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Science Center To Go

SCeTGo Pedagogical Framework

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The Education, Audiovisual and Culture Executive Agency

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Executive Summary

This document is D2.1 – SCeTGo Pedagogical Framework – defines the scope and the theoretical background behind the SCeTGo project. The project combines Augmented Reality and miniature science exhibits with an inquiry based teaching and learning approach. The goal is to increase interest of students to experimental science in general within and outside the classroom. The approach chosen is to combine the formal classroom activities with more informal approach, presented in science centers. The approach will possibly further increase pupils interest in participation in extra scholar activities related to science, such as visit of science centers or interactive museums.

This report describes in detail the proposed pedagogical framework and the main pedagogical ideas that guide the work in this project. The report describes how the proposed approach provides ways to analyze, plan and respond to a scientific inquiry. Furthermore, issues such as identifying and visualizing information, evaluating resources, and integrating knowledge and experience are considered. It also includes a review of current trends in science education and communication.

The pedagogical framework presented in this document is a basis for the creation of concrete SCeTGo scenarios, which will be implemented in several educational settings, including secondary schools, universities and a science center. The scenarios will follow the steps described in this document and also consult the issues, factors and constrained listed.

The pedagogical framework provides the structure direction for the development of SCeTGo scenarios and their implementation in real educational settings. Important to consider issues are reviewed and pedagogical factors and constraints are listed and explained.

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[1] 505318-LLP-1-2009-1-FI-KA3-KA3MP

1 Introduction to SCeTGo

High-quality education is one of the principal objectives of all levels of education for all EU Member States in the context of the learning society. One of the factors to increase the quality of education is the incorporation of innovative educational approaches and renewal of current pedagogical practices.

The EU project Science Center To Go (SCeTGo) has started in January 2010 with the goal to study the possibilities of incorporating innovation into the classroom and stimulate new pedagogical approaches. SCeTGo is a two years project with a consortium of ten partners from seven European countries. The consortium will develop a set of miniature exhibitions enhanced with Augmented Reality, together with detailed pedagogical scenarios related to each miniature's usage in and outside the classroom, focusing on inquiry-based methods. Furthermore, through extensive trial implementation, the consortium will validate the approach and further improve the scenarios and the miniatures.

The SCeTGo project builds upon the work performed in the very successful project, CONNECT (www.connect-project.net) where an Augmented Reality (AR) system was developed, extensively tested and evaluated in science centres in UK, Sweden, Greece and Finland with school students. The SCeTGo approach goes one step further and aims to bring similar comprehensive learning experiences out of the Science Centers and into a school's classroom and/or everyone's home. The miniature exhibits which will be produced and tested within SCeTGo will be "fitting into a pocket" and operate with ordinary hardware, thus will enable learners to experiment whenever and wherever they please. Furthermore, the consortium will make full use of the powerful capabilities offered by tailor-made exhibits combined with Augmented Reality.

1.1 Project Objectives

In the framework of SCeTGo the consortium aims to:

a) develop a series of miniature exhibits that will illustrate various physical phenomena enabling learners to visualize the invisible through AR technology

b) develop a pedagogical framework that attempts to blend informal and formal learning and to situate learning in real-world contexts

c) develop advanced pedagogical scenarios that are shaped around a mission guided by a general scientific question

d) pilot, to validate and to demonstrate the SCeTGo approach in formal & informal educational environments

e) facilitate lifelong learning and to improve quality of learning

In the framework of SCeTGo learners will be able to use a series of prototype miniature exhibits and educational analysis tools in order to experience science by actively manipulating the experiments.

The aim of the SCeTGo is not solely to produce more scientists and technologists; it is also to produce a new generation of citizens who are scientifically and technologically literate.

1.2 Consortium

The SCeTGo project is being carried out by a consortium of 10 partners located in 7 different countries (Greece, Finland, Germany, Sweden, Spain, Romania and UK). These partners, listed in Table 1, bring a real cross-disciplinary know-how, with expertise in e-learning, mixed reality and wearable devices, wireless networks and devices, scenario design, pedagogical research and evaluation in science teaching and applied research in implementing innovative educational techniques in school / university environments.

WP	Partner Full Name	Acronym	City, Country
P1	Tiedekeskussäätiö	Heureka	Vantaa, Finland
P2	ΕΠΙΣΕΥ - Institute of Communications and Computer Systems	ICCS	Athens, Greece
P3	Fraunhofer-Gesellschaft zur Förderung der angewandten Forschun	Fraunhofer	München, Germany
P4	Universitat de Barcelona	UB	Barcelona, Spain
P5	University of Bayreuth	UBT	Bayreuth, Germany
P6	University of Helsinki	UniHelsinki	Helsinki, Finland
P7	Linnaeus University	LNU	Växjö, Sweden
P8	Centre for European Research	CER	Anglesey, UK
P9	CASA CORPULUI DIDACTIC CLUJ - Cluj County Teacher Training Centre	CCD Cluj	Cluj-Napoca, Romania
P10	ΕΛΛΗΝΟΓΕΡΜΑΝΙΚΗ ΑΓΩΓΗ - Ellinogermaniki Agogi	EA	Pallini, Greece

Table 1. SCeTGo consortium

The project brings together top-level technological research institutions (ICCS, Fraunhofer), top-level pedagogical research institutions (VXU University, University of Helsinki, University of Barcelona, University of Bayreuth, Centre for European research), one science centre (HEUREKA) which is the top science centre in Finland and one of the most identifiable in Europe, a teacher training organization (CCD Cluj) and Ellinogermaniki Agogi a private school organization which is considered among the most active organizations of its type in an EU level.

1.3 Work packages and Deliverables

Work within SCeTGo is split between several Work packages (WPs) as shown in the Table 2.

WP	Title	Lead Partner	Person
WP 1	Management & Scientific Coordination	Heureka	Hannu Salmi
WP 2	Pedagogical design & Feasibility Study	UB	Mario Barajas Frutos
WP 3	Scenarios Adaptation & development	CER	Martin Owen

WP 4	Implementation & Trials	EA	Angelos Lazoudis
WP 5	Validation & Quality Assurance	UBT	Franz Bogner
WP 6	Dissemination	UniHelsinki	Arja Kaasinen
WP 7	Exploitation	Fraunhofer	Hagen Buchholz

Table 2. Work packages

The “Science Center to Go” main tangible outcome will consist of a suitcase of five small artefacts or miniature exhibits (miniatures) together with the software that will enable them to be used on a standard desktop or laptop computer with a Microsoft XP operating system, linked to a good quality web cam. When the webcam is directed to the miniature, the software detects it and responds by adding elements to the image of the object on the screen. These elements are usually aspects of phenomena that cannot be seen, such as wind speed, centre of gravity, or spacing of molecules. Thus the additional information on the screen augments what the student sees. This is the Augmented Reality.

This suitcase will be a self-contained science centre (SC) that will enable users of any age from 8 to 80 to use AR to explore scientific phenomena. This portable science centre will be trialled in schools and higher education institutions to bring a science centre experience to formal educational establishments.

The possible candidate miniatures for development in SCeTGo are listed below:

1. Bernoulli's principle / MiniWing: model of an aeroplane wing that can be rotated. The AR adds in lines indicating the direction and speed of airflow over the wing at different orientations. Different shapes of wing can be compared.
2. Doppler effect: model of a fire engine and an observer. As the vehicle and observer move relative to one another the AR adds in the sound of the fire engine and an exaggerated visualisation of the sound waves.
3. Double-slit: visualisation of wave/particle duality. The model is of a series of screens with two slits in and a source of particles or waves. The AR shows the patterns that would be made on a background when waves or particles reach them through the slits.
4. Leybourne's uphill roller: explaining why a double cone apparently climbs a slope. The AR tracks the centre of gravity of the double cone, enabling students to work out that it isn't actually rolling uphill.
5. Boltzmann constant/Hot air balloon or Fridge & Heater. The miniature will be either a hot air balloon or a setup with a mini fridge and a mini heater. The AR shows the molecules, which move faster and are less densely packed as the balloon rises or their speed depends on the temperature.
6. Darwinsim vs Lamarck: simulating evolution by "killing" vulnerable creatures. The AR is of creatures against a background provided by the webcam. The objective is to "kill" the creatures. They reproduce according to the theories of either Darwin or Lamarck, so that they gradually "evolve" to be less visible against the background.
7. Arch bridge: building a stable bridge. The model is of bricks that can be put together to form a stable bridge. The AR shows the forces acting on the structure.

At the moment of writing of this document (May-June 2010) the most probable candidates for inclusion in the suitcase are the first five from the list.

In the project the miniatures will be tested in four types of classrooms:

- Late primary school (aged 8-11)
- Early secondary school (aged 11-14)
- Science specialists (late secondary or undergraduate)
- Non-specialist (late secondary or undergraduate)

The current document is part of WP2 – Pedagogical Design and Feasibility Study. As suggested by its title, the work package consists of two main parts, namely a) the desing of the Pedagogical Framework (D2.1) that will set up the guidelines for the derivation of the scenarios and b) perform a feasibility study (D2.2), which will include scoping study of interoperability of technology within schools and SCs, risk management analysis of proposed solution and a limited cost-benefit analysis in order to identify the financial risks that can arise from the implementation of the SCeTGo technology/exhibits within schools and science centres (SCs).

The aim of the first part of WP2 is to design the SCeTGo Pedagogical Framework to be used for developing the educational scenarios to be described in a commonly understandable and identifiable way. The pedagogical design, based on an inquiry-based approach, will demonstrate a next generation learning scheme that not only crosscuts the boundaries between formal (e.g. schools, universities) and informal (e.g. SCs) learning settings but also recognises the diversity of personal learning styles and behaviours in different contexts and applications. Various AR scenarios can be developed on the same miniature exhibit for different learners based on their scientific background.

This report – D2.1: SCeTGo Pedagogical Framework – describes in detail the proposed pedagogical framework and the main pedagogical approaches behind SCeTGo. The report describes how the proposed approach provides ways to analyze, plan and respond to a scientific inquiry. Furthermore, issues such as identifying and visualizing information, evaluating resources, and integrating knowledge and experience are considered. It also includes a review of current trends in science education and communication.

The pedagogical framework provides the structure direction for the development of SCeTGo scenarios and their implementation in real educational settings. Important to consider issues are reviewed and pedagogical factors and constraints are listed and explained.

2 Theoretical Framework

SCeTGo aims at improving science education, enhancing scientific literacy and students' critical thinking skills, involving various learning environments (schools, universities, science centers) and recognising the diversity of personal learning styles and behaviours in different contexts and applications. Furthermore, SCeTGO intends to promote young people's interest in science through the introduction of its informal character in formal educational environments, which motivates students of both genders and encourages students to consider science and science-dependent vocations as careers. In long terms this should boost gender equality through stimulating the engagement of young girls in experiential learning.

The theoretical framework underpinning SCeTGo which is presented in this document is grounded on and structured under three interrelated bodies of research, namely:

- inquiry-based and creative problem based approaches
- Augmented Reality (AR technology) and its integration with miniature exhibits
- blended learning - crosscut the boundaries between formal (schools, universities) and informal (SCs, home) learning settings

Each of these is developed in the rest of this chapter, to outline their basic theoretical premises as well as their specific applications in SCeTGo.

