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Lab of Tomorrow

GUIDE OF GOOD PRACTICE



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www.laboftomorrow.org

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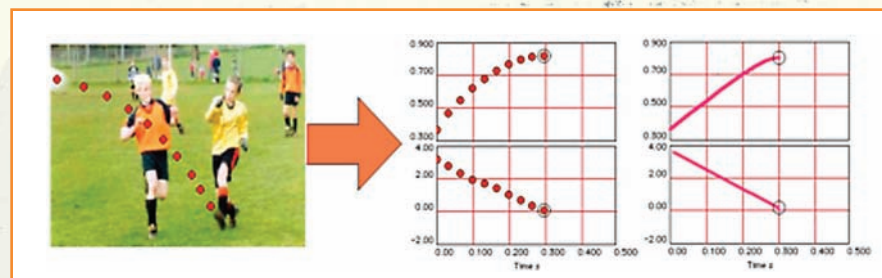
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Our vision for the school of tomorrow is that it will not be an island, a self-contained campus, a counterworld. The school of tomorrow will be able to emit and absorb along different wavelengths, be immersed in contemporary culture, be open to the emotions, facts and news of its time. It will be permeated by society, but not unprotected: the relationship between school and society will be one of osmosis, where the proposed pedagogical framework filters, guides, and acts as a membrane and interface.

The Lab of Tomorrow partnership, 2000







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For the User

The aim of the Lab of Tomorrow guide of good practice is to support the users, mainly teachers, to effectively use the Lab of Tomorrow (LOT) systems in their teaching and learning practices. The guide provides support on how to use these systems within the framework of the normal school curriculum. Moreover, by reading this guide one can find very valuable hints on how to utilise Lab of Tomorrow, not only in science teaching but in gymnastics or in investigating every day activities in a more scientific manner. Thus the aim of this document is to help, both teachers and students, to reach teaching and learning fields in which they can make the most valuable contributions, and potentially improve the way of teaching and learning respectively. To assure maximal usability of the new tools, optimal adaptation to the local environments and realistic evaluation of the pedagogical effects, the Lab of Tomorrow proposes the adaptation of a student-centered approach. Lab of Tomorrow as a project included three extended periods of school-centered work. These trials involved teachers and students to giving direction to the project and its technological and pedagogical results. This guide summarises also, aspects of the evaluation results of the pilot implementation of the project that provide useful information for the users.

During implementation, users are advised to experiment with the LOT axions, embedded in objects (toys, clothes) in their everyday activities and measure a series of quantities like acceleration, forces, temperature etc. Almost all physical phenomena and fundamental laws of Mechanics as well as aspects of in disciplines like Chemistry

and Biology can be studied using the data acquired by the LOT systems. The open architecture of the axions and the user-interface allow the adoption of the new ideas in short time. The LOT partnership believes that have the opportunity to view their involvement with Lab of Tomorrow as a craft that rewards dedication and precision but simultaneously encourages a spirit of creativity, exuberance, humour, stylishness and personal expression. The Lab of Tomorrow user is familiarised with the scientific method, design and conduction of scientific experiments, collection and display data, as well as reporting of results. Students in particular, are given examples of how scientific method can be used to solve real world problems.

Following the echo from IST'99 session "Children shaping the future" and the hope that the passionate debate about children and how their voices can bring freshness and new meaning in the development of a better IT world, with Lab of Tomorrow, students and teachers come together with researchers, psychologists, designers and technologists to re-engineer the lab of the school of tomorrow. This is achieved with the introduction of a new learning scheme based on the production of computational tools and educational material that allow high school students to design their own scientific projects.

The document consists of four main chapters which include all the necessary information successful implementation of Lab of Tomorrow both in a secondary education class as well as in real life situations by individual users. The first chapter is describing the basic aspects of the pedagogical approach of the project and the basic concepts that govern the design of the Lab of Tomorrow lesson plans. The second chapter describes the functionalities of the Lot tools in detail. It includes specific guidelines for their use and technical maintenance. In addition it focuses on the Lab of Tomorrow User Interface and its capabilities not only for the demonstration of the collected data but also as a pedagogical tool. The third chapter presents paradigms of good Lab of Tomorrow practice that are based on the pilot implementation of the project in five different schools in Austria, Germany, Greece and Italy during the school period 2003-2004. These good practice paradigms mainly aim to support teachers during the implementation of LOT in their classes and should be conceived as recommendations to teachers in order to get familiarized with the use of axions and discover their functionalities. The fourth chapter describes the evaluation methodology of the project and includes specific evaluation data referring to the project's pilot implementation. In addition this document includes appendices that the user can be considered as a quick guide to the use of the systems and supporting material. All these documents are necessary not only for the smooth implementation of Lab of Tomorrow but also for own evaluation purposes in order to make direct, informal comparison between the proposed approach and the traditional approach in Science teaching.

This document, in parallel with the already published issue of the Lesson Plans, the Teachers Workshop Proceedings and the on-line training material, published on the project's web site (www.laboftomorrow.org) aims to provide help and support to the teachers of the Lab of Tomorrow.



Introduction

*[Science, whatever be its ultimate developments,
has its origin in techniques, in arts and crafts...
Science arises in contact with things, it is dependent
on the evidence of the senses, and however far it seems
to move from them, must always come back to them.]*

B. Farrington, *Greek Science*, 1949

There is sufficient evidence to suggest that both the persistence and the quality of learning are highly enhanced when the student is actively participating in the learning process. This is the essential and widely accepted message of “constructionism” (Papert, 1994 & Resnick, 1993). Juxtaposing this ideal with the current reality of organized learning in school environments creates the impression that the school is not connected at the desirable degree with daily life experiences.

One particular and most striking example is science teaching. Throughout history science has advanced through observation, inspection, formulation of hypotheses, testing of the hypotheses by means of experiments and collection of data, rejection or acceptance of the hypotheses, formulation of topics for further research. It seems that in schools this process of acquisition of scientific knowledge gets reversed. Science is presented as a coherent body of knowledge, the experiment is the illustration of the phenomenon, and the questions are answered

even before they are asked. The result is that the student acquires short-term knowledge targeted at standardized test questions, and in many instances this “forced and inefficient” learning lacks on long term sustainability. Possible pragmatic remedies have been proposed. Regarding to (Glaserfeld, 1995) the constructivist point of view has been very fruitful to develop science instruction. In this model knowledge acquisition is only a matter of individual mental activities. But, constructionism (Duit, 1995) in its pure, so-called “radical” version is also discussed controversially. The instructional component is missing in the model and therefore it is very difficult to derive investigation methods and codings which are able to represent the instructional influence upon learning processes. Thus, since the early 90s a pragmatic interim position was discussed, named by (Merrill, 1991) as “instructional design of the second generation”. It is seen as integration of constructionism and cognitive theory. It accepts learning as a process of individual cognitive construction and states the dependence of this process on adequate learning environments (Weidenmann, 1993, Derry, 1996). Even models of situated learning (Mandl et al., 1997, Roth, 1995) can be seen as a combination of these two approaches, taking into account the learning situation and motivating and communicative aspects, which is an obvious weakness of radical constructionism. As it turns out the main link missing in the learning process is that students do not learn sufficiently through experience but through a systemic model based approach, which should be the culmination of learning efforts and not the initiation. A particularly disturbing phenomenon that is common knowledge among educators is that students fail to see the interconnections between closely linked phenomena in e.g. biology and chemistry, or fail to understand the links of their knowledge to everyday applications. In most cases the physical quantities have become abstract for the students and the experimental set-ups alien or distant to every day experience.

