts of interesting physical phenomena take place most of which is impossible to reproduce in any scientific laboratory.

Remote and robotic telescopes in the past have used either custom graphical interfaces limited to a particular computer platform, or simple electronic mail gateways. Producing a custom graphical interface for telescope would allow great flexibility in the operations that could be performed but would be a huge task, as applications for many different computer platforms and operating systems would have to be written and maintained. It is estimated that there are four platforms used by the majority of people interested in controlling the telescope: PCs using Windows, Macs, UNIX Workstations and text based terminals. With a Web interface, the telescope can become part of a seamless virtual reality linking in not only its documentation, technical reports and astronomy lessons but also any other relevant work done by anyone else around the world. Following these evolutions about 30 observatories around the world have been outfitted with specific software and hardware interfaces in order to be used remotely over the past few years. Currently these telescopes operate as independent observatories with little leverage of resources, communication and coordination.

There are many on going projects at the time that use robotic telescopes for educational purposes and many other that at the time are under construction. In Table 4.1 projects are labelled according to whether they are in operation (◆), or under construction (■).

Table 4.1: Operating and under construction Remote - Robotic Telescopes

Project	Remote Telescope(s)	Purpose
◆ EUDOXOS	AM 60cm Cassegrain, Solar	High School, Undergraduate
■ Bradford Robotic Telescopes (Bradford Univ., IAC, Manchester)	46cm	High School, Undergraduate
◆ Ceres Project (Montana State Univ./NASA)	Hubble Space Telescope Archives	Elementary, High School
◆ Faulkes Telescope Project (large consortium)	2x TTL 2.0m Haleakala/Hawaii, Siding Spring/Australia	High School
◆ Hands-On-Universe (HOU) (Berkeley/NSF)	Berkeley 30"	Elementary, High School
◆ Iowa Robotic Telescope Facility (IRTF) (Univ. Iowa)	Torus 50cm	Undergraduate
◆ National Schools' Observatories (John Moores Univ., Liverpool)	3x TTL 2m (Hawaii, Australia, Spain)	Elementary, High School
■ Nepean (Univ. West. Sydney)	20"	HOU, Undergraduate

◆ Micro Observatory (Harvard)	4x 6" Maksutov	High School, Undergraduate
■ MONET (Univ. Gottingen, McDonald, SAAO)	50-80cm	High School, University
◆ RoboSky.com (commercial)	2x Meade 8" (night), 1x Meade 8" (solar)	Elementary, High School
◆ SKYWatch (Illinois State Edu. Board)	7", 5x8", 2x10", 24"	Elementary, High School
◆ Student's Telescope Network (Univ. Denver, Software Bisque)		Elementary, High School
◆ Telescopes in Education (JPL)	Mt. Wilson 24"	Elementary, High School

In all cases data can provide evidence that the idea of using robotic telescopes for educational purposes is experiencing significant growth. In the following we are presenting two very successful cases that have been developed in parallel with the EUDOXOS project.

The Schools Observatory project (UK, Japan)

The International Schools observatory (ISO) is a web-based observatory that provides schools around the world with access to professional robotic telescopes. Students can access and control the telescopes through the Internet. Provided by Liverpool John Moores University and the Japan Spaceguard Association, the ISO allows students or schoolchildren from different countries to work together on science projects, make new friends and experience the excitement of science observation and discovery in exactly the same way as professional astronomers. Two telescopic centres make up the ISO.

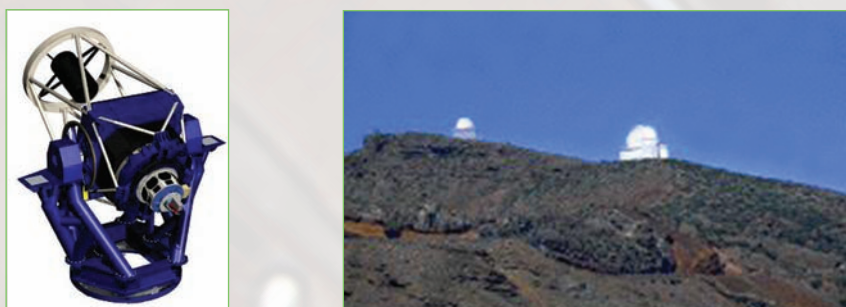


Figure 4.1: The Liverpool Telescope is the largest robotic telescope in the world and is located on the island of La Palma in the Canaries. The LT has been manufactured by the Telescope Technologies.

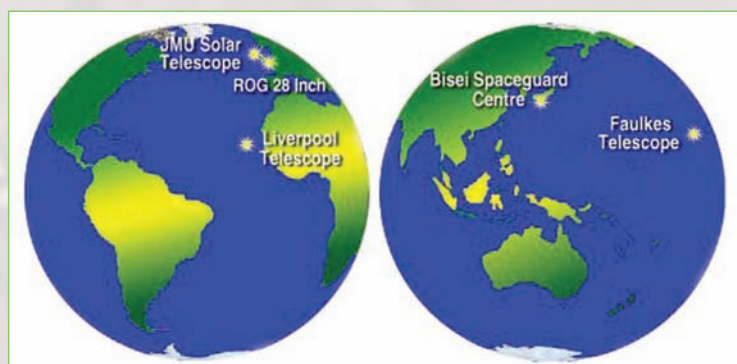


Figure 4.2: The locations of the robotic telescopes that are used by the schools of the International Schools Observatory.