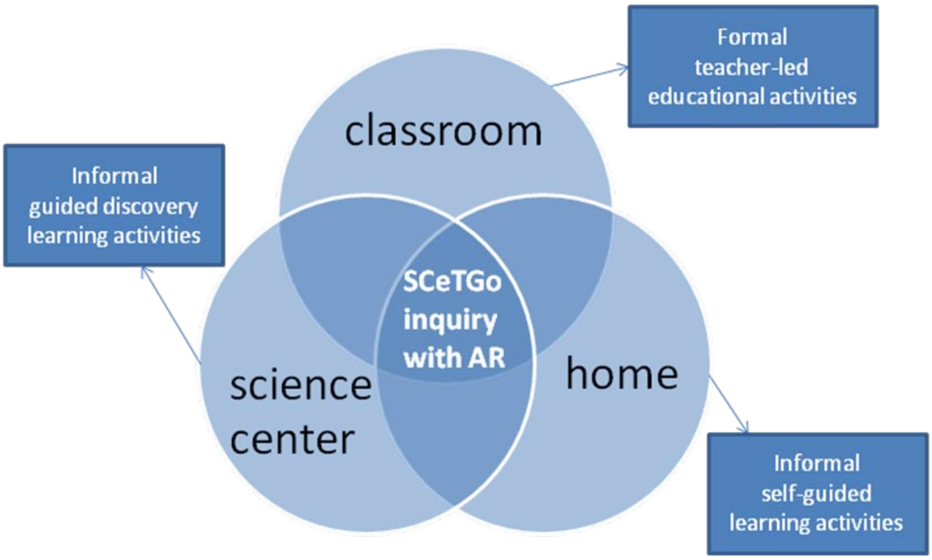


Figure 1: SCeTGo approach: Crosscut the boundaries between formal (school/university) and informal (SCs, home) learning settings

In general, SCeTGo's pedagogical approach is strongly based on the field of technology enhanced learning, more concretely focused on information and communication technology (ICT). There is empirical evidence of a positive relationship between ICT use and educational attainment (BECTA, 2004). The study reports a statistically significant positive association between ICT and higher achievement in National Tests for English and for Science. Although not as striking and not statistically significant, positive associations were also found for mathematics too. Furthermore, the "E-learning Nordic 2006" study (Pedersen et al., 2006) revealed that the potential of ICT is not being fully realised at all schools and that more focus should be paid on ICT potential for improving knowledge-sharing, communication and home-school co-operation. The technological support could be beneficial for wide variety of pedagogical methods for both the teacher and the student. It is believed that ICTs can empower teachers and learners, promote change and foster the development of ‘21st century skills, transforming teaching and learning processes from being highly teacher-dominated to student-centered. This transformation is believed to result in increased learning gains for students, creating and allowing for opportunities for learners to develop their creativity, problem-solving abilities, informational reasoning skills, communication skills, and other higher-order thinking skills.

Many prior research studies have reported positive impacts of the use of digital and ICT technology in education (Balanskat et al., 2006; Bayraktar, 2001; BECTA, 2004, Pederson et al., 2006, Ilomäki, 2008; Scanlon, 2003; Underwood, 2009). Such impact include: improved progress, stronger learning outcomes, increased motivation and enthusiasm, increased efficiency and collaboration.

The investigation of Ilomäki (2008), however, shows that:

> *There is a generation gap in ICT use and competence between teachers and students. This is apparent especially in the ICT-related pedagogical practices in the majority of schools. The new digital affordances not only replace some previous practices; the new functionalities change many of our existing conceptions, values, attitudes and practices. The very different conceptions that generations have about technology leads, in the worst case, to a digital gap in education; the technology used in school is boring and ineffective compared to the ICT use outside school, and it does not provide the competence needed for using advanced technology in learning.*

The results described by Ilomäki (2008) indicate that in schools that dedicate special attention to ICT based projects for improving their pedagogy teachers adopted student-centred and collaborative, inquiry-oriented teaching practices as well as practices that supported students' authentic activities, independent work, knowledge building, and students' responsibility.

The results considering students are mostly positive and show that they “are capable and motivated users of new technology”. Students’ ICT skills and attitudes are mainly acquired at home and through their use in the leisure time. Furthermore, Ilomäki (2008) underlined that students “have the skills to use new kinds of applications and new forms of technology, and their ICT skills are wide, although not necessarily adequate” to the educational context, as they might have inadequate or even wrong working habits.

Considering teachers, more heterogeneous situation has been observed – “The large majority of teachers have sufficient skills for everyday and routine working practices, but many of them still have difficulties in finding a meaningful pedagogical use for technology”. Furthermore, it has been concluded that “teachers’ good ICT competence help them to adopt new pedagogical practices and integrate ICT in a meaningful way”.

As the individual teacher is usually the one who makes the decisions on the classroom practices, variety of studies have been done on the teacher characteristics in relation to the use of technology in the classroom. Ilomäki (2008) provides a list of teachers’ problems when implementing ICT scenarios into educational practices. The focus has been on individual pedagogical conceptions and problems that teachers experience while preparing the lessons as well. Very often, teachers with more ICT skills use more often ICT solutions in their teaching and they do it in a more learner-centered way.

A major challenge in the use of technology in teaching and training could be the tension between learning the subject matter/argument and the simultaneous technical mastery of the technological tool (e.g. the software). Barab et al., (2000) show examples on how the inability to use the tool is interferring with his ability to perform the tasks and thus might negatively impact the understanding as the focus of attention of the learner is shifted.

The European SchoolNet report (Balanskat et al., 2006) also identifies several barriers to ICT uptake in schools. Teachers' poor ICT competencies, low motivation and lack of confidence in using new technologies in teaching are significant determinants of their levels of engagement in ICT. These are directly related to the quality and quantity of teacher training programmes and continuing professional development. Furthermore, school level barriers, such as limited access to ICT (due to a lack or poor organisation of ICT resources), poor quality and inadequate maintenance of hardware or unsuitable educational software are also defining elements in teachers' levels of ICT use.

SCeTGo will include innovative and cutting age technology into the classroom to bridge the "generation gap" discussed above. Furthermore, throughout the lifetime of the project, extensive teacher training is planned, so that to assure that barriers in this respect are eliminated. Finally, the design of the miniatures and the Augmented Reality application is done with the clear perspective of diminishing the technology related issues, such as the need for technical mastery or difficulties in AR manipulation, and thus allowing the students and teachers attention to focus on the educational activities.

2.1 Current Trends in Science Education

Historically, there are two main pedagogical trends in science education – 1) a deductive approach and 2) an inductive approach. The deductive approach is a top-down method where the teacher presents the concepts, their logical implications and gives examples of applications. According to Rocard (2007), for this approach to be used, the children must be able to handle abstract notions, what makes it difficult to start teaching science before secondary education. On the other hand, the inductive approach is a 'bottom-up' approach, which "gives more space to observation, experimentation and the teacher-guided construction by the child of his/her own knowledge". In most European countries, science teaching methods are essentially deductive. The presentation of concepts and intellectual frameworks come first and are followed by the search for operational consequences, while experiments are mainly used as illustrations. A change is under process in some countries towards more extensive use of inquiry-based methods however, the mainstream still remains mainly deductive (Rocard, 2007: 10).

Due to the decline of the interest in young people's for key science studies and mathematics, European Commission's Directorate-General for Research has gathered a group of experts "to examine a cross-section of on-going initiatives and to draw from them elements of know-how and good practice that could bring about a radical change in young people's interest in science studies" (Rocard, 2007: 29).

Previous studies, as the 2005 Eurobarometer study on "Europeans, Science and Technology" (Eurobarometer, 2005) report that only 15% of Europeans are satisfied with the quality of science classes in school. According to the analysis in Rocard report, in the 2001 survey, the sample population interviewed on the causes for declining interest in scientific studies and careers ranked foremost the fact that "science classes at school are not sufficiently appealing" (59.5%). In the same survey 60.3% of Europeans state that "the authorities should try to resolve this situation".

The same decline of the interest on behalf of the wider public concerning science is observed in many surveys (Salmi et al., 2010: 193) "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.

There are, however, various on-going initiatives in Europe that actively contribute to the renewal of science education.

InLOT[2] - “In the Lab of Tomorrow” project aimed at introducing to science teaching an innovative combination of a new approach to learning with application of new technologies. Within the framework of the “In the Lab of Tomorrow” project wearable computers and intelligent sensors have been developed that can be used by students for experimentation, data collection and storage. The wearable sensors are embedded in everyday objects (e.g. t-shirt, ball, vest) that are used from the students during their usual activities.

EXPLOAR[3] project: Visualising the Invisible - demonstrated an innovative approach involving science centre and museum visitors in playful learning, through Augmented Reality and wearable technology. The EXPLOAR project aimed to demonstrate to all visitors, and especially the young people, the rich opportunities offered when visiting a science centre or museum and support them in accommodating as much content and information they can. This is realised by using the Augmented Reality technology to provide the visitors with relevant information as they interact with the exhibit. The real exhibits are mixed in the visitors’ optical view with the 3-D visual objects and representations that the AR system embeds through their glasses, thus producing an augmented world. In this way many “invisible” parameters in physical phenomena (e.g. forces, fields) are visualised and presented in the eyes of the visitors augmented on the real experiments. The presentation of such augmentations in the visitors’ optical view, explaining the physical laws and phenomena under investigation enables them to observe and thus better understand the world in which they live, work, play, and perform.

ROSE project - Relevance of science education[4] – states that “The lack of relevance of the S&T [n.a. science and technology] curriculum is probably one of the greatest barriers for good learning as well as for interest in the subject”. This relevance could be increased by bringing the science education and the studied subjects closer to the students, their interests, worries, their lives and the environment surrounding them. It could be also increased by adapting the teaching methods to be closer to the natural learning styles of pupils of different ages.

ATLAS@CERN[5] project aim is to improve science instruction by expanding the resources for teaching and learning in schools, universities and science centers & museums, providing more challenging and authentic learning experiences. The project approach emphasizes curiosity and observations followed by problem solving and experimentation in both real and virtual settings. Through the use of critical thinking and reflection, users of the ATLAS@CERN educational environment are able to make sense out of gathered evidence based on the most recent developments of science. Moreover, such an approach is perfectly adapted to the young audiences.

The COSMOS[6] project aims to create an experimental laboratory for students and teachers in order to improve science instruction by expanding the resources for teaching and learning in schools and universities and by providing more challenging and authentic learning experiences for students.

[2] www.inlot.eu

[3] www.ea.gr/ep/exploar

[4] http://www.ils.uio.no/english/rose/about/rose-brief.html

[5] http://www.learningwithatlas-portal.eu/

[6] www.cosmos-project.eu

Science on Stage – science teaching festival continues Physics on stage project of EIRO forum. All countries involved in current SCeTGo poject have also science teachers attending SonS Festival. Science on Stage Festival consists in European fair and workshops presenting the best good practices examples from 27 European countries and Canada (French area).

Furthermore, many teachers, both at primary and secondary levels of education have developed multiple innovative practices based on inductive approaches and inquiry-based or problem-solving teaching methods.

Teaching is more than a set of methods, as it means addressing a set of objectives for a particular group of pupils at a certain point in the school year with certain resources within a particular time frame in a particular school and community setting. It means finding a balance between direct instruction and designing cooperative activities of individuals and/or groups of pupils. It means developing pupils' skills and strategies for learning and simultaneously offer them access to new content of the curriculum. It is important to see disciplines in experimental science, such as Physics, not as static knowledge or inert ideas, but as ways of knowing. Using ways of knowing — thinking within physics' content — means to command a set of concepts and a set of strategies for asking questions and creating knowledge. To think *across* disciplines means to identify problems, to ask the right questions, to bring the right knowledge to bear, to find the right solutions, and to apply the right measure of one's success.

With regard to the pedagogy of learning mediated by computers, Macdonald et al., (1977) and Kemmis et al., (1977) proposed a classification for computer based learning materials that is still relevant today. Four paradigms were proposed, instructional, revelatory, conjectural and emancipatory.