Students are early faced with two separate fields: “school science” and every day life’s “rules and principles”. Such separation commonly leads to the formation of misconcepts (Nachtigal, 1991). “School science” explains adequately “school science lab phenomena” while preconceptual or misconceptual reasoning explains daily phenomena. Various approaches try to bridge these two fields (Nachtigal, 1992). They converge in the wide usage of every day materials and means in the classroom, something relatively easy in primary school level. In higher levels this becomes less effective since the phenomena and the concepts under study (like acceleration, momentum transfer or energy conservation) are more abstract. In such cases technology is providing some help with the supply of educational scientific instruments and software. Both the power and the problem with modern scientific instruments used in the school laboratories are reflected in the term “black box” that is commonly used to describe the equipment. Today’s black-box instruments are highly effective in allowing students to make measurements and collect data - enabling even novices to perform advanced scientific experiments based in most of the cases on advanced simulations. But at the same time, these black boxes are “opaque” as their inner workings are often hidden and thus poorly understood by the users. Furthermore they are bland in appearance making it difficult for students to feel a sense of personal connection with scientific activity. “To many students a lab means manipulating equipment and not manipulating ideas” (Lunetta, 1998).



Electronics and computational technologies have accelerated this trend, filling science laboratories and classrooms with ever more opaque black boxes. Paradoxically, the same electronics technologies that have contributed to the black-boxing of science can also be used to reintroduce a vigorously creative and aesthetic dimension into the design of scientific instrumentation - particularly in the context of science education.

The Lab of Tomorrow project introduces innovation both in pedagogy and technology. It aims at developing tools that will allow for as many links of teaching of natural sciences as possible with every day life. It will allow the student to link i.e. physics with “physis” (Greek word for nature), biology with “bios” (Greek word for life) and so on. The Lab of Tomorrow project is developing a new learning scheme by introducing a technologically advanced approach for teaching science through every day activities. Science deals with the study of nature and the world around us, so teaching science cannot be separated from daily experiences resulting from student’s interaction with the physical phenomena. The connection of tangible phenomena and problems provides students with the ability to apply science everywhere and not only in specially designed experiments under the laboratory’s controlled conditions (Nachtigal, 1992).

In the Lab of Tomorrow project the re-engineering of the school lab of tomorrow is proposed by developing a new learning scheme based on the production of computational tools and project materials that allow high school students to use their every day life environment as the field where they will conduct sophisticated experiments experiencing the applicability of the theoretical background given at school. The partnership proceeded to the development of a wearable technology, a series of “artefacts”, called axions, that allow students to derive experimental results drawn from their everyday activities and which, in many cases, involve data collection over extended periods of time. The axions embedded in every day objects (for example an accelerometer embedded inside a ball) or in clothes (for example a heart pulse meter embedded in a T-shirt) are used in order to collect data during students’ activities. Important factors of their design are ergonomics and economy, so they will not stay on a test bench nor used by a small number of users. The data collected by the axions¹ are presented with the use of advanced programming tools compatible with graphing and analysis software components so that students can easily investigate trends and patterns and correlate them with the theory taught at school.

The Lab of Tomorrow project adopts an activity-based design methodology. It has been recently questioned (Barber et al., 1999) whether the contemporary approach to the design of computer applications can be sustained for future technologies. Norman suggests that a primary reason why the desktop metaphor remains in vogue is that it allows designers and manufacturers to strive for the production of multipurpose products, i.e., products

¹ The partnership has chosen this specific name for two reasons. In physics axion is a hypothetical elementary particle. Even though the axion -- if it exists -- should have only a tiny mass, axions would have been produced abundantly in the Big Bang, and relic axions are an excellent candidate for the dark matter in the universe. The second reason is the word game between axion and action.

and applications that can be used for any job in any office. This seems to take good business sense, with most people finding most of the functions useful. Nevertheless, it also leads to claims that the majority of the functions offered will not be used by the majority of users (Norman, 1998).

Norman's proposal is that future computers will offer restricted function sets, and that people will select the function set most appropriate to their defined requirements. He calls this "activity-based computing" since computers will be designed to support specific activities. This would mean that the wearer would have less equipment to operate and carry, and it could also mean that interaction with the computer could be performed via familiar objects and products.

In Lab of Tomorrow it is believed that activity-based computing extends the basic assumptions of user-centered design and requirements engineering, because it allows considering the architecture that might be appropriate for a specific wearable product. The approach, which has been adopted in the framework of the project, is to use scenario-based design methods as a means of defining suitable applications of wearable technology.



Chapter 1

The Pedagogical Approach of Lab of Tomorrow project

Usually pre-designed experiments are used in science teaching. In the framework of the Lab of Tomorrow project students will be able to use the axions and the wearables to set up their own experiments, which they will conduct autonomously. In this way the procedure of scientific inquiry is fully simulated: formulation of hypothesis, experiment design, selection of axions, implementation, verification or rejection of hypothesis, evaluation and generalisation are the steps that will allow for a deeper understanding of the science concepts.

The partnership believes that the proposed approach will act as a qualitative upgrade to everyday teaching for several reasons:

Motivation: Students are more likely to feel a sense of personal investment in a scientific investigation as they will actively participate in the research procedure and will add their own aesthetic touches to their intelligent toys and cloths.

Extending the experimentation possibilities: The axions can serve as spurs to the imagination, promoting students to see all sorts of daily activities as possible subjects of scientific investigation. The proposed procedure will be freed from the pressing time limitation of the teaching hour.

Developing critical capacity: Too often students accept the readings of scientific instruments without question. When students will get involved in the proposed activities for example by measuring their physical parameters as they are playing, they should as a result develop a healthy scepticism about the readings and a more subtle understanding of the nature of the scientific information and knowledge.

Making connections to underlying concepts: In the framework of the project's application to the school communities, students will be asked to design their own projects. During this procedure students will figure out what things to measure and how to measure them. In the process they will develop a deeper understanding of the scientific concepts underlying the investigation. If students use a wearable thermometer, for example, they naturally encounter (and make use of) the concepts of thermal conductivity and heat capacity.

Understanding the relationship between science and technology: Students participating to the project will gain firsthand experience in the ways that technology design can both serve and inspire scientific investigation.



1.1 Concepts

The pedagogical concept of the project has to represent two corresponding features: The first refers to the general education aims of our modern societies and the results of recent research in science education, the second has to take into account the specific conditions of the project like requirements of the national curricula and the specific background of the schools involved. The partnership proposes the following two concepts that match these requirements of Lab of Tomorrow as a modern and trend-setting European project:

- The PISA concept of scientific literacy
- The theory of basic concepts on teaching and learning

Reasoning

General discussions in science, society and politics about scientific literacy agree that it must be based on the development of a general understanding of essential “key concepts” of physics. These concepts should enable the students to recognize scientific questions and to realize scientific processes. They allow an autonomous reasoning and a communicative interaction in the field of physics. Accordingly, these considerations have to be transformed to sequences of teaching and learning physics. We have to take into account the results of the international large scale assessments TIMSS (Baumert et al., 1997), PISA of the last five years which indicate that subject oriented planning and performing of physics lessons is not as successful as expected.

The theory of “basic concepts about learning” of Oser & Patry (1990) and Fischer & Reyer (2002) can be used to plan teaching and learning processes at school. This theory has two decisive advantages: it allows a reasonable planning of teaching and it is not strictly subject oriented but focussed on enabling subject related learning processes. For example the usually applied subject related teaching aim “Newton’s laws” is transformed into “problem solving (using Newton’s laws as an example)”, “theory development (using friction as an example)” or “training to use force concepts to enable routines”.

1.2 Scientific Literacy

“(...) the ability to recognize scientific questions and to draw scientific conclusions in order to understand decisions and to take decisions according to the world and to changes of the world, based on human activity.”

OECD/PISA scientific literacy 2000

The scientific literacy is clearly more than the knowledge of facts and terms. It contains an understanding of basic concepts and requires a decontextualized, global applicability. Tasks in the frame of scientific thinking have to take into account the following levels of scientific reasoning:

- Applying scientific concepts
- Organizing scientific processes
- Communicating scientific contents

Consequently, these three levels are part of the pedagogical frameworks of the Lab of Tomorrow project. To design a task- and learning process-orientated structure of the lesson plans the range of the sequences planned has to ensure that scientific knowledge in its different complexities is used in as well versatile meaningful contexts as possible.