Liverpool John Moores University provides access to a world-class astronomical telescope. **The Liverpool Telescope is the largest robotic telescope in the world and is located on the island of La Palma in the Canaries.** The Bisei Spaceguard Centre in Japan has telescopes that enable students to view all-sky image data, perfect for searching for asteroids. Observing time has been specially reserved on these professional instruments for schools. Working with the resources developed by the Schools' Observatory, students can prepare and carry out their own astronomical research and share in the excitement of discovery. Using the full power of the Internet, the Schools' Observatory brings cutting-edge science and technology into the classroom.

Telescopes in Education project (USA)

The Telescopes in Education (TIE) project began in 1992 with NASA funding. The first telescope to participate in the TIE project was the 24-inch at the Mount Wilson Observatory, coming online in 1993, and since that time, students from hundreds of schools in the US, Australia, Canada, England, and Japan have remotely controlled the telescope from their classrooms. To help teachers and students understand what they are doing and how to do it, the TIE project and members of the growing TIE community have developed a suite of guidebooks, sample projects and lesson plans (see <http://tie.jpl.nasa.gov>).

TIE has been tremendously successful as a pioneer in robotic observatory technology, as demonstrated by the many awards it has won over the years for its activities using the Mount Wilson Observatory. TIE program brings the opportunity to use a remotely controlled telescope and charge-coupled device (CCD) camera in a real-time, hands-on, interactive environment to students around the world. TIE enables students to increase their knowledge of astronomy, astrophysics, and mathematics; improve their computer literacy; and strengthen their critical thinking skills. The TIE program currently utilizes a science-grade 24-inch reflecting telescope located at the Mount Wilson Observatory, high above the Los Angeles basin in the San Gabriel Mountains of Southern California. The telescope has been used by students in grades K-12 to observe galaxies, nebulae, variable stars, eclipsing binaries, and perform other ambitious projects and experiments. Hundreds of schools in the US and around the world (including Australia, Canada, England, and Japan) have successfully used the prototype telescope on Mount Wilson. Through TIE, students have rediscovered and catalogued a variable star and assisted the Pluto Express project at NASA's Jet Propulsion Laboratory to revise the ephemeris (orbital location) for the planet Pluto. The telescope and CCD camera located at the Mount Wilson Observatory can be operated remotely by educators and students from the convenience of computers in their classrooms via modem and special astronomy software. Images can be downloaded to a remote user of the telescope in five minutes or less (the time depends upon the speed of the user's modem). These images can be stored in the user's computer for later image processing and study. The software also serves as an excellent stand-alone, educational astronomy program. Educators and students can reserve observation time on the Mount Wilson telescope for any evening of the week. Observation sessions can last from one hour to an entire night. Arrangements can be made for projects requiring special observation times or long-term, repetitive observing runs.

4.3 Towards the future: The development of the Virtual Observatory

The EUDOXOS consortium aims to investigate all the possibilities of using robotic telescopes for educational purposes by taking advantage of the tremendous synergistic potential of an international network of professional-grade, remotely accessible observatories. The aim of the consortium is to integrate 5 robotic telescopes, the two telescopes of the National Observatory of Education EUDOXOS located on Kefallinia island in Greece, the Liverpool Telescope (the largest robotic telescope in the world) located on the island of La Palma in the Canaries and the two telescopes of the Observatory Science Center at Herstmonceux (UK), seamlessly into one virtual observatory. It will provide the services required to operate this facility, including a scheduling service, tools for data manipulation and access to related educational materials provided by the currently running projects and networks. Additionally, the EUDOXOS consortium will facilitate the usage of broadband communication channels as a means of interaction and data transfer mechanism between the telescopes and the remotely located users around the world. In this way the effective and fast response of the service is safeguard-

ed. In this way EUDOXOS will become a distributed network of robotic telescopes accessed by students, educators, researchers and the wider public via Internet. A network of robotic telescopes has several advantages. Weather is less likely to cancel or delay an observing session if automated telescopes are available in widely different geographical locations. More telescopes will serve more users with fewer delays and on the preferred schedules. The potential EUDOXOS portfolio could consist of

- a) on-line access to the network of the robotic telescopes (on-line or scheduled requests),
- b) access to scientific data and resource archives (data and images) ,
- c) access to a central data archive, making use of a common archive and distribution system,
- d) access to educational material and interactive tools (allowing for data representation and analysis),
- e) access to teacher resources (e.g. professional development materials, lesson plans),
- f) student-centred materials (e.g. data library, communication area, student's magazines),
- g) on-line training courses at different levels (for school students, for university students, for the wider public),
- h) participation contests (the contests will cover the levels of all targeted groups of users, e.g. scientific contests, best science project contests for students, best photo contest for the wider public) ,
- i) participation to conferences, workshops and summer schools (the users of the service will have the opportunity to visit the observatories during different events),
- j) information on specific events (e.g. transit of Mercury or Venus).

Linking robotic telescopes around the world could revolutionize both amateur and professional astronomy in the future. Virtual Astronomy with EUDOXOS:

Now everyone can make a discovery!

Join the excitement!

Join EUDOXOS!

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