- At the instructionalist level the model is simple: the learner answers questions on screen. Progress may depend on the answers given, for example wrong answers may lead to another page of similar questions. This is a behaviourist model that the SCeTGo project seeks to avoid, but it may apply to some assessment techniques, which teachers may be required to use.
- At the revelatory level the learner has to explore and experiment to reveal an underlying model. It is consistent with Bruner's theories (see Bruner, 1961 and Bruner, 1962). The double cone and evolution miniatures are examples of this within SCeTGo.
- At the conjectural level learners can use software to model and to test hypotheses[7]. It is based on the extension of constructivist theories of Piaget, described by Papert as constructionist (Papert, 1980). There is some overlap between this and the revelatory paradigm[8]. In its present iteration SCeTGo software conforms to this paradigm to a limited extent. Pupils can experiment with the orientation of different aeroplane wing shapes provided but to be a truly conjectural activity the learners would need to be able to design and test their own wing shapes.
- Finally, at the emancipatory level the learner uses the computer as a tool and is freed from routine tasks, giving them time to concentrate on educationally rich experiences. An example of the emancipatory paradigm is using a database to find information. In SCeTGo this could occur if learners use spreadsheets to perform calculations on data that has been collected. This could also occur in follow-on activities in which learners look for further information on the Internet.

[7] *the authors had the programming language LOGO in mind*

[8] *"Typically the view of learning emphasises closing the gap between the structure of the student's knowledge and the structure of the discipline he is trying to master." (Kemmis et al., 1977: 25)*

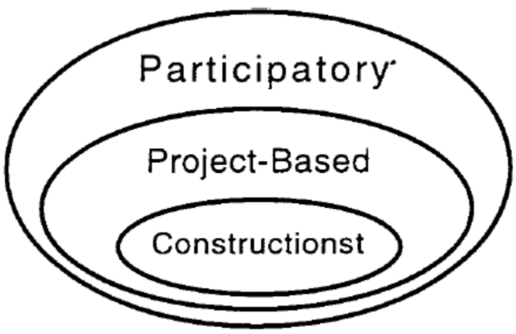
2.1.1 Constructivism, Socio-Constructivism and Constructionist Theory

Constructivism is a theory of learning that has been widely embraced by the math and science education communities. The backbone of the theory is that learning should be an active process in which children interact intellectually with both subject content and with each other (Au, 1993; Cobb, 1994; Mayer, 1992). It rests on the idea that students create their own knowledge in the context of their own experiences (Fosnot, 1996). Knowledge is not passively received through the senses or by way of communication and cannot be imparted, but rather it is constructed by each person through his or her experiences. Constructivism focuses on students being engaged in "doing," rather than passively engaged in "receiving" knowledge. Furthermore, knowledge does not simply arise from experience, but is build through experience over the current knowledge structures.

Many researchers emphasize the need to incorporate constructivist approaches in the teachers' learning programs (Appleton, 1993; Eylon & Bagno, 1997; Putnam & Borko, 1997; Loucks-Horsley et al., 2003). Teachers have to be engaged in activities that address their current knowledge or views and help them in refining and enriching their own understandings. The constructivist approach has been recommended for science education in secondary schools by Saunders (1992). The author argues that the science laboratory should move from a place where knowledge is verified to one where relationships are actively investigated through hands-on, cooperative activities.

Learning occurs in a socio-cultural system in which learners use various tools and multiple forms of interaction to create collective activities. Social Constructionist Theory developed by Russian psychologist Vygotsky in 1920 (Vygotsky, 1978) is based on four major principles[9]:

1. Learning is collaborative and grounded in social experiences.
2. The zone of proximal development should be used by teachers throughout learning experiences. It suggests that students can learn things that are beyond their understanding through collaboration and help.
3. “Real world” experiences give students context for learning.
4. School experiences should be enriched by out-of-school experiences.



Source (Barab et al. 2000)

Figure 2: The nested relations among the three pedagogical frameworks

Since the 1960s, teaching and learning of mathematics and science has been heavily influenced by the theories of psychologists such as Piaget, Bruner and Vygotsky (Wood, 1998). Whilst Piaget studied learning from the point of view of child development, Bruner

[9] Source: Fiore C. (1999)

considered the processes people use to solve problems and Vygotsky looked at learning as a collaborative process, dependent on cultural and historical factors. A feature shared by all of their theories was the importance of activities and problem-solving to learning.

> *"I have never seen anybody improve in the art of a technique of inquiry by any means other than engaging in inquiry"* (Bruner, 1961: 31)

Piaget proposed that understanding of abstract mathematical concepts had to be preceded by practical activities. Wood (1998) did not accept this hierarchical model. He proposed that theory and practice were *"distinct mental technologies"* (p. 275), a view he believed to be compatible with the constructivist and socio-cultural schools of thought of Vygotsky and Luria.

There is also within this a vision of constructionism:

> *"Constructionism — the N word as opposed to the V word — shares contructivism's view of learning as "building knowledge structures" through progressive internalization of actions. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe"* (Papert, 1980: 1).

The pedagogy of SCeTGo draws heavily on these theories, placing high value on learning by making enquiries and solving problems and on constructing knowledge by interacting with others.

2.1.2 Teacher Led vs. Participation in Learning

In contemporary pedagogical approaches there is obvious shift of the focus from the teacher-directed instruction to student-centered approaches. Constructivism's main pedagogical implication is that during instruction the centre must be the learner and the development of meaning and understanding from his/her part (Cobb, 1994; Perkins, 1991; Von Glasersfeld, 1995; Bagley & Hunter, 1992). By placing the learner in the centre of instruction learning occurs as an act of cognitive restructuring (rather than transmission) and the student's activeness and metacognitive capabilities are augmented (Koschmann et al., 1994; Greening, 1998). Training of behaviour or performance is not conducive to understanding and should be used in a limited extent when it aims in proficiency in routines (Von Glasersfeld, 1993). In many practices a step further has been done towards student-directed learning and even toward object-directed activity.

There is sufficient evidence to suggest that both the persistence and the quality of learning are highly enhanced when the potential learner is actively participating in the learning process (Papert, 1994; M. Resnick, 1993).

Participatory learning is often supported by digital tools, so called participatory learning environments (PLEs). Such environments "immerse students within contexts that challenge, ground, and ultimately extend their understandings. […] These environments are collaborative in nature, with students negotiating goals, tasks, practices, and meanings with peers" (Barab et al., 2000: 3).

The best way to teach sciences is to provide opportunities to practice it in schools, in museums and in science centres. This can be accomplished by using active methods and active learning, in order to take advantage of the students' experience. Teachers' role will be changed, as they are no longer the "source of information", but the coaches of learning activities. The role of students will be also changed, as they are no longer passive receivers of information, but become active seekers of knowledge and active participants to the learning process.

Here are some issues regarding the building of a learning program in teacher led learning and inquiry-based learning approaches. SCeTGo scenarios are designed from the inquiry-based learning point of view, because this is the way that science can be connected with real life experiences of the students.

Table 3: Side by side comparison of Teacher led and Inquiry-based Learning

The issues	Points of view	
	Teacher led	**Inquiry-based Learning**
Approaches for designing the learning activities	Receptive: absorbing information Directive: frequent responses coupled with feedback (behavioral roots)	Guided Discovery: active constructive process mediated by problem solving Exploratory: finding and processing information
Methods for presenting instructional content	Deductive: having the learners work from general information to examples	Inductive: giving the learners examples to abstract
Approaches for helping the learners to learn	Expository: explicitly giving examples and general information	Inquisitory: the learners find examples or general information
Ways of learning	Absorbing (read, hear, feel)	Doing Interacting (socialize) Reflecting

2.1.2.1 Principles of Learner–Centered Approaches

The goal in participatory learning is to establish rich contexts that encourage students own explanation and discovery over the studied field or phenomena. Participative learning is consistent with the constructionist[10] theory which argues that knowledge is generated and learning happens from people's experiences (constructivism[11]), where individual learners construct mental models to understand the world around them.

A set of Learner-centered principles was created to help the learning process (Ellis, Wagner, & Longmire, 1999; McCombs, 1992) [12]:

1. Learning does not occur in a vacuum. Learners discover and construct meaning from information and experience based on their unique perceptions, thoughts and feelings.
2. More information doesn't necessarily mean more learning.
3. Learners link new knowledge to existing information in ways that make sense to them.
4. Personality influences learning.
5. Learners want to learn.

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10 http://en.wikipedia.org/wiki/Constructionist_learning

11 http://en.wikipedia.org/wiki/Constructivism_(learning_theory)

12 Sourse: http://www.nwlink.com/~donclark/hrd/learning/active.html

6. Learners like challenges and are most creative when it is challenging and meets their individual needs.
7. Learners are individuals. Trainers must take into account such differences between learners.
8. The learning environment is important.
9. Learners like positive reinforcement.
10. Past experience matters.

Active learning means to learn new ideas, skills and attitudes through what we do at work or in other situations that involve intellectual activities. It is about learning from doing, performing, and taking action. Here are some of the methods or learning strategies used:

a. Case studies
b. Games
c. Simulations
d. In-basket exercise
e. Reflections or introspection
f. Surveys
g. Role playing
h. Fishbowls
i. Icebreakers
j. Visualization
k. Modeling

The classes are often broke into small groups of 2 to 5 learners. Some believe groups of 3 (Triad) is the most effective for promoting interaction, while a dyad (groups of two) promotes intimacy and sharing.

Critical thinking allows us to think about our own thoughts and the reasons behind our points of view. It means that we reflect on our own ways of making decisions or solving problems. These pupils are mindful of opportunities to use their critical thinking skills and typically engage these opportunities eagerly—whether in the classroom context, in virtual activities or in the world of their own communities. These are the pupils who make teaching enjoyable and exciting.

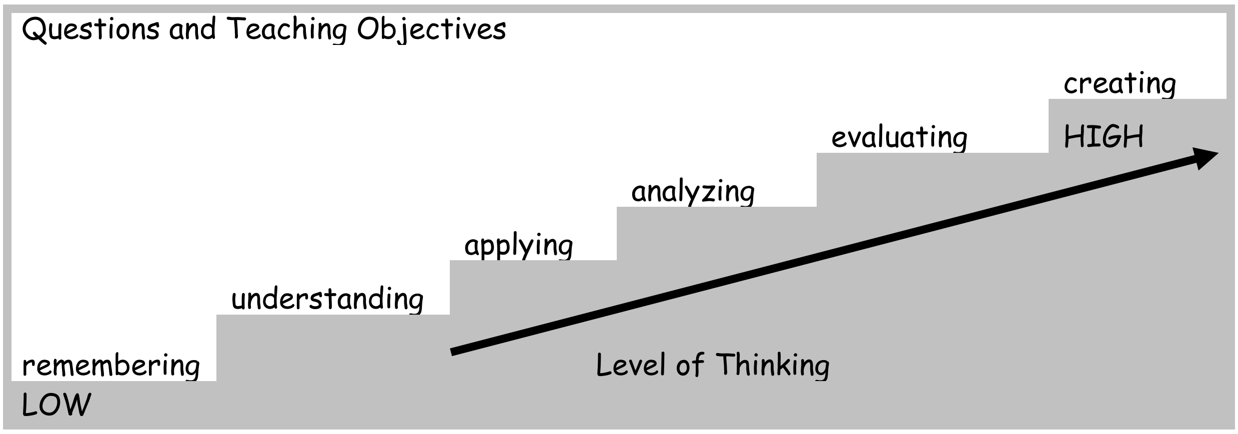

Figure 3: Teaching objectives vs. the level of thinking, based on Steele et al., (1997)

2.1.3 Inquiry-Based Learning and Project-Based Learning

European Commission with the Rocard report recommend renewal of school's science-teaching pedagogy by "introduction of inquiry based approaches in schools" (Rocard, 2007:

22), as they provide increased opportunities for cooperation between actors in the formal and informal arenas. Furthermore, it states that inquiry-based methods proved their efficacy in science learning at primary level with increasing both children's interest and teachers' willingness to teach sciences.