Scientific Concepts

Concepts are so far recognized experiences, which can be summarized in a category. They enable a connection of new with already made experiences to construct a meaningful activity in the field of physics. Scientific concepts are formulated in many different ways, from general terms until detailed lists of features. For the Lab of Tomorrow project, concepts should satisfy the following requirements:

- Importance of the concepts and contents for everyday life
- Significance to prove scientific literacy
- Enabling student's communication about physics



As a situation close to reality, OECD/PISA 2000 puts forward situations containing problems related to individuals, members of the society or citizens of the world. In addition, historical information can be integrated in order to gain an understanding of progress of scientific knowledge.

Scientific Processes

Scientific processes are predominantly mental actions like the interpretation or the assessment of data to organize mental, manipulative and/or social activities. Thus, they are always related to a specific content.

Based on the notion of scientific literacy, five processes can be identified:

- Solving tasks
- Identifying scientific evidences
- Concluding from or judging scientific topics
- Organizing group communication
- Organizing scientific working (experimental and theoretical)

1.3 Theory of Basic Concepts

The theory of Basic Concepts of teaching and learning is based on the “Choreography of classroom learning” (Oser & P atry 1990). This project examines three criteria that characterize successful teaching. These are the “atmosphere” during the lessons, the “content structures” and the “chronological order of the lessons”, build up by a sequence of teaching methods, instructional tasks and learning offers. The last aspect is the cornerstone of Oser’s theory of Basic Concepts of teaching.

Deep structure and apparent structure

Teaching and learning is guided by rules, which are not necessarily evident for the teacher or the learner. Sometimes they are too complex to be easily expressed, or they are not explicitly known by the teacher.

However, by an observer a single lesson can be judged as “wrong” or “right”, or decisions in different situations are more or less suitable for achieving a teaching aim. But the teacher mostly cannot say explicitly why a decision was right or wrong - he/she acts intuitive. This intuition can be expression of a guiding concept if it is consciously based upon a theory and the related activities are routines of pedagogical behaviour.

Consequently, in order to describe lessons in different levels, should be established a disting between a surface structure and a deep structure. The surface structure describes the observable activities and interactions of a lesson. For instance, the instructions of the teacher, the teaching methods or the behaviour of the students are elements of a surface structure. The deep structure contains concepts, theories and beliefs of the teacher concerning teaching and learning in general, but also his/her own way of teaching and his/her beliefs about the learning processes of his/her actual students in the classroom. The teachers concepts and beliefs can be expressed as a great variety of possible surface structures. According to Oser, these combinations can be systematically described by the following Basic Concepts of teaching relevant to students:



The basic Concepts of teaching

Learning by experiences	Deductive-inductive linkage
Search processes	Automatism
Transformation	Expressive affect-transformation
Problem solving	Exchange of social behaviour
Learning of facts	Identity development
Concept learning	Learning by consensus
Mediation	Meta-learning

These models of teaching make the hypotheses of different learning methods into account. They are independent of the teaching content. Each content model is based on a section of the deep structure. This part is called Basic Concept and contains all rules and theories that are necessary for this particular teaching model.

Operation sequences and apparent structure

According to Oser the achievement of a teaching aim is determined by a chronological sequence of different operations related to the planned learning processes. These operations are located on a level between the apparent structure and the deep structure. Related to the intended teaching aim, each Basic Concept is consequently justified by an operation sequence as the smallest unit of “time structure” and “methodical structure”.

For designing lessons with this model, the teacher can use different kinds of actions in the apparent structure to realize a unit in the operation sequence. Figure 1.1 illustrates this aspect: Each education aim is respectively based on a Basic Concept, and this Basic Concept can be operationalized by an operation sequence. The three examples express operation sequences, which are consisting of five steps. Each teaching sequence can be realized in different ways, for instance symbolized like a)-c). The single steps of an operation sequence can although be realized in many ways, expressed by the different symbols. For instance, a teacher choosing teaching sequence (a) realizes step one by giving his students a text and ask questions.

Another teacher although chooses this educational aim but realizes the first step by designing an experiment together with his/her students, and they work in small groups on this experiment or further tasks, a third teacher uses interviews in a shopping centre to organize the learning process. There are many possibilities for the apparent structure, and they are all based on the same operation sequence.

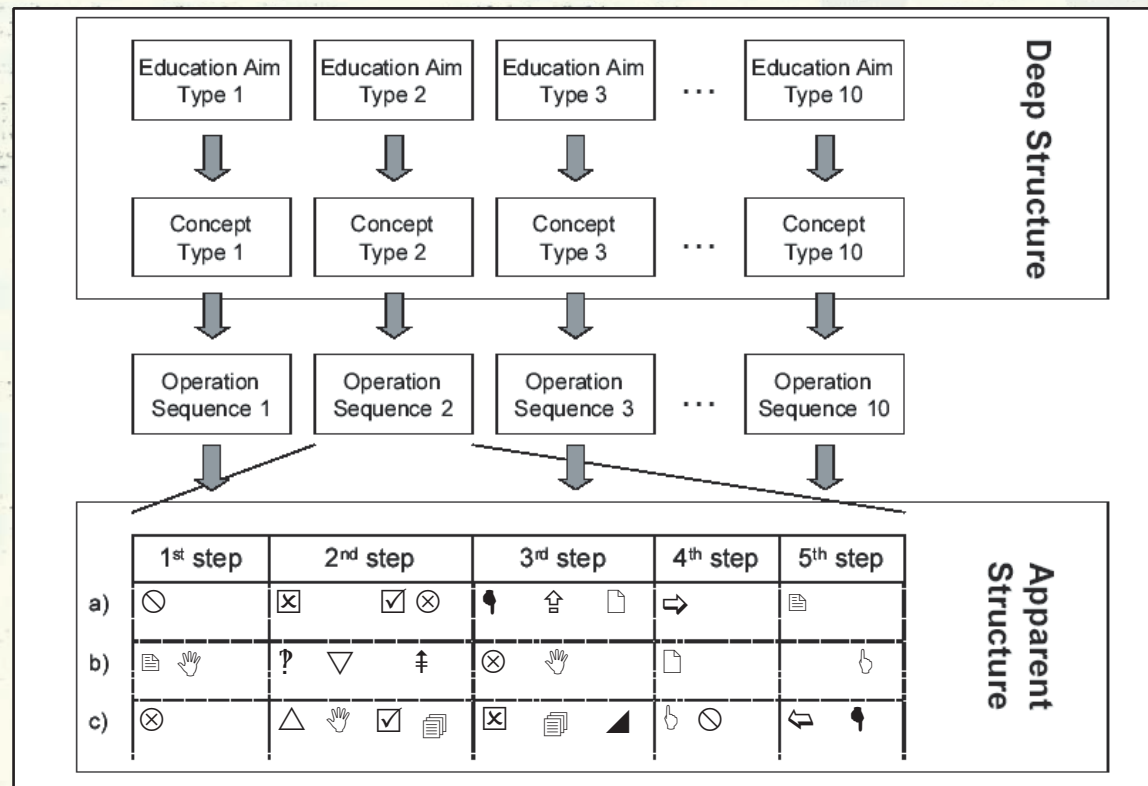


Figure 1.1: Deep Structure and Apparent Structure, linked by Operation sequences.

Design of lessons

The operation sequences are suitable to explain the activities of the students. Planning a lesson by means of Basic Concepts offers the possibility to concentrate on an intended learning process. The method fits with the cognitive background of the students and allows for a more efficient way of teaching (Brouer 2001). The following list describes the design of a lesson based on the theory of basic models. Starting with an edu-



cational aim is different from conventional lesson planning starting with a content and, hopefully, looking for an educational aim related to this content.

1. Determination of the educational aim
2. Classification of the basic model
3. Classification of the operational sequence
4. Methodological design of the lesson

The educational objective is closely related to the subject matter, but starting with an educational aim is a new way of organizing teaching and learning.