2.1.3.1 Project-Based Learning

Project-based learning can be viewed as one approach in which students construct personal knowledge. It is an example of a participatory approach, emphasizing learning activities that occur across extended time frames, are student centered, interdisciplinary, have real-world relevance, and engage students in an inquiry process (Barab et al., 2000). A problem-based learning situation should place students in various authentic context- and task-related situations in which they will not be artificially constrained within the task. For example, students may be working on long-term projects with an authentic purpose (Means & Olson, 1995), thus providing vast occasions for construction of knowledge (Bagley & Hunter, 1992). A central characteristic of well-designed projects is that underlying the work is a set of driving questions or problems, developed by the students or the instructor that focuses and provides motivation for student activity.

Project-based learning frequently includes teams of students engaged in cooperative learning and collaborative problem solving as they work to complete a project. Cooperative learning has been shown to be effective in improving academic and social skills; however, successful cooperative learning requires careful organization, and sometimes explicit training in collaboration and communication (Johnson, 1986; Johnson & Johnson, 1989). Using this method in designing the SCeTGo scenarios, the teachers will create an authentic learning environment for the students who will develop their skills in cooperative learning and collaborative problem solving.

The characteristics of project-based learning activities are[13]:

- Students have some choice of topic as well as the nature and extent of content of the project. Students can shape their project to fit their own interests and abilities.
- The teacher acts as a facilitator, designing activities and providing resources and advice to students as they pursue their investigations. However, the students collect and analyze the information, make discoveries, and report their results.
- The context for the subject matter is larger than the immediate lesson.
- Students conduct research using multiple sources of information, such as books, online databases, videotapes, personal interviews (in-person or conducted via telecommunications), and their own experiments. Even if their projects are based on the same topic, different students may make use of considerably different sources of information.
- The project usually cuts across a number of disciplines. Students are expected to draw upon a broad range of knowledge and skills, and to "stretch" their knowledge and skills.
- The project extends over a significant period of time, usually from several class periods to an entire school year. Students plan for the effective use of their time and share resources such as computers, camcorders, and computer network access. One goal in project-based learning is for students to increase their skills in budgeting their time and other resources.

[13] Source: http://www.iste.org/content/navigationmenu/research/reports/the_road_ahead_background_papers_1997_/project-based_learning.htm#Characteristics

- The project involves the design and development of a product, presentation, or performance that can be used or viewed by others. Students may simply present the results of their projects in class as reports or posters. The projects may extend beyond the school boundaries in the form of broadcasts, publications, and public events. Students may create products of significant and lasting value, such as environmental assessments or permanent information displays.
- A team of people may work on the project. The team may be an entire class, several classes, or even several remote sites.
- The instruction and facilitation is guided by a broad range of teaching goals, and students may achieve additional (unforeseen) goals as they explore complex topics from a variety of perspectives.

2.1.3.2 Inquiry-Based Learning

Inquiry-based learning is rooted in the scientific method of investigating phenomenon in a structured and methodical manner. Related to teaching and learning, it is an information-processing model that allows pupils to discover meaning and relevance to information through a series of steps that lead to a conclusion or reflection on the newly attained knowledge. In most cases, teachers use a "guided inquiry" method to facilitate the learning experience and structure the inquiry around specific goals of instruction. The benefits of inquiry-based learning include the development of critical thinking, creative thinking, and problem solving.

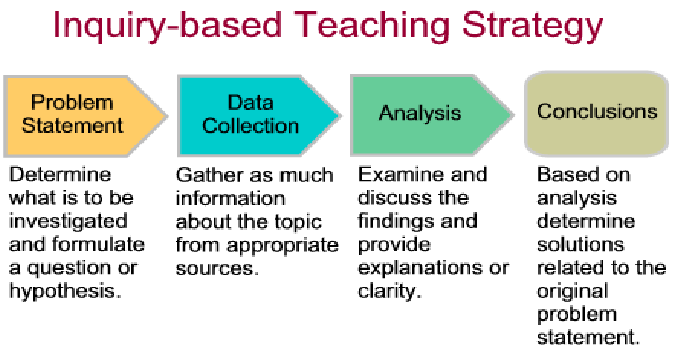

Figure 4: Inquiry-based Learning Visual Concept Diagram[14]

The research in (CILASS, 2008) shows two perspectives of the inquiry-based learning, the authors call them ‘information’ and ‘discovery’ frames. From the perspective of the information frame inquiry is perceived as the exploration and acquisition of existing disciplinary knowledge. On the other hand, from the discovery frame the inquiry is perceived as participation in building on, and contesting, that knowledge.

[14] Source: http://www.worksheetlibrary.com/teachingtips/inquiry.html

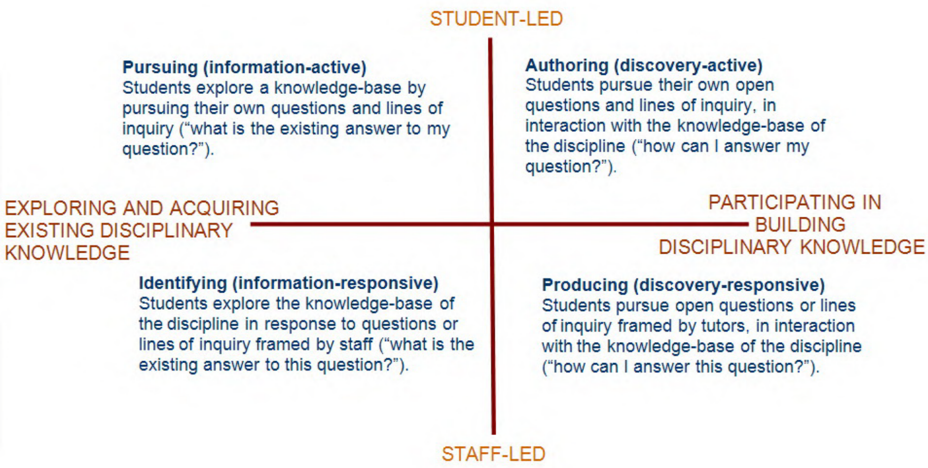

Figure 5: Inquiry-based Learning: Conceptions and Approaches, source (Levy, 2009)

The framework (see Figure 5) also describes inquiry-based learning in terms of whether the tasks are allocated by the teacher (teacher-led) or whether the learners formulate questions themselves (student-led). As learners develop skills of scientific enquiry they should move towards the student-led inquiry. Within SCeTGo teachers can encourage learners to compose questions that can be answered either by using the software or by further research.

2.1.3.2.1 Principles of Inquiry-Based Learning

The main components of the inquiry-based learning approach include:

- a question(s) related to the topic of inquiry to be explored (problem statement),
- followed by an investigation and gathering of information related to the question (data collection),
- continuing with a discussion of findings (analysis),
- commencing with a reflection on what was learned (implications/conclusion).

2.1.3.2.2 Procedures

The first step in any inquiry is the formulation of a question or set of questions related to the topic of inquiry. The question can be posed by the teacher or by the pupil(s). Sometimes the question is referred to a hypothesis or a problem statement.

Once a question is posed, pupils are encouraged to investigate the topic by gathering information from sources that either the teacher provides or within learning resources or tools that are readily available to the pupils.

When enough information related to the topic of inquiry is gathered, it is organized in categories or outlined by highlighting the important information relative to the topic. This helps the students to make connections with new learning and prior learning.

The information is discussed and analyzed for further understanding. The teacher can direct the discussion and highlight the implications that arise from the investigation and show how it relates to the solution of the problem.

Conclusions are made and related back to the original question. Student reflections are encouraged and serve as a way to relate back to the inquiry and retrace the steps that led to the conclusion. This also serves to reinforce the model so that pupils can repeat the process in any problem-solving situation.

Building on the work of Bruner, Taba (1962) outlines a scenario for discovery-, or inquiry-based learning:

1. Confront learners with a problem that initially baffles them.
2. Prompt to utilise previously acquired knowledge and perception to recognise ways to tackle the problem.
3. When learners have solved this problem, present them with another one in which they can demonstrate the principles they have now acquired.

A more recent analysis divides inquiry-based learning into two types (see CILASS, 2008):

- finding out information from existing knowledge, the "information frame"
- building and evaluating new knowledge, the "discovery frame".

Both of these frames can be relevant to SCeTGo but the initial focus is on the discovery frame. The learners are encouraged to be real scientists and to find out something using the miniature and the AR that they did not know before. They can then judge whether this fits in with their pre-existing perceptions, for example, "objects do not roll uphill" or "light is a wave."

In SCeTGo the information frame would normally come into play after the encounter with the miniature, if the intention is to follow up the activities with further research into existing disciplinary knowledge. It is important that the learners have not studied all of the theory, appropriate to their level, behind the miniatures before they see them, so that there are still opportunities learn by discovery. For example, younger learners may have learned about the observable properties of sound but they may not know that it travels in waves. So one challenge for them would be to say what they thought the lines represented on the Doppler AR.

A possible exception to this general principle is that learners could find out how scientists work, for example how they make incremental changes and how they think of theories and then test them. This would be a useful strategy if the learners are not familiar with laboratory techniques.

2.1.4 Adaptation of Learning to the Student's Profile

It is well known that people have different approaches to learning. These individual differences are called learning styles. The research field of learning styles is both extensive and conceptually confusing (Coffield, 2004) with many models proposed by different authors. The idea of learning styles is based on the observation that most people favour particular types of interactions when it comes to learning. Technology based or mediated learning facilitates the support of learning styles and inclusion of different teaching/learning approaches associated to them.

Multiple intelligences theory, first put forth by Howard Gardner in 1983, supports the need for personalization of schooling (Gardner, 1996). Gardner argues that each person has a number of different types of intelligence. Through appropriate training and experience, these various intelligences can be enhanced - a person can develop his or her own individual potentials. Gardner strongly supports the use of project-based learning as one approach to creating a learning environment that enhances each student's multiple intelligences.

Most of the models of learning styles include the following types:

- Auditory learning occurs through hearing the spoken word.

- Kinesthetic learning occurs through doing and interacting.
- Visual learning occurs through looking at images, mindmaps, demonstrations and body language.

Montgomery and Goat (1998) believe that each teacher/professor should incorporate an understanding on learning styles in their teaching practice. This approach is consistent with the ideas of active student participation in the classroom and stimulates the dialogue between the teacher and the learner.

SCeTGo applications aim at developing the multiple intelligences: visual- spatial, verbal-linguistic, logical- mathematical, bodily- kinaesthetic, interpersonal, naturalistic etc. Furthermore, through combining the Augmented Reality technology with miniature exponents and the inquiry-based pedagogical approach, all of the above listed types of learning styles could be covered. For example, the visualisation of the invisible phenomena (through the AR) will facilitate students with more visual learning preferences. On the other hand, those in favour of kinesthetic learning will profit more from experimenting with the miniatures. The inquiry-based approach stimulates discussion and group work, thus learning will be facilitated for pupils with auditory learning style.

SCeTGo miniatures will be used by learners at different ages, cognitive development and scientific knowledge. The targeted audience is late primary school (aged 8-11), early secondary school (aged 11-14), science specialists (late secondary or undergraduate) and non-specialist (late secondary or undergraduate). Furthermore, the miniature exponents enhanced by the AR technology will be used inside the classroom (i.e. in formal settings) and in a science center (i.e. informal setting). The same miniatures will be available for all of these categories. The main difference in the way that they are used would be in the language employed, ranging from, for example, “That line moves faster than the other one” at primary level to use of equations and graphs at the specialist level. Furthermore, multiple scenarios might be developed for the same miniature and AR “object”.

2.2 Learning in Science Centers

Traditional museums have an important role in facilitating lifelong learning, in terms of cultural and intercultural activity beyond any merely vocational aspects. Meanwhile, the importance of science and science education has been increasingly recognised within the European society. In this context, in the recent years, science centers (SC) and interactive science museums are also becoming more important and more popular (Caulton, 1998; Ogawa et al., 2009).

Objects (i.e. exponats) are the unique attributes of a museum, yet in the recent years many museums and science centres apparently seek combination of objects and interactivity. 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 (Salmi et al., 2010). Science Centers adopt this philosophy of offering intriguing exhibits that enable their visitors to experience science first hand by actively manipulating the experiments, thus delivering natural ways of active playful learning. The visitors find the interactive exhibitions more absorbing and enjoyable than static exhibitions in traditional museums or classroom lectures (Oppenheimer, 1975). Science museums and science centers offer to their visitors unique informal learning opportunities through its demonstration of a new method of interaction between a visitor and an exhibition (Salmi et al., 2010).

Apart from interactivity, the goal of many museums is learner participation, involving a simple feedback (often digital voting), digital storage of images and ideas (for subsequent remote retrieval) or even contributing directly to the museum's own exhibits and interpretation. Over the last years digital media has increasingly entered the field of museums and science centers (Salmi et al., 2010). Traditional media such as illustrated charts and audio guides together with interactive exhibits take the knowledge transfer to a complete new level of experience. Modern technologies like Augmented Reality are often used to enrich the experience and display otherwise hidden phenomena. However, experiencing mixed reality requires visiting the SC.

The educational approach of science centers and interactive museums are rooted in the work of Jean Piaget and Vygotski (see Section 2.1.1 of this document) and the understanding that learning occurs as a result of direct interaction with the environment. Furthermore, Piaget argues that children learn differently from adults, i.e. they (kids) learn from actions rather than observations (adults). In this context, the role of the teacher is to create environments where learning will happen most effectively, by encouraging students to ask questions rather than accept information unthinkingly (Caulton, 1998). Studies show that the didactics in teaching science in museums involves creativity, complexity, and skills (Tran, 2007).

Science centers are mostly visited by parents with their kids (i.e. in family environment), but often also by students and their teachers in class trips - about 40% of the visitors – as the expositions are relevant to various curriculum subjects (from physics, chemistry, biology, geology, environmental education, to history and language learning). In this sense, the visitors might vary significantly in their interest in learning science, in their abilities to learn science, but also in their previous level of knowledge of different scientific phenomena.

Recent research (Salmi, 2001; Dierking & Falk, 2003; Salmi, 2010) in science centers indicates that informal educational activities appear to have a positive effect on motivation of students of both genders and on career choices of students. SCeTGo aims at promoting young people's interest in science through the introduction of its informal character in formal educational environments. More specifically it is expected to boost gender equality through stimulating the engagement of young girls in experiential learning.

Ancestor of SCeTGo is the project CONNECT[15] – a project that explored the possibilities to promote learning outside the formal classroom settings by involving users in science museums and science centers. Through the Exploar[16] service, the real exhibits of the science centers have been extended with virtual objects by visualizing complex concepts in physics (such as electric or magnetic fields, forces, etc) or by adding virtual annotations and explanations. Furthermore, the CONNECT project's approach has been to keep the real classroom as the point of reference while making more personalized the visit to the museum by keeping a profile of the visitor (i.e. knowledge level and personal interests). This is achieved by providing the teacher with the tools to specify such profile. The EXPLOAR service specifically uses informal education as an opportunity to transcend from traditional museum visits, to a "feel and interact" user experience, by allowing a learning "anytime, anywhere", an openness to societal changes and at the same time a feeling culturally conscious.

The EXPLOAR innovative approach includes the enhancement of some science expositions with Augmented Reality. The study of the educational effect of the selected approach has shown positive outcomes especially on students with performance below average in their usual classroom activities. No statistically significant gender differences were found. This is

[15] http://www.ea.gr/ep/connect/

[16] http://www.ea.gr/ep/exploar/

an important result because very often the high-tech or ICT-solutions are classified as male activities, see (Salmi et al., 2010).

In a Science Centre, however, engagement with an object is typically less than 5 minutes, while in school or in semi-formal settings activity is likely to take place in the context of lessons, which last approximately 60 minutes. Furthermore, studies show that people (especially youngsters) do not spend sufficient time to read all of what is described in the posters to absorb the corresponding information (Salmi et al., 2010).

In Science Centres there is less requirement for formal recording of activity, need for checks on understanding and mutual teacher/learner feedback. In a formal situation there is an opportunity to interact with other relevant materials - books, teachers prepared material, internet etc.

2.2.1 Inquiry in Science Centres

A significant aim of SCeTGo is to improve motivation towards science, also a key aim of science centres. This is a long-term effect. Graham & Gammon (1999) ask questions about the nature of what people take from engagement with science centre exhibits. They suggest that at one level science centre staff may be satisfied if learners report having “a nice time”, but they need to go further to realise the potential of the place as a centre of learning. This also applies to SCeTGo. In order to assure learning in the informal atmosphere of science centres, their exhibitions should provide to the students something memorable.

> *"Experiences in an informal setting can form part of long-term learning, in which understanding comes months or years after the (initial) museum experience. Memory is a vital component of this. There are many elements that affect the formation and retrieval of memories. We have chosen to highlight a few to the teams including the importance of:*
>
> - *emotions*
> - *the physical environment*
> - *actively engaging the brain in mental manipulations*
> - *providing explicit links between information*
> - *providing a clear overview of the exhibition subject"* (ibid.)

These are also important to the portable science centre and must be fully addressed in order to fulfil the aim of increasing interest in science.

2.3 Augmented Reality and its Application in Education

Augmented Reality is a term describing those technologies that allow the real-time mixture between computer-generated digital content and the real world (Haller et al., 2007). AR can also be defined as being an overlay or superimposing of digital data visualised on top of the real view of the surrounding environment. From a technological perspective, AR is often related to wearable computers and overhead monitors (Johnson et al., 2010). People usually associate AR with expensive hardware that requires significant processing capability which can be found only in research and specialist environments, as fighter pilots cabins. Nevertheless, nowadays we can witness a wide variety of AR alternatives that can be implemented by much simpler solutions, such as a laptop and a web camera or even with the use of a PDA or a mobile phone (see for example, http://www.wikitude.org/).

In recent years and with the rapid advances of wireless and mobile technologies, experimenting with Augmented Reality has moved beyond expensive military applications and AR has now entered a wide variety of domains. In the field of education, AR has been widely experimented in laboratory settings and more recently various tests in real classrooms have been made (Woods et al., 2004; Balog et al., 2007; Johnson et al., 2010). By using AR technologies it is possible to combine real objects with virtual ones and to place suitable information into real surroundings. Novel uses of AR application make it possible to converge the fields of education and entertainment, thus creating new opportunities to support learning and teaching in formal and informal settings (Salmi et al., 2010). Natural or historical events and characters, reconstructed monuments or archaeological sites could be now simulated and augmented to the real world. AR is a booming technology which attracts more and more attention from HCI (Human Computer Interaction) researchers and designers. This allows for the creation of meaningful educational experiences that are grounded in a substantive subject area of knowledge and they focus on the intellectual and emotional development of the viewer. From these latest perspectives, AR learning environments have the potential to offer both educational and entertainment value.

Previous research efforts in the field, shows that AR can have a great potential in education. Construct3D[17] is a tool for exploring and learning about geometry. It takes aspects of computer-aided-design (CAD) and combines it with AR technology to create a learning tool aimed to promote social interaction in the shared space, allowing its users to communicate with each other in a natural way (Kaufmann, 2003). Construct3D was mostly used in an experimental setting, requiring personnel doing maintenance and technical support to run. One key finding from the project was that in order for the AR application to be used for learning, it needed to be seamless and transparent; allowing the user to focus on the actual task rather than the application itself. In line with the constructivist theory of learning, it is good for students to have the opportunity to explore on their own or in collaboration with others, however some guidance might be required or the task at hand might be too hard to understand.

Research efforts regarding earlier uses of AR in education show that in classroom settings students' work more effective together if they can share a common workspace, something that can be difficult with the traditional desktop computer-based education (Billinghurst, 2002). By using AR applications based on a tangible interface metaphor, physical objects can have virtual information tied to them, allowing students to control it in an intuitive way and collaborate and communicate in a more natural way within the physical environment. One conclusion is that educators and researchers should work together in order to explore novel uses of these technologies in educational situations in which "visualizing the invisible" becomes central for trying to explain difficult phenomenon. The Human Interface Technology Laboratory in New Zealand (HIT Lab NZ)[18] developed a number of AR applications for educational exhibits aiming to be used in a Science Centre setting (Woods et al., 2004). Based on the observations concerning the used of these applications, the authors have identified a number of possible educational benefits regarding the use of AR technology.

In UK, the learnAR[19] project has developed a package of ten Augmented Reality curriculum resources that teachers and students can explore in various environments. AR solutions have been used in a flexible way, so that to allow a teacher to make demonstrations to a whole class. The same technology can be used by students in a class through laptops, netbooks and desktop computers or, most importantly, by students exploring it independently at home. No extra software is needed, just access to the internet and a printer to print the markers. The project, however, relies very much on overlay and presentation of information and has very little focus on supporting inquiry learning.

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[17] http://www.ims.tuwien.ac.at/research/construct3d/

[18] http://www.hitlabnz.org/wiki/Home

[19] http://www.learnar.org/

The ARiSE project (Pemberton & Winter, 2009) aims at using AR in a school environment. It combines physical and virtual objects and lets users collaborate in close vicinity to each other or to a remote location to manipulate virtual objects relating to their local culture. In this project, different aspects of AR were identified and the preliminary findings indicated that the proposed solution has been well received by students and teachers, and is well suited for remote collaborative learning.

Based on the preliminary findings of the projects described earlier in this section, the impact of AR in education can be summarized as follows:

- AR technology can add excitement and entertainment to the learning activities, thus increasing motivation among participants of the learning experience.
- AR technology is well suited for demonstrating spatial and temporal concepts and it provides advantages over traditional media. For instance, in the AR Volcano Kiosk exhibit (http://www.hitlabnz.org/wiki/AR_Volcano) the eruption of a Volcano is displayed in interactive animated 3D, something that could be very hard to communicate using a traditional book.
- AR has the possibility to offer contextual benefits, being able to compare different objects, which also can be in context of the real world. A user can for example hold different models in his/her hands and compare them.
- AR could be used as a ground for supporting constructivism. It can allow students to explore information about the surrounding environment at his/her own pace, and to construct his/her own knowledge.

Overall, Augmented Reality provides both powerful contextual, situated learning and explorative and discovery learning experiences that may help to connect “new layers” of information in the real world. From another different perspective, the combination of physical and computational media (as the one AR represents) allows moving the interaction beyond the computer screen and it offers new opportunities for interaction between the virtual and the real world in novel ways. One major benefit of doing so is to provide different ways of thinking about the world than interacting solely with digital representations or solely with the physical world. The purpose of providing this kind of multiple representations is to provide a link between the abstract data and the physical activity of collecting it, in a way that enables learners to reflect on how the different combinations of the variables they have been measuring or aspects they are investigating, affects these latest processes. The visualizations of these phenomenon also provide a sense of personal relationship with the data that can facilitate learners’ ability to recall what happened for the various projected data points connected to what they experimented and saw. Having a more intimate relationship with the abstract data, in the sense of knowing how they were physically created, it may trigger strong associated concepts related to complex learning (Milrad et al., 2002).