1.4 Summary of the Basic Concepts, examples of necessary features and a possible surface structure

The theory of Oser proposes 14 Basic Concepts, based on approaches concerning a non-science research field. As a result of reviewing these models for their suitability in research on science teaching and learning the following models remain

Basic Concept	Necessary features	Example of a surface structure
Learning by own experiences	Everyday activity, integration of scientific knowledge in every day knowledge	“rediscover” of everyday phenomena
Structure transforming learning / developing fostering learning	Processes of de-equilibration, new construction instead of adapting knowledge	Dilemma discussions like wave-particle dualism, misconceptions like energy consumption
Problem solving	Problem solving with an information value	Determination of a new value like angular momentum or electrical resistance, construction of a physical relation like Hook’s law
Theoretical knowledge/knowledge of theory	Isolated aspects, abstraction, analogies, limitations	Elaboration of relations like $F=ma$ or the decay law, perception of causalities like thermal conductivity
Contemplate learning, meditation	Internal recapitulation of ontological, fateful, religious, realities, ...	To be astonished about selected physical phenomena like astronomical distances or nuclear physics
Routine, skill training	Repetition and training, relieving of consciousness	Learning of practical methods like the use of an oscilloscope, presentation of data or the use of mathematical calculations
Motility	Creative elaboration of events, expressions related to the fine arts	Creative presentation of phenomena or results, e.g. as wall papers of project results, artistic play with phenomena or conjuring tricks
Dynamical social relationships	Pro-social acting, acting/living in groups, development of friendships	Cooperative learning, group work like distribution of tasks during an experiment or mutual learning support
Development of values and identities	Value constitution by participation, main method: scientific literacy	Discussion of relevant topic for the society like pro and contra “nuclear energy”
Over all view - learning	To judge and select information, surveys	Judgement and arrangement of physical aspects of everyday activities with the help of papers, articles, internet, literature, ...



Basic Concept 1: Learning by own experiences

In a learning process at school the students should integrate their own experiences in already existing knowledge.

These experiences are always connected to actions. According to Piaget (1977) the objectives of learning by own an experience is an assimilation of new knowledge.

Operation sequence:

1. Internal, contextual representation of acting (preparation, design ...)
2. Contextual acting (doing an experiment, categorizing, searching ...)
3. First critical reflection of the acting pathway, the aim of acting and the intention of action
4. Generalisation of the results of the reflexion process
5. Transfer of the learning consequences onto larger contents, start of a symbolic representation

Main characteristics of this basic model are the everyday conceptions as starting points and implementation of this prior knowledge into the learning process.

Basic Concept 2: Structure transforming learning / developing fostering learning

This model is based on the ideas of the conceptual change approaches. The recognition of new knowledge elements that cannot be fit into already existing structures generates a cognitive conflict. Piaget (1977) calls this process of integration of new concepts accommodation. Oser (1990) describes this model for learning as an element to judge in moral situations. For teaching science, it can easily be modified for learning scientific contents.

Operation Sequence:

1. Rattling of the learner in his way of thinking and de-equilibration of existing structures (concerning social and/or moral and/or political values)
2. Disintegrate existing knowledge structures and recognition of important new elements, discussing advantages and disadvantages of different suggestions, seeing different ways of reasoning

3. Integration of the new elements, change of values and relationships, as a consequence transformation of the structure or dismantling of old elements
4. Testing and securing the new structure by transferring to new contents

Basic Concept 3: Problem solving

In contrast to the general understanding of problem solving in science education research model problem solving is not understood as a meta-competence, but related to the way of recognizing new elements as necessary and to integrate them into the knowledge. It is only possible to focus on content orientated problems, if the students have an adequate repertoire of problem solving strategies - and are able to use them.

Accordingly, problem solving as a methodological competence can only be learned in meaningful, “real” contents.

Operation Sequence:

1. Students discover a problem that is important to them «here and now”. It must originate from their experiences.

As an alternative the teacher could present a problem, related to their experiences and interests that emphasise a discrepancy between expectations and experience (Problem stimulation).

2. The students describe a problem based on this stimulation that consists of the conditions at the beginning and an aspired solution. The “tools” (strategy of solving the problem) are unknown (problem description, as accurate as possible).
3. Students suggest strategies of solving the problem (also suggestions that are judged by the teacher as not successful).
4. Proving the suitability of the suggested strategies for a successful problem solving with the given starting conditions (testing the ways of problems solving, selection). If there is no satisfying possibility to solve the problem, then start again with step 3.
5. Use of the strategy for new problems of the similar categories and analysis of the possibilities for transfer or generalisation of the strategy.



Basic Concept 4: Theoretical knowledge/knowledge of theory

This model is based on the assumption that knowledge is built up on a network of related concepts and can be represented with propositional maps. This basic model is a combination of two Oser-models, generation of terms and generation of concepts. Both are determined by very similar operation sequences, so consequently both models are combined to the model of theoretical knowledge.

Operation sequence:

1. Become directly or indirectly aware of already existing, and for the lesson necessary, theoretical knowledge
2. Presentation and elaboration of a prototypical example, which consists of all essential elements and features of the learning concept
3. Explication: elaboration of the essential features and principles of the concept
4. Elaboration: active usage of the new concept (use, analysis, synthesis), compare/ relate/mark off with already known concepts and examples on different representation levels
5. Linkage: connecting of new concepts with already existing ones

Basic Concept 5: Contemplate learning, meditation

Learning by mental lapsing with an objective of an internal recapitulation of ontological, fateful or religious realities is rather emotional than cognitive. It is not based on a de-equilibration of knowledge or a conceptual change like most of the other learning strategies. And it seems not to be suitable for science teaching. But nevertheless, to discover aspects of science as astonishing, offers possibilities and change the point of view on effective teaching and learning also in science. Contemplate learning can be the beginning of a learning process, as great researchers in history start their discoveries by astonishment and enthusiasm.

Operation sequence:

1. Create an internal void, leave the will, be ready for a way
2. To touch, to hear, etc. The external structure of a phenomenon, a work of art (flower, music, picture...)
3. First spontaneous interpretation of the recognized semantic

4. Second interpretation of the recognized semantic, but now transcendently, religiously or aesthetically
5. Integration in life context

Basic Concept 6: Routine, skill training

The objective for becoming routine is the development of an automatism for complex cognitive tasks. The operation sequence of this model fosters a mechanism of expectation-action-correction and matches with results of cognitive psychology.

Operation Sequence:

1. First attempt of single action steps and presentation/elaboration of the linkage of means and aims (What is the aim of the action?)
2. Creation of the complete actions by determination of the action range and regularities; analysing the meaning of single elements and relations
3. Repetition of action steps, combination of action steps or complete actions and checking and control with correction.
4. Complete evaluation of single steps. Repetition of operation 3 and 4 until automatism.
5. Discrimination of situations of application and training of discrimination

Basic Concept 7: Motility

Motility is fostering and grounding on an expressive transformation of affective states of excitements. Like contemplative learning, this model might not seem suitable for science teaching and learning. Nevertheless, also motility enriches the possibilities of different teaching methods.

Operation Sequence:

1. Explanation of ways to reach “motility”
2. Creation of anxious expectation: presentation of an object or phenomena which is suitable for creating an anxious expectation



3. Cognitive restructuring of accumulated energy and inducing of a “creative” break
4. Creative transformation of this energy
5. Strengthening and transferring of these experiences by comparison with results of strange transfer processes

Basic Concept 8: Dynamical social relationships

The operation sequence maintains a reflection of spontaneous actions in social contexts. The sequence can be combined with other learning methods for fruitful outcomes, for example experimental laboratory work.

This implies that the following operation sequences must initiate another basic model or its operation sequence, respectively, for a “methodological situated” construction of dynamical social relationships.

Operation Sequence:

1. Holistic recognition, presentation and evaluation of social skills
2. Build up conditions for testing these skills and their suitable application
3. Reflection of these skills and explanation, legitimating or criticism of them
4. Behaviour exchange with different persons for a generalisation of the skills

Basic Concept 9: Development of values and identities

The operational sequences of this model are aimed at a classification of actions in an ethical way. Science education refers to the identity of a researcher and to his/her responsibility for an honest interpretation of the data and for the society.

Operation Sequence:

1. Analysing already existing values (rules) concerning a current problem. Building a hierarchical structure of rules for a discursive discussion
2. Suggestions for an integration of new rules

3. Participation in decision-making for the integration of the new rule in already existing ones
4. Realization of the new rule by single persons, by the society or by bodies

Basic Concept 10: Over all view - learning

The objective of this model is not to learn details or to identify gaps in the knowledge structure, but to recognize and outline a topic “top down”. An “over all view - learning” needs a longer period of time, consisting of several learning processes that are framed by this way of learning. This matter is obviously described in step 3 and 6 of the operation sequence.