In order for AR applications to be widely adopted in education, it would be fair to assume that the technology needs to be easy to use for the average teacher/educator. Some projects that heavily rely on experimental/complex technological solutions will be hard to implement in schools mainly because the need for special education and training. This is likely to change in the very near future, as wearable computers and mobile devices, as well as AR applications are becoming ubiquitous. Currently, there are a couple of AR authoring tools that appeared in the last years and can be characterized by its relatively easy to use. These applications required actually no more than a standard PC computer and a webcam to function and more information about them is available at ARSights: (http://www.arsights.com/) and BuildAR (http://www.hitlabnz.org/wiki/BuildAR).

3 Implementing SCeTGo Pedagogical Framework

3.1 Motivation / Introduction

The main objective of SCeTGo, as earlier described, is the development of an innovative learning system that merges advanced AR technologies and miniature exhibitions and allows active learning in schools, universities and science centers. SCeTGo will make a step forward in merging formal and informal learning and demonstrate to the learners new ways of interacting with scientific concepts and phenomena, rise public interest and awareness on science, enhance scientific literacy and critical thinking skills of the students.

The SCeTGo pedagogical concepts and learning practices would be addressed by implementing a set of learning scenarios (missions) tailored to the needs of the diverse groups of learners. These scenarios will be built in accordance with the current trends in science education, including learning-by-doing, inquiry and problem-based approaches in order to stimulate profound understanding on how science works and enhance the effectiveness and the quality of learning.

The SCeTGo project aims at the integration of the AR technology in science teaching both in formal and informal educational environments in order to facilitate lifelong learning by offering to learners the opportunity to gain exposure to everyday science in a way that is appropriate to their individual level of understanding. The SCeTGo introduces an ICT-enabled learning approach that has the following innovative characteristics:

a) Makes use of advanced visualization technologies (i.e. the AR) that not only have the potential to enrich the learners optical view with relevant information but also allow the learners to interact dynamically with the miniature exhibits.

b) Is easy to operate. As it is based on common devices there are no real obstacles that a potential learner has to overcome in order to use the system.

c) Promotes an inquiry-based and experiential learning approach. Learners experience science first hand at their own pace and engage in activities where information is discovered by them rather than passively transmitted to them. By interacting with the miniature exhibits learners can not only visualize invisible physical quantities but can also control the conditions that need to be met in order for an phenomenon to occur (e.g. learners by rotating a miniature wing, namely the prototype MiniWing, at different angles can see through the augmentation of the airflow on the wing why planes fly).

d) Demonstrates the possibilities that students will experience in the future during their educational training in respect to AR technological applications.

e) Promotes the importance of science to all European citizens through a journey of entertainment & learning.

f) Contributes 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 & technology.

g) Offers a modern science centre experience outside the walls of the science centre in school classrooms.

The SCeTGo project aims to provide European Citizens with miniature exhibits that will illustrate various physical phenomena enabling learners to visualize the invisible through AR technology. At the same time science teachers will have the opportunity to introduce new approaches in the classroom by using the new customized AR tools. The project's work is building on this aim as it offers to students the opportunity to use innovative technological tools in the framework of their normal school curriculum.

The SCeTGo approach facilitates lifelong learning as it aims to improve the quality of learning by providing access to resources (mixed reality tools) with significant educational value and reinforces the contribution of lifelong learning to social cohesion, active citizenship, intercultural dialogue, gender equality and personal fulfilment. These are some of the major priorities of the EC's Lifelong Learning Programme which support the development of innovative ICT-based content, services, pedagogies and practice for lifelong learning.

SCeTGo project is aiming at promoting population's interest in science by building on the strengths of both formal educational settings (e.g. schools) and informal learning environments (e.g. homes).

3.2 SCeTGo Learning Scenarios

The devised in this document pedagogical framework will serve as basis for the following work package – WP3 - Scenarios Adaptation & Development. In WP3 a set of SCeTGo learning scenarios (missions) will be developed and later used for the implementation phase of the project. The learning scenarios will be specifically designed to expose students and learners to a mixed reality world where invisible physical phenomena or processes can be visualized. Thus, the well structured scenario implementation will help learners overcome difficulties in comprehension of science education issues. The creation of exemplary scenarios will support content delivery for formal (linked to school curricula) and informal learning enhancing the quality of the learning process for diverse groups of learners.

More specifically, the objectives of WP3 are:

a) to identify and define the usage scenario's from the functional and technical point of view: integration of scenarios and available resources

b) to identify and define the usage scenario's from the business point of view

c) to identify and define the usage scenario's from the service point of view: applications and functionality of the system, input sources and amount of service offered

Additionally, the partnership will develop a series of miniature exhibits that will cover different subjects (e.g. Physics and Mechanics) of science as a consequence of the scenario-designing approach.

The sections below give general guidelines for the creation of SCeTGo scenarios. This includes suggested structure for inquiry-based learning activities. Scenarios length might vary from one classroom hour of instruction (the typical case) to a longer (e.g. double) lesson in the lab. Sessions of more than one hour will allow doing a "circus" of activities, making the learning experience more meaningful and including evaluation of about 15 minutes. The resources should be flexible enough to be used with different outcomes for different students at different ages in different contexts.

Furthermore, if and when required, the teachers involved in SCeTGo implementation will receive training on inquiry-base learning and on technical aspects related to the miniatures through special workshops and on-line manuals.

3.2.1 Structure

The following structure of the scenario has been adapted for SCeTGo, based on Steele & Meredith (1997):

A. The Anticipation Phase

First, each learning activity begins with a phase of **anticipation**, in which pupils are directed to think and ask questions about the topic they are about to study. The Anticipation Phase serves to:

- call up the knowledge students already have
- informally assess what they already know, including misconceptions
- set purposes for learning
- focus attention on the topic
- provide a context for understanding new ideas
- create an expectation horizon for the new knowledge;
- create the student’s motivation for learning.

B. The Building Knowledge Phase

After the learning activity gets started, the teaching leads pupils to inquire, find out, make sense of the material, answer their prior questions, and find new questions and answer those, too. We call this second or middle phase of the learning activity the **building knowledge phase** that serves to:

- compare expectations with what is being learned
- revise expectations or raise new ones
- identify the main points
- monitor personal thinking
- make inferences about the material
- make personal connections to the learning activity
- question the learning activity

C. The Consolidation/Reflection Phase

Toward the end of the learning activity, once pupils have come to understand the ideas of the learning activity, there is still more to be done, namely, teachers want pupils to reflect on what they learned, ask what it means to them, reflect on how it changes what they thought, and ponder how they can use it. This phase of the learning activity is called the **consolidation/reflection phase** that serves to:

- summarize the main ideas
- interpret the ideas
- share opinions
- make personal responses
- test out the ideas
- assess learning
- ask additional questions

3.3 Important Pedagogical Factors and Constraints

SCeTGo will produce a suitcase with at least five miniatures demonstrating scientific principles in the areas of Physics, which will be augmented digitally with helpful for the understanding and learning visual data. The miniatures are targeted to classroom use of a broad audience, including late primary schools (aged 8-11), early secondary school (aged 11-14), science specialists (late secondary or undergraduate) and non-specialist (late secondary or undergraduate).

There are two main ways in which these classrooms are likely to be organised. One scenario is a "Classroom Science Centre": a session in which the class is divided into groups and:

- each group spends a short time with every miniature;
- or each group spends some time with some of the miniatures;
- or each group works with one miniature.

The second way of using the miniatures is to use them individually in the teaching at the appropriate point in the curriculum or module. For example the Doppler effect miniature could be used as part of a teaching session on sound. Groups of learners would take turns to use the miniature. However, the overall aim of this project is to develop skills of scientific inquiry rather than to demonstrate specific scientific principles.

SCeTGo aims to demonstrate that engagement with scientific thinking will enhance students' subsequent visits to a science centre, sensitising them to the philosophy underlying the exhibits there. However the suitcase also has potential for use as a follow-up activity to a visit, or as a stand-alone activity when no science centre is within reach.

To ensure these conditions the miniature and its supporting materials must ensure that the following are fully addressed:

- Ergonomics – can learners effectively operate the miniature and its supporting environment, for example can they find the relevant instructions and controls? Do they notice and correctly interpret the feedback from the exhibit?
- Comprehension – can they identify the key messages of the miniature i.e., does their interpretation of the exhibit broadly match the aims of the our designs?
- Motivation – how successfully does the exhibit attract and hold learners, attention and thus fulfil the aim of increasing interest in science? (Graham & Gammon, 1999)

The engagement with each miniature will include the following elements, typically but not exclusively in this order:

- Setting the challenge
- Recalling prior learning
- Collaboration
- Making and testing hypotheses
- Teacher intervention/prompting
- Feedback
- Assessment

The pedagogical factors and constraints associated with each of these elements will be considered in turn.

3.3.1 Setting the Challenge

Hawkey (2004) advises staff of museums, science centres and galleries organising learning experiences to "engage in learning as a constructive dialogue rather than as a passive process of transmission." This is the type of experience that SCeTGo seeks to reproduce in the formal education sector. It is possible to use the miniatures to demonstrate concepts rather than explore them, but that is not the way they will be used in this research.

Potential aims of an inquiry could be, for example, to:

- deduce what is happening in a miniature by manipulating it and observing what the AR does e.g. observing the movement of the centre of gravity in the double cone;
- work out how to use the miniature to prove or disprove a given hypothesis, e.g. light can behave waves or particles, a parabolic curve is a good shape for a bridge;
- solve a specific problem e.g. what is the optimum shape and orientation for an aeroplane wing?;
- develop and testing a hypothesis, e.g. the Doppler effect appears also when the observer is moving or evolution favours creatures that blend with their environment;
- use the observations to deduce something that you can't confirm in this experiment, e.g. how do you construct an uphill roller?

However, whatever the challenge is for each miniature, the overall challenge for the learners is to work in groups to develop their skills of scientific inquiry.

The challenge for the teacher is to identify a challenge suited to the age group and ability of the learners, and to introduce it in such a way as to give them enough background information, but not so much that there is no issue left to investigate.

3.3.2 Recalling Prior Knowledge

The way to solve the challenge should not be initially obvious to the learners, but they should already have in place the mental tools to tackle it. The main role of the teacher will be in encouraging the learners to recall the skills and knowledge they need whilst leaving plenty of scope for discovering new knowledge. For example younger learners could practice the vocabulary they use to describe sound, for example loud, quiet, pitch, note, high, low. For the Young's double slit miniature younger learners could describe what they already know about waves on the sea shore, and older science students could recap on what they have learned about the properties of waves and particles. The objective is to recognise patterns that can be used to tackle the challenge. The recall could be prompted by, for example, a quiz or a short video that the group could discuss.

In each activity there are two new situations. One is the science and the other is the technology, the AR. The learners will need to master the AR before they can tackle the scientific challenges. This is a scientific inquiry in itself. In some situations it may be useful to have a group discussion what the learners prior knowledge leads them to expect when they start to interact with the miniature.

The learners are likely to be able to extrapolate their existing knowledge of ICT skills to understand the AR fairly quickly but they will probably need some practise before they can manipulate the miniatures effectively. With each successive miniature they use they will have an increased body of prior knowledge.

3.3.3 Hypotheses Definition and Testing

The same miniatures will be available for all ages of learner. The main difference in the way that they are used would be in the level of scientific and mathematical language employed, ranging from, for example, "That line moves faster than the other one" at primary level to use of equations and graphs at the specialist level. This is consistent with Bruner's views that content need not be age-dependent providing that the subject is presented from a appropriate viewpoint for the learners. What a learner will get from an investigation will differ according to age.