Operation Sequence:

1. Selection of a topic
2. Over all view of the resources
3. Decision of the learning method
4. Selection of a guided or unguided way of learning
5. Feed back orientated doing of a task, reading...
6. Evaluation



1.5 Pedagogical framework

The described concepts of “Scientific Literacy” and “Basic Concept theory” are both necessary for a holistic strategy to plan lessons in the context of the Lab of Tomorrow project. While scientific literacy generates the general frame for the project, the Basic Concept theory generates the “tools” for a successful implementation of the project’s objectives as outlined in the following Table:

Table I: The basic concepts for the implementation of the Lab of Tomorrow project.

Scientific Literacy

- Concepts:** force, motion
energy, conservation of energy
- Situations:** everyday activities
physical education, sports
- Processes:** reconstruction of physics (science) tasks
constructivist approach
communication

Basic Concept Theory, preferred models

- Learning by own experiences
- Problem solving
- Routine, Skill training
- Theoretical knowledge
- Dynamical social relationships
- Motility

The design of learning processes

According to modern pedagogy teaching should be guided by a holistic planning process that takes the students' learning processes, the subject matter and the teaching methods into account. As a maximum of students' orientation, it is a very important and significant variable which correlates positively with the students' performance. It offers the students the chance to link the teaching contents to their experiences and their prior knowledge.

They have the chance to remark the characteristics of an active and self-guided learning process.

Consequently, learning processes must be designed on conditions that they are oriented to the student's prior knowledge.

For learning science this means to enable students to see connections to familiar problems relevant and important for their lives. Additionally, the situated learning fosters the ability of transferring acquired knowledge to a variety of different situations. One of the main objectives is to acquire the ability of self-organised and self-regulated learning. Schools should generate the conditions for the development of the competence to learn and, as a perspective, an autonomous learning. This includes the development of meta-cognitive learning competences like e.g. elaboration strategies or learning strategies and their application and usefulness.

Learning processes in the future will be embedded in communicative situations, where teaching science offers good conditions by fostering communication and cooperation in students' experimental practices.

For a content orientation the planned teaching topics should be based on a broad field of knowledge and application. The teaching sequences must be build up in a way that knowledge can increase and link. Learning processes in science are orientated to the typical increasing complexity in science. An increasing process of finding systematic and rules, a more and more theoretical guided model building on the basis of an experimental extraction of a part of reality are features of each scientific inquiry. The necessary systematic, long time planned and cumulative learning contributes to a well-arranged, internal linked and in different situation flexible adaptive knowledge.

Of course, the school is a part of the student's life, but learning in school can only be successful, if the contents are also relevant behind the border of school reality. There should be a guaranteed link to future learning processes. Summarizing these aspects, teaching and learning in science is successful, if it will be possible to realize a sequence of topics that equally guarantee a systematic learning (vertical knowledge transfer) and situation orientated learning with every day tasks and problems (horizontal knowledge transfer).

A method orientation expresses the possibility for the students to learn the necessary subject and cross subject methods. In the learning groups there should be occasions for dialogs, at first guided by the help of a teacher,



but more and more autonomous and aimed at the development of scientific orientated conceptions and concepts. The students should have the possibility to describe their individual learning pathways and their individual solutions of problems. Creativity, efforts and flexibility must be acknowledged. A teaching method contains the teaching sequences, work-methods and the structural elements of ways of teaching and learning.

Task-oriented lesson plans

Regarding actual research in science teaching and learning the structure and the transparency of lessons are crucial features of teaching. Both are organised by task orientation (e.g. according to the results of SINUS).

In the Lab of Tomorrow project the lessons are organised in tasks according to two different levels of understanding, so two sequences of tasks are offered to students like to perfect pathways for conceptual growing.

For the tasks all problems are well described in literature, concerning e.g. preconceptions or problem solving processes, so parallel to the two pathways alternatives with learning aims according to these problems are offered. Such a structure requires small learning groups to enable individual experiences with the offered phenomena.

Moreover those tasks have to be arranged in conventional, so-called learning cycles.





Chapter 2

Technical description of the Lab of Tomorrow system

This chapter aims to help the teacher who is using the Lab of Tomorrow system during his lesson by giving specific guidelines of the functionalities of the main components of the Lab of Tomorrow system.

The Lab of Tomorrow system consists of the following modules:

- Base Station Set, that receives all data from the peripheral units and transmits them to the workstation:
- Base Station Unit with a stub antenna @ 433MHz.
- Base Station Power Supply Pack.
- RS-232 cross-cable.
- Student Set, for the collection of the SensVest data and their transmission to the base station via the radionetwork:
- Belt Assembly.
- Heart-Rate Measurement Belt (Polar Belt).

- Temperature Sensor.
- Leg Accelerometer Module.
- Arm Accelerometer Module.
- Bracelets for Leg / Arm Accelerometer Modules - 3 sizes (small, medium, large).
- Belt Assembly and Leg-Arm Accelerometer Battery Chargers (x2).
- Ball Module Set, which transmits the acceleration data to the base station:
- Ball Module.
- Ball Module Battery Charger.
- The workstation, which collects and processes all system data.
- The User Interface, which presents the graphical representation of the data.

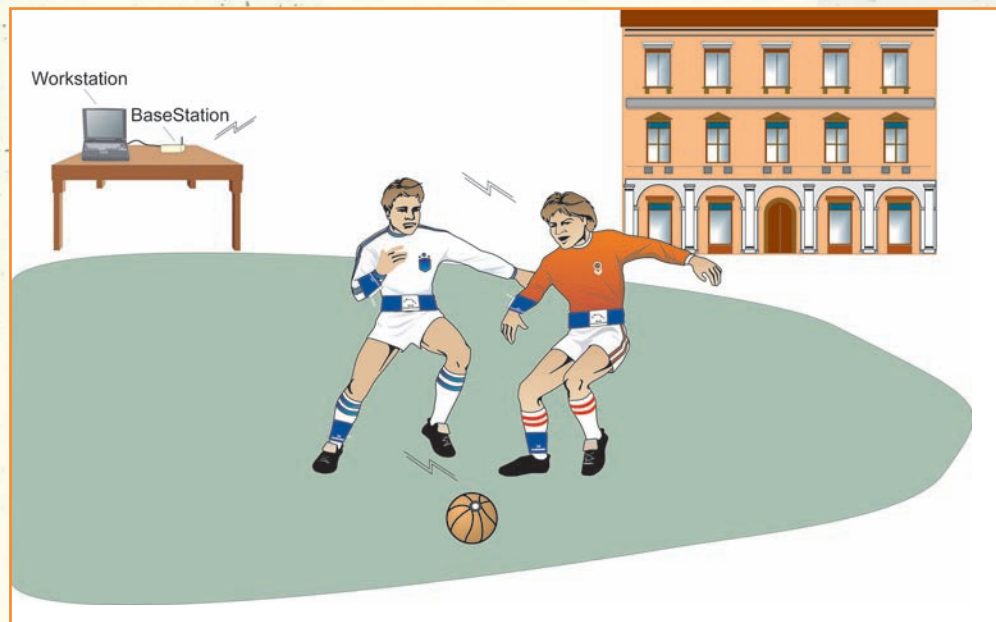


Figure 2.1a: The components of the Lab of Tomorrow system

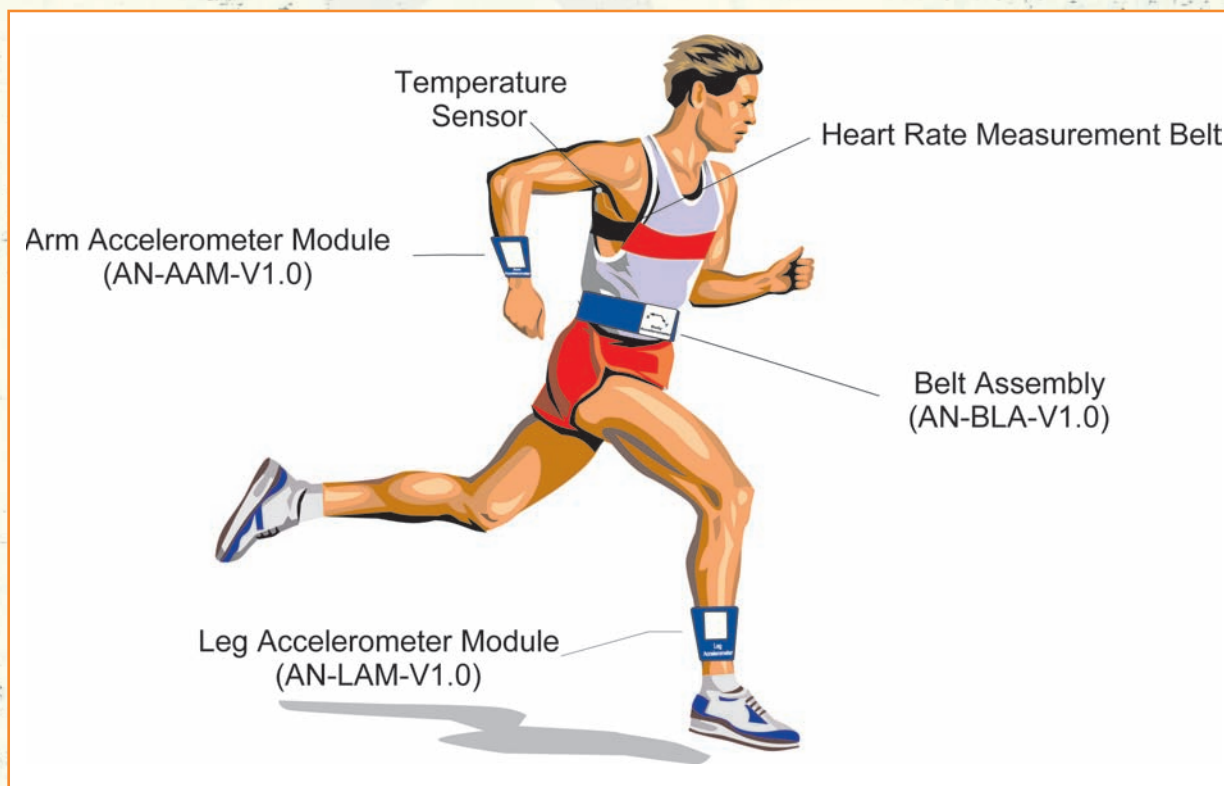


Figure 2.1b: The components of the Lab of Tomorrow system

Additionally an LPS (Local Positioning System) is used in order to help the students to estimate the position of different objects during their activities.

In the following paragraphs a short description of the Lab of Tomorrow system will be given. For those teachers who want to have a detailed description of the system they have to refer to the technological report of the project and the relevant technical reports of each device which are also available.

2.1 Base Station

Power Supply

The Base Station is powered by the power-pack provided. Just plug the power-pack to the main supply and connect it to the Base Station.

Operation

For proper operation place the Base Station on a table, at a height about one meter above the ground. The area near it should be clear from any obstacles. The Base Station is connected to the Work Station (a PC with LOT software installed) with the RS-232 cross-cable provided.

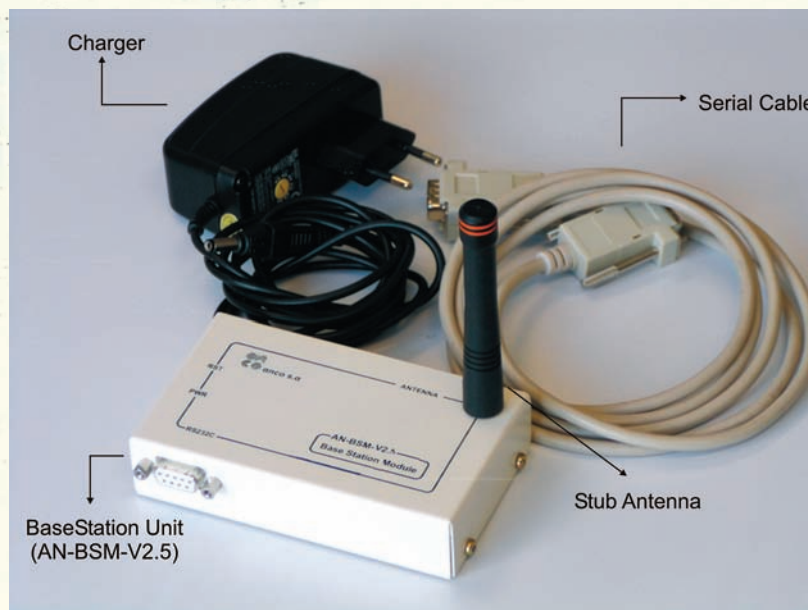


Figure 2.2:
Base Station



Attention: Use only the RS-232 cable provided.
The Base Station will not work with a straight, PC-to-modem cable.



2.2 Student Set

The Student Set consists of the following modules:

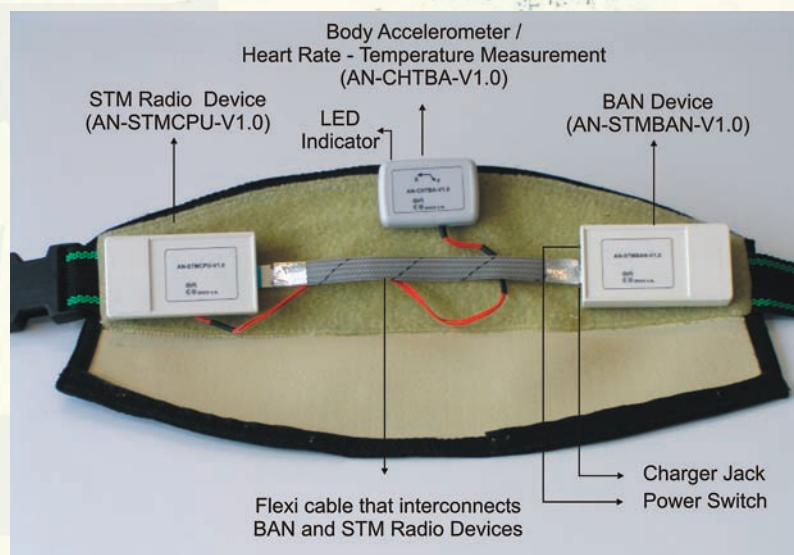
- Belt Assembly (AN-BLA-V1.0).
- Arm Accelerometer Module (AN-AAM-V1.0).
- Leg Accelerometer Module (AN-LAM-V1.0).
- Heart Rate Measurements Belt (Polar Belt).
- Temperature sensor.
- Bracelets for Leg and Arm Accelerometers (3 sizes - small, medium, large).
- Battery charger (2 items).

Belt Assembly

Power Supply

The Belt Assembly is the main part of the student set. To switch the module on, open (de-strap) the belt and press the button on the AN-STMBAN-V1.0 module for about one (1) second, until the LED flashes twice. Once the module is switched-on, the LED flashes every two seconds. To switch the module off, press the button, until the LED flashes twice.

Figure 2.3: Belt Assembly



Operation

The Belt Assembly consists of three main modules:

- The student set radio module (AN-STMCPU-V1.0), which establishes the radio communication with the Base Station of the network.
- The Body Area Network radio module (AN-STMBAN-V1.0), which collects wirelessly via the BAN all data from the Arm and Leg Accelerometer modules.
- The Heart - Rate - Temperature - Body Accelerometer module (AN-CHTBA-V1.0), which includes the heart rate receiver, the temperature connector and read-out circuit as well as the body accelerometer sensor.



Temperature Measurements

To conduct temperature measurements, connect the temperature sensor to the available connector at the ANCHTBA-V1.0 module (See Figure 2.4). The temperature sensor should be placed under the armpit, with the metal surface at the skin contact side.

Figure 2.4: Temperature Connector

Heart-Rate Measurements

To conduct heart-rate measurements, the student should wear the Polar belt, following the instructions in Figure 2.5.

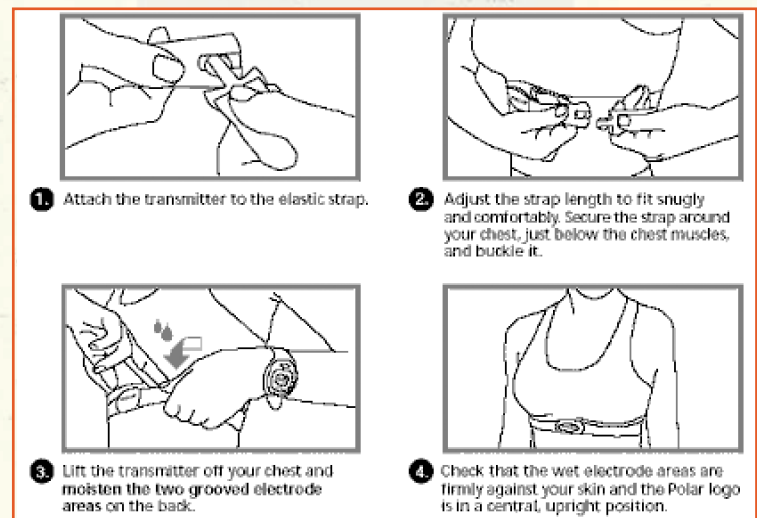


Figure 2.5: Polar Belt Instructions



After the experiment has finished, carefully wash the belt with a mild soap and water solution, rinse it with pure water and dry it carefully with a soft towel. The belt should be stored in a clean and dry place.

Battery Charging

The battery of the module is a state-of the - art Li-Polymer type and can be charged at any time, without affecting battery life. To re-charge the battery, take-off the belt, switch it off and connect it to the charger provided.

The battery becomes fully charged at less than two hours and provides power for about 3.5 hours of continuous operation.



Attention:

The module is not operational, when charging is in progress and it should not be turned on during this process.

Leg and Arm Accelerometers

Power Supply

The Leg and Arm Accelerometers have no power switch. They are switched on and off by the Belt Assembly, whenever an experiment starts and stops. The module will also switch itself off, if it is unable to communicate with the Belt Assembly for a long period of time.

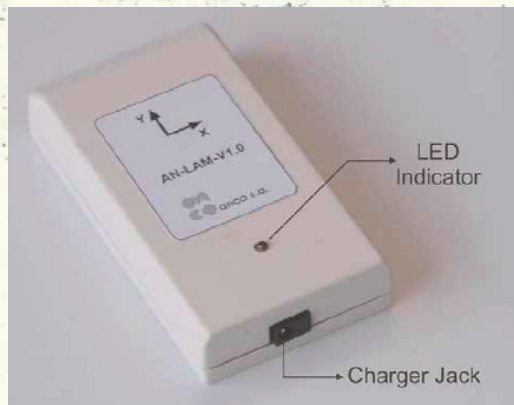


Figure 2.6: Leg Accelerometer

Operation

The student should wear the Leg Accelerometer at his/her leg and the Arm Accelerometer at his/her arm. When the Work Station issues an experiment start command, the student wearing the belt and the accelerometers must stand in such a way, that the y axis of both modules is vertical to the earth's surface. The student must remain in this position until the modules LEDs are turned on and remain lit. This means, that the activation signal has been received. After a while, the LED will switch off and start blinking. This means that the experiment has started and the sensors are gathering data. The LED will switch off permanently, when the experiment stops.



Attention:

All the Leg/Arm accelerometers, that are located in the vicinity of the experiment area and are not taking part in the measurements, should be placed in the horizontal position in order not to interfere with the working system.

Battery Charging

The accelerometer modules have the same battery as the Belt Assembly. The same charger is used to recharge these batteries. The battery becomes fully charged at less than two hours and provides power for 24 hours of continuous operation and for months, when in idle state.



Attention:

The module is not operational when charging is in progress.



Attention:

When an Arm/Leg Accelerometer is in the horizontal position, it does not search for activation signals. For this reason, place the accelerometers horizontally when you store them for long periods, as this will extend battery life.



2.3 Ball module

Power Supply

To power-on the Ball Module (Figure 2.7), press the switch momentarily using a ball-point pen or a pencil. Do not use sharp objects to press the switch. Upon power-up, the LED flashes twice. When the Ball Module is powered up, the LED flashes every four seconds.

Operation

When an experiment is in progress, the LED flashes every two seconds. To power off the Ball Module, press the switch once again.

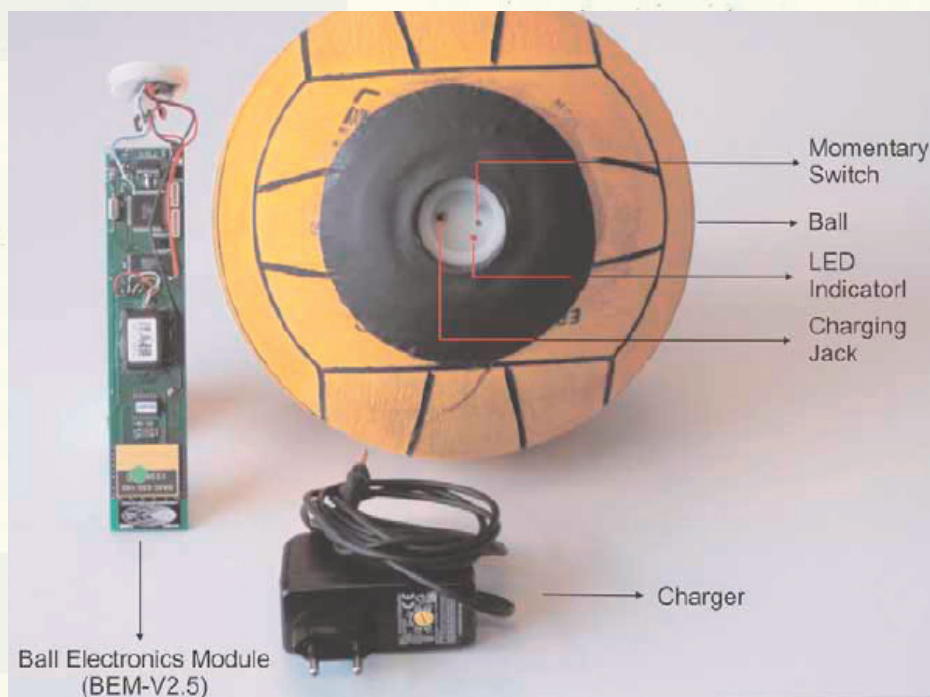


Figure 2.7: Ball Module

Battery Charging

The battery can be re-charged with the corresponding charger provided. The battery becomes fully charged at about 3 hours and provides power for about 4 hours of continuous operation.



Attention:

When no experiment is executed, the Ball Module should not be left switched on, as this will consume the battery very quickly.



2.4 The LPS (Local Positioning System)

Based on the consideration of a reliable solution and in order to provide a short-term result the option of using a 2- CCD camera solution was adopted for the test phase of the project's implementation. The space to be observed will be viewed with two cameras (Figure 2.8).



Figure 2.8: One of the LPS cameras as it is mounted on the wall

The scenes to be recorded (frames) by the two cameras will be synchronized in time and the observation in two orthogonal planes will provide the coordinates in 3D space as shown in Figure 2.9.

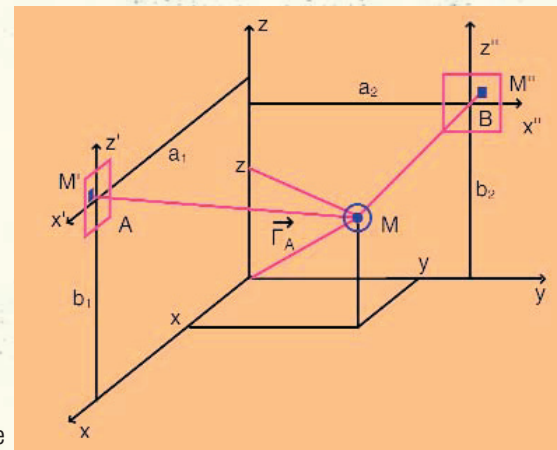


Figure 2.9: The basic principle of the LPS architecture

By measuring (x_1, z_1) and (y_2, z_2) coordinates the absolute coordinates (x_M, y_M, z_M) of the ball (point M) can be obtained provided the positions A and B of cameras are known. In Figure 2.10 two views of the experimental area (including a table and the Axion Ball) are presented as they were captured by the LPS.



Figure 2.10: Two views of the experimental area captured by the LPS. Students have to point the Axion Ball with the cursor on the two frames and the coordinates of the ball will be calculated automatically.

The minimum test area required for the whole 2-camera system would be 5mX5mX3m. This means that the system will be able to identify and record the position of an object (ball) at least within this area.

The pixel analysis for the proposed cameras will be 768X512 pixels. The accuracy of the system for the above field of view and the specific pixel analysis will be around 5-10 cm. Of course as the field of view increases, the actual accuracy of the system will deteriorate because the pixel size for each camera is constant.

The indoor application of the system could be situated in closed basketball or volleyball court where the ball game will take place. Alternatively any closed recreation ground with the above minimum dimensions could be used for the first series of experiments. It is recommended to start the series of experiments with indoor applications and these can be justified considering the illumination requirements of the camera system. Such systems that involve these kinds of experiments require constant illumination conditions for the field of view.

The outdoor experiments might be affected by the climatic conditions, which of course involve the illumination parameter.

The basic architecture of the system is schematically shown in Figure 2.9. Two CCD cameras are positioned on the x-y, x-z or y-z levels. The cameras must form a right angle between them in order to achieve the best accuracy. At least 2-3 meters between the cameras and the field of view is required for the proper focusing of the test area. Both cameras are connected to a PC, which will be located nearby. The system will record the trajectory of the object of interest and the relevant players during the proposed activity.

The cameras are connected to the personal computer through the parallel ports. Two frame grabber PC cards are used. Each camera has the ability to record 50 frames/sec. The LPS system is able to capture 25 active frames per second. This is due to the parallel frame grabber's architecture that is utilized. Since both cameras must be synchronized and each frame must be recorded at the same time, the final capacity of the system is



diminished from the 50 frames of the individual camera to the 25. Additionally to the position of the observation object, the relevant time parameter is recorded simultaneously for each frame. By this way a few minutes video with the game will be produced.



Figure 2.11: The student will be able to recover to the PC screen the frames from both the cameras, which are referring to the same time parameter. Then the student will identify the ball in each frame and with the help of the mouse will mark the ball producing the relevant set of coordinates (x_1, z_1) , (y_2, z_2) . With the use of these coordinates, a simple software program based on the previous mathematical analysis, will produce the absolute coordinates (x_0, y_0, z_0) of the ball.

For the presentation of the recorded frames a user-friendly software tool is used. Students are able to recover to the PC screen the frames from both the cameras, which are referring to the same time parameter (see Figure 2.11). Then they identify the ball in each frame and with the help of the mouse mark the ball producing the relevant set of coordinates (x_1, z_1) , (y_2, z_2) .

With the use of these coordinates, a simple software program based on the previous mathematical analysis produces the absolute coordinates (x_0, y_0, z_0) of the ball. The coordinates will be written on a file along with the time parameter.

Having recorded all these parameters, students are able to reconstruct the trajectory of the ball or the movements of a player through out the observation period. Other parameters such as velocity and acceleration can be also calculated indirectly with the use of other small independent software programs. These calculations are very useful and can be used as a reference for the same measurements that will be conducted through the axions embedded in the foot anklet and the ball. By this way an accurate method for the verification of these measurements will be simultaneously available.

2.5 The Lab of Tomorrow User Interface

The axions give data in a format compatible with graphing and analysis software tools; so that students can easily investigate trends and patterns in the data they collect with the wearable sensors. A database and an advanced web based software tool have been created to process the received information. The information is retrieved and effectively classified in order to decode it and present it with the help of the graphical User Interface in a way familiar and adjustable to the student. The main innovation of the approach is that students are able to study the physical phenomena emerging from their own activities and everyday situations and not only from specially designed experimental set-ups with the use of simulated data. Students through a sequence of steps involving, data accessing, plotting data on a graph, creating a mathematical model to fit the data and relate the graph with the motions of the axions provided by the user-interface, gain deeper understanding of the phenomena. Necessary information may comprise diagrams of a variable versus an independent value (kinetic energy vs. distance), mathematical models that make possible the interpretation of information within the laws of physics (e.g. position, velocity and acceleration will be plotted and fit to see the correlation of the real data and the kinematics equations), graphic diagrams of the changes in pulse beat or temperature as in a medical instrument with the use of statistical models, the use of thresholds and different windows to observe instantaneously different variables etc.

Lab of Tomorrow User Interface Guide Quick Launch Form

Quick Launch Tab

The quick launch screen, appears at the start-up of the Lab Of Tomorrow application. It intends to provide to the user, a collection of the most common tasks. The quick launch tab, contains the following 6 tasks, represented by their corresponding icons

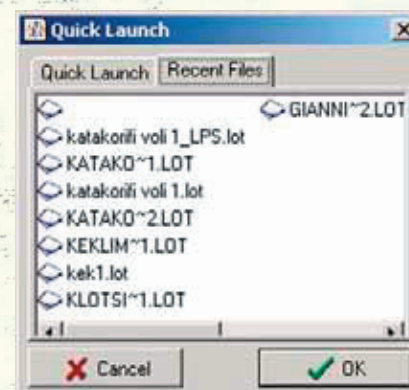
- Start A New Experiment
- Open A New Experiment
- Browse Experiments
- Import And Merge
- Help
- Courses



The Help, and Courses sections, are not implemented at the current version. Each of the following sections that are functional, are described at later chapters.

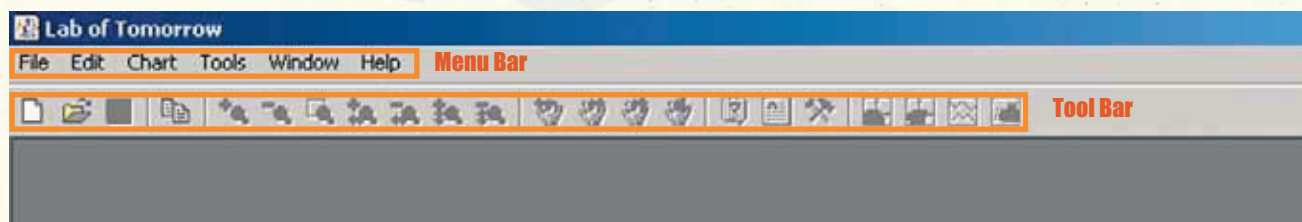
Recent Files Tab

The Recent Files tab, intends to facilitate the post processing procedure, by providing a list of the recent files, the user has created, edited or opened. If you double click on a file from the list (or select it and press "OK"), the application will open the corresponding experiment for post processing.



Main Form

The main form, holds all experiment forms, and contains a menu bar and a toolbar. These two elements (Menu and Tool Bars) contain all the basic and advanced functions. If a button, or menu item is disabled, it will appear as "grayed", and the user will not be able to use that function. In the following both these objects are described in detail.



Menu Bar

"File" Category

The "File" menu bar category, contains the following items:

- New
- New Session File (Creates a new session file)
- New From Raw Data (Creates a new file from raw data-Used only for debugging purposes.)
- Open (Opens a new file)
- Save (Save the current file)
- Save Us (Saves the current file, under a new name)
- LPS Data Import (Imports or merges, LPS data, into an sensors only experiment file)
- Explorer (A windows explorer style, with usefull information about experiment files)
- Recent Files (Contains a list with the recent files , used by the application)
- Exit (Exits the Lab Of Tomorrow application)

"Edit" Category

The "Edit" menu bar category, contains the following items:

- Cut (Cuts data from the selected cells. Used only when viewing the raw data tab)
- Copy (Copies data from the selected cells. Used only when viewing the raw data tab)
- Paste (Pastes data from the clipboard. Used only when viewing the raw data tab)

"Chart" Category