> *“We begin with the hypothesis that any subject can be taught effectively in some intellectually honest form to any child at any stage of development.”* (Bruner, 1961: 33)

The investigation itself will consist of a cycle of making and testing hypotheses, following an experiential learning cycle, first suggested by Dewey and developed by Kolb (Petty, 2004):

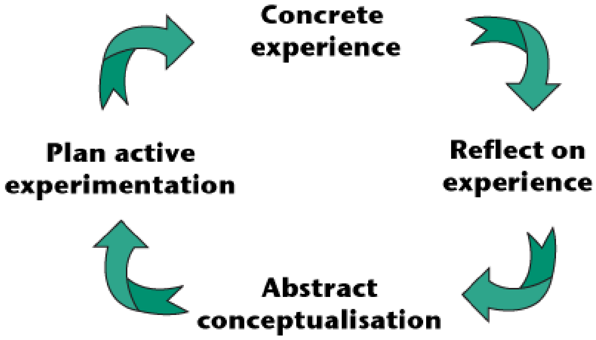

Figure 6: Inquiry cycle

At first the cycles will be very brief, and will consist of hypothesising what the miniature and screen will do in different alignments, and testing this out. Once this has been achieved the group can turn its attention to the main challenge it has been presented with.

An important principle of scientific investigation is that only one change is made at a time. It is likely that untrained learners will make multiple changes, for example the rate of "killing" creatures, the total time and the background in the evolution scenario.

At first the learners can be allowed to make these "mistakes" in order to learn that, ultimately, a methodical approach is needed, but they may eventually need prompting. If all or most of the miniatures are explored by each group in one class, or series of classes, then this is an excellent opportunity for the learners to improve their techniques with each exhibit they visit and to apply their newly-learned skills of scientific investigation to new situations.

The learners may need to be encouraged to stop to reflect on what they have learned, to fit that into their mental model of the situation (adjusting it if relevant) and deciding whether they have completed their challenge, and if not what to do next. The skill here in classroom organisation is to achieve this but without imposing so much structure on it that the whole process ceases to be playful and exploratory.

3.3.4 Collaboration

In SCeTGo the most likely classroom organisation will be that groups of up to six learners working with one miniature at a time. Early adopters of computer-mediated learning noticed that working in groups was preferable to each learner working alone at a computer because of the interaction between the learners (Underwood & Underwood, 1998). To Vygotsky, a person’s understanding comes from interaction with other people:

> *“Every function in the child's development appears twice: first, on the social level, and later on the individual level; first, between people, and then inside the child”* (Vygotsky, 1978: 57).

Interpersonal relations are precursors, and necessary conditions, for the emergence of individual understanding. Learners first share their experience with others, before they become able to master and understand them for themselves.

This works well if the learners are familiar with group work, familiar with sharing a task and respecting the opinions of other members of the group. The situation will be more challenging for both the teacher and the class if this is a new way of working for them. The basics of collaborative learning need to be in place at the start, particularly the etiquette.

3.3.5 Teacher Intervention / Prompting

Obviously teachers will apply their normal strategies in their classrooms to encourage appropriate behaviour and productive interactions within the groups, so this will not be elaborated further.

However, it is important to note that in the constructivist model the plausibility of guesses should be recognised, providing that the learners are being scientific in their approach. Learners' prior experience may have led them to believe that the objective is to get the "right" answer as quickly as possible rather than to spend time perfecting models and testing hypotheses (Wood et al., 1978). Learners are often skilled at getting the teacher to give them clues as to what the expected answer is. There is a fine distinction between correcting student misconceptions and "giving the game away". Often what is needed in these situations is reassurance that it is acceptable to be doing something different from the other groups with a particular miniature.

There may be some circumstances in which required to redirect the learners to the formal curriculum. In these cases, in the final whole-class discussion in which the groups compare their findings, the teacher will be able to acknowledge scientific thinking as well as correct solutions.

Obviously intervention is needed if a group is not making any progress. The teacher needs supply of questions that stimulate higher order thinking, and possibly other resources such as different equipment (for example ping pong balls on strings to "discover" Bernoulli's principle).

At the other end of the spectrum if learners solve a problem quickly the teacher needs ideas for further work. It is possible someone might solve the uphill roller puzzle very quickly. If so they could explain it to the rest of the group, and then they could deduce the conditions needed for an uphill roller to work. Depending on the age and ability of the learners this could be descriptive or mathematical.

3.3.6 Feedback and Assessment

Good feedback is one of the key tenets of constructivism. There are five opportunities for feedback in the wider SCeTGo scenario:

1. At the recalling prior knowledge stage, to confirm that learners have the background knowledge and skills they need in order to start the inquiry
2. During the inquiry, as a prompt, to redirect learners if necessary
3. At the end of the enquiry, to comment on the conclusions the learners have drawn
4. At the end of the class, as a class discussion to share results and observations
5. Following further research into the topic

According to Black and Wiliam (1998), research shows very clearly the conditions under which feedback is successful. For example when feedback focuses on what learners need to do to improve, and, in particular, how to go about it, then you get very large impacts on learner achievement. So the challenge for teachers is to take these very broad principles and work out what it means for SCeTGo. Critically important are the dialogues that take place whilst the miniatures are used. This is key to learning.

Some of this feedback can be mediated by paper or digital resources, for example answers to quizzes or videos. However the important role of the teacher is as an observer / guide / feedback-giver and not answer-giver. In the earlier stages the feedback can be in the form of questions, to encourage learners to find their own solutions. Ideally most of the feedback should be face-to-face, but in a busy classroom where several groups of learners are working on different activities this is not always feasible.

If we wish to find out whether learners have made progress in scientific inquiry then the processes are more important than the products of their work. In this case formative assessment involves making the students' thinking visible (Duschl, 2003). This can happen as an ongoing process throughout the class as the teacher observes and intervenes in the experimentation by the learners. There should be a great deal of peer assessment in these classes, as the groups make and test hypotheses collaboratively. Normally this type of assessment is a longer-term process. Progress is noted as learners acquire skills in one situation and then use them in another. If the learners have the opportunity to use more than one of the SCeTGo miniatures, either in one session or a series, then their development as scientific inquirers can be observed.

In the constructivist classroom assessment should be "a tool in service to the learner" rather than an "accountability device" (Brooks & Brooks, 1999). It should credit plausible guesses rather than valuing only "right" answers. Intrinsic motivation is valued over extrinsic drivers.

> *"Discovery and the confidence it provides is the proper reward for learning"* (Bruner, 1961: 124).

However, schools, education bodies and governments generally have a much more behaviourist perspective on assessment. Learning is only considered to have taken place if this can be demonstrated in a measurable way. In the SCeTGo classrooms teachers will have to devise methods of summative assessment whether or not they believe that it will contribute to the overall scientific literacy of the learners. They must endeavour to use techniques that do not discourage the learner from being inquisitive. One way to achieve this is to follow methodologies used in World-Class-Tests (Ridgway & McCusker, 2003) in which learner's predictions of the results of experimental situations are elicited.

It is theoretically possible to give a score to each student based on the results of the group experiment with the miniature, allowing for the individual's contribution to the debate, but in a busy classroom over a relatively short timescale this would not be practical.

Alternatively learners could be asked to prepare a presentation of their work, which could be marked. This could be associated with more inquiry-based learning in the information frame (CILASS, 2008). This is also resonant with the creative aims of SCeTGo.

Formative assessment that is of assistance to the learner is an integral feature of constructivism. Formal summative assessment does not fit easily with this philosophy, which is why we suggest attention to World-Class-Test. It is a challenge for the teachers and the SCeTGo project.

Notwithstanding the test result at the end of a period of instruction using the miniatures, a significant aim of SCeTGo is motivation towards science. This is long term. We would like the visit to the portable science centre to be memorable in the way that Graham & Gammon (1999) are aiming for in their science centre.

3.4 Assessment of the Pedagogical Value

Pedagogical evaluation is regarded as a central activity in SCeTGo. It will be addressed in depth through WP5 – Validation & quality assurance. A validation methodology will be devised and applied firstly in schools (formal educational settings) and later in an informal environment (Heureka science center). A series of validation events, both small scale and large scale, will be organised.

The pedagogical models that are combined in SCeTGO project are: inquiry-based learning, blended learning (i.e. combining formal and informal educational activities) and integration of Augmented Reality with miniature science exhibitions. All of them should inform the evaluation in terms of methodologies and parameters to look at.

It is of capital importance to envision to what extent the technologies involved - Augmented Reality on the miniature science exponents - will enhance the potentialities of learning in the specific locations (i.e. classroom, home or science centers), as well as the engagement of the inquiry strategies. Another key aspect is to what extent the learning experience (which includes the represented by the miniatures phenomena and the lecture organisation in the form of inquiry) fits with the school curriculum. Finally, a key aspect of these pedagogical models is to enhance communication and collaboration skills of the students.

The research process that will be adopted should include both measurements (subjective and objective data) and observations. In the educational aspect there will be a complete evaluation concerning how the tool influences student's learning as well as evaluation of the proposed pedagogical framework in general. The educational value of the proposed learning environment will be evaluated during the repeated cycles of the validation.

The evaluation of the didactic approach could be performed on at least four aspects: evaluation of student's learning, evaluation of the underlying pedagogical framework, ethnographical evaluation and evaluation of the impact of the proposed approach from social and psychological perspective.

1. **Evaluation of the student's learning**. Pedagogical experts in WP5 will undertake the task of the development of methodology and empirical research to investigate processes of learning and knowledge acquisition in the framework of the proposed application.
2. **Evaluation of the pedagogical framework**. A major issue underlying the proposed project is whether the implementation of the emerging technologies (e.g. inquiry with AR) could offer a qualitative upgrade to the everyday teaching at school and university levels. In such a case the introduction of technology would not act 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 teaching practices.
3. **Ethnographic evaluation.** The project will take advantage of different environments (school/university/science center) across Europe and will study the attitudes of students and teachers with different cultures towards the implementation of advanced technologies in education as well as the attitudes between students themselves coming from different countries.
4. **Evaluation of the impact of the introduction of technology from social and psychological perspective.** Central long-term goal of the project is to increase the interest in European society towards science, scientific studies and carear possibilities. Furthermore, the selected pedagogical approach is expected to increase students' consecutive visits to scince museums/centers. The achievent of these goals should be evaluated.

SCeTGo, therefore, needs to observe and analyse the effect of technology on learner actions, activities, intentions and goals as they engage in learning. SCeTGo might also look at the institutional and management issues arising from the implementation of mobile devices within educational settings.

4 Visualise the difference: the SCeTGo approach

The main advantage of the AR, which is one of the basic innovative aspects of SCeTGo is that invisible information about a phenomenon is visualised to the students.

In order to make AR to be of value, the overlay has to be strong in showing the "difference", otherwise we are just contributing to confusion. In fact AR should be amplifying the difference. The pedagogy of AR (which we are pioneering) needs to be clear in delivering the advantage. This advantage comes not just from showing what cannot be seen, but making sure that when the invisible is made visible it adds value and not confusion.

The challenge for the scenario design is:

1) Adding AR should do something that is difficult to do without AR

2) AR is about adding things you cannot see - it may be measurements, vectors/scalars, particles, waves, etc.

3) Teachers should not have to spend more time explaining the AR overlay than they would on the phenomenon itself

4) The AR should be truly explanatory or preferably the AR contributes to an investigation of a phenomenon, which is important for Inquiry-Based Science Education (IBSE).

5) Teachers should not have to tell students what the AR is showing and apologise for where it is confusing. In general, misconceptions could be expected but such misconceptions should not be a result of the AR.

4.1 What can the SCeTGo hope to learn?

People watched many apples fall from trees before gravity was formulated as a hypothesis. Many baths were taken before the Eureka moment. We are seeking new ways to trigger inquiring minds to trigger insight of what is happening in front of our eyes.

Learning with Augmented Reality in this way in school settings is novel. There are many things in the pedagogy which are emergent. There are a set of things to learn about the perception of phenomenon and the visual aid to understanding what is happening. There is another set of things to learn about what makes a good explanation and good use of AR. There are new opportunities for teacher and learner creativity - opportunities to invent new things of doing things - in teaching and learning about phenomena and in teaching and learning the process of scientific inquiry. There are new ways in which learners might express and communicate what they understand about a phenomenon. These are particularly important in an EU funded project in which creativity in learning and the use of IT were foregrounded.

The scale and scope of SCeTGo does not allow for us to make breakthroughs in cognitive science. It will not have the resource to undertake NMR studies of brain patterns when observing AR experiments or undertake analysis of attention focussing by monitoring eye movement. SCeTGo's implementation is not so massive, not its funding cycle long enough so that to gather data on the longitudinal effects on students using AR as part of their explanation repertoire. However we still need to make observation, no matter how informal, of the real differences in the teaching and learning methodologies we are adopting as important pointer for further study and view ourselves as sending out probes rather than providing definitive evidence.

4.2 Learning from Overlays

In four of the five miniatures in the project 4 are explicitly attempting to make the invisible visible as an overlay: Forces, and airflows with the Airplane Wing; the movement of molecules in the Boltzmann constant, the apparent change in frequency and relative change in velocity of sound waves in the Doppler Effect and waves and particles in the Young's Double Slit experiment. With the fifth, the Uphill Roller, we use a different technique. We create an Augmented Reality meter that display the angles, tangents of angles in the apparatus set up and also display the results of putting that data into a formula.

We are presented with a new mixed media formulation. We have a real or simulated set of apparatus which can be physically manipulated. This is in turn represented on a screen by a video camera. Markers within the apparatus are also detected by the camera and from the relative positions of the markers and/or markers which distinguish one piece of apparatus from another. This in turn generates the augmented visual information on the computer screen. In some cases, such as the Doppler effect, we also have an audio component to the augmentation.

We are adding complexity to a situation in the belief that the extra information lead to a better understanding. In the case of inquiry based science education we believe that we are providing significant extra clues that we will help the learner formulate a theory through a scaffold to the observation.

According to the information theory (Bateson, 2000), from the point of view of learning about certain phenomena, the learner should observe change and reflect on it in order to understand what is happening. Bateson defined information as "a difference which makes a difference." (i.e. it is within the difference where the main information for the learner is). The challenge is to design the right and significant differences within the overlay. It is not enough to draw lines to show the air over an aeroplane wing. The lines need to clearly show a difference. The difference really needs to be communicated to the student. Moreover the really important factor is that the student has to recognise the difference and know that the difference is salient. Newton knew this for apples - the rest of the world didn't. This is a significant challenge for the pedagogy of AR.

In the following tables (4-8) we summarize the description and explanation of the five SCeTGo miniatures to be developed.

Table 4: Aeroplane Wing

real world difference[20]	**physics difference**[21]	**SCETGO design**	**SCETGO difference** *These are design considerations in implementation*	**Student perception specific to the AR implementation**
the plane goes up –i.e. flies	*Two explanations (in reality identical - but quite a different narrative)* Air pressure above the wing is less than below the wing producing upthrust. OR There are more air molecules hitting the wing with upward momentum (i.e. below the wing) than air molecules hitting the wing with downward momentum. The difference between upward and downward momentum changes are greater than the force of gravity on the plane.	*What we show depends on the narrative we choose.* We clearly need to show a difference in speed of airflow - and that needs strong exaggeration. This in turn needs to show up either areas of high and low pressure (classical Bernoulli explanation) or show more particles hitting the lower side of the wing than the upper side of the wing in the up thrust direction.	Colour changes with velocity More arrows on lines for faster airflow Shaded pressure areas OR Molecules of air represented as in Boltzmann experiment greater density where airflow is less	The student clearly has to be aware of what it is the overlay is actually showing, etc. and if it is showing a variable (like velocity of airflow) then that has to be emphasised. The same is true for whatever explanation we are aiming for - the difference the student is expected to see needs to be emphasised.

[20] *Real World Difference* is what the everyday observer perceives without asking scientific questions.

[21] *Physics Difference* is the explanation that a good science teacher would use to explain a phenomenon.

Table 5: Uphill Roller

real world difference	physics difference	SCETGO design	SCETGO difference *These are design considerations in implementation*	Student perception specific to the AR implementation
Most examples of things put on the roller apparatus appear to roll downhill, However due to a combination of 3 types of slope, under some conditions a double cone configuration appears to roll uphill	There are three variables the angle of the slope to the horizontal (α) the angle of the spread of the track (β) the angle of the cone (γ) The cone will appear to roll uphill if: $tan\ (\alpha) < tan(\beta)\ tan\ (\gamma)$	We commence with the track, a ball, a cylinder and some cones. Only when the cone is introduced do we see the phenomena. We expect students to deduce the fact there are three variables. After initial investigation with the other shapes we focus only on the cones. Students get the opportunity to vary(α),(β) and (γ) We expect the students to deduce the three variables. The second elements of learning design is that we want students to understand the optimisation of $tan\ (\alpha) < tan(\beta)\ tan\ (\gamma)$	We will allow stepped variation of the angles with our apparatus. We could use an overlay to plot the trajectory of the CG. Because we expect students to deduce the three variables we would not want to display “clues” before hand. At the proposed level of implementation we are not expecting derivation of the formula $tan\ (\alpha) < tan(\beta)\ tan\ (\gamma)$ At some point the following would be and overlay: angles (α) (β) and (γ) $tan\ (\alpha)$, $tan(\beta)$, and $tan\ (\gamma)$ and the formula with substitution $tan\ (\alpha) < tan(\beta)\ tan\ (\gamma)$	There is limited AR in this miniature- principally we have the items previously mentioned on screen. The formula, etc. will change based on real world changes.

Table 6: Boltzmann constant

real world difference	physics difference	SCETGO design	SCETGO difference *These are design considerations in implementation*	Student perception specific to the AR implementation
Hot and cold are subjective appreciation of temperature. We experience the air as having different temperatures	Temperature of a gas is a function of the kinetic energy of the gas molecules. The higher the velocity of the molecule the higher the temperature. This energy is a function of the square of the velocity. $pV = NkT$	We make visible a fixed number of molecules in a specific volume. We measure temperature in three environments. The velocity of the molecules changes in the three environments. This is reflected on the on-screen temperature and velocity meters. OR we keep p constant and change N	Perceiving the changes in velocity is crucial. This might be better achieved by having a countable number of molecules. Or if changing the value of N - holding the p and V constant - making sure students appreciate the control of variables.	There is limited AR in this miniature - principally we have the items previously mentioned on screen. The formula, etc. will change based on real world changes. Changes can be highlighted as they happen.

Table 7: Young's Double Slit

real world difference	physics difference	SCETGO design	SCETGO difference *These are design considerations in implementation*	Student perception specific to the AR implementation
When light (or any electromagnetic source) or an electron source is projected onto a screen through double slits an interference pattern is detected on a detection screen. This phenomenon seems to hold when describing light or electrons as waves - emulating what is observed when water or sound waves are subjected to a similar set up. However it obviously holds true even if we believe light or electrons to be particles. Except, if we have a detector to detect particles, the phenomenon does not occur – i.e. once we decide that radiation or electrons behave as particles and detect them as such the phenomenon is not observed.	The phenomenon is described by the equation: $\frac{n\lambda}{d} = \frac{x}{L} \quad \Leftrightarrow \quad n\lambda = \frac{xd}{L}$ where λ is the wavelength of the light, d is the separation of the slits, the distance between A and B in the diagram to the right n is the order of maximum observed (central maximum is n = 0), x is the distance between the bands of light and the central maximum (also called fringe distance), and L is the distance from the slits to the screen centre point.	We provide two electron and a light sources - particles and waves, three sets of slights of differing separation, and a screen for detecting the interference pattern We allow two types of overlay Waves - like water waves and particles These will provide two different kinds of animation overlays. The overlay's result will vary dependent of the spacing of the slits used. This will change the interference pattern	As Waves, the overlay will replicate wave tanks and wave tank interference patterns As particles, discreet blobs are fired at the slits. These will build up interference patterns with distribution of "blob hits"	The main limitation in perception is that ripples/waves are normally viewed from above. To observe the particle behaviour we would need to view from a different angle. The animation of particles - we have to give an idea of time lapse - we would expect a continuous show of the interference phenomena (as happens in real life) and maybe show the pattern as it builds up

Table 8: Doppler Effect

real world difference	physics difference	SCETGO design	SCETGO difference *These are design considerations in implementation*	Student perception specific to the AR implementation
As a fire engine approaches the pitch of the note of the siren seems higher than it would be for a static vehicle. As it moves away it gets less. This is compounded by changes in volume one might expect. However the change in note is perceived as the vehicle passes. It is equally important that the phenomenon is also considered in “frame of reference” terms. A moving observer and a static sound source would note the same phenomenon. In the real world - but not experienced by people or observable in a school or museum sense- are shifts in the light spectrum in large astronomical objects within an expanding universe.	The perception of wave phenomena are governed by three factors, the velocity of the wave, the frequency and the wave length. The velocity is relative between the source and the observer. Therefore the perception of the frequency of a wave will change dependent on the velocity of the source and the observer. If the observer is stationary and the source is moving towards the observer there will be an apparent increase in frequency of the wave, if the source is moving away there will be an apparent decrease in frequency. With sound this appears to be a change in pitch; in light - at astronomical speeds, this appears as a change in colour.	We have a model fire engine as the source of waves and a model observer/listener. When the source is stationary, a sound of constant pitch is generated. As the source and observer move the perceived frequency will change. This will be a change relative to movements of source or observer. Sound waves are represented by concentric circles of moving wave fronts in the overlay. One thing to consider is whether the volume (amplitude) should change as well. If the astronomical Doppler shift is also included there should be some options to change colours.	There are two and possibly three significant differences with the sound wave experiment - changes in pitch, the change in the shapes of the patterns and colours of the propagation of sound changing the apparent wave propagation in the direction of travel. We might consider changing the volume. The change in the shapes representing wave propagation and speed will show a difference - so that the speed of waves traveling towards or away from the observer (relative) represented as concentric circles/elipses seem to be closer (indicating that they are moving slower) or further (indicating they are moving faster) apart.	The crucial understanding comes from knowing the way we are representing the propagation and speed of sound waves, i.e. the slower sound waves are moving the closer they are. The important difference for the student to observe is simultaneously realising that the change in frequency of the sound source and the asymmetric propagation of the sound “circles”.

5 Conclusions

This report presents SCeTGo pedagogical framework. The project combines Augmented Reality and miniature science exhibits with an inquiry based teaching approaches. The goal is to increase interest of pupils to experimental science in general within and outside the classroom. The approach chosen is to combine the formal classroom activities with more informal approach, presented in science centers. The approach will possibly further increase pupils interest in participation in extra scholar activities related to science, such as visit of science centers or interactive museums.

The pedagogical framework presented in this document is a bases for the creation of the concrete SCeTGo scenarios, which will be implemented in several educational settings, including secondary schools, universities and a science center. The scenarios will follow the steps described in this document and also consult the issues, factors and constrained listed.

List of Abbreviations

AR	Augmented Reality
HCI	Human Computer Interaction
IBSE	Inquiry Based Science Education
IT	Information Techology
ICT	Information and Communication Technology
SC(s)	Science Center(s)
SCeTGo	Science Center To Go

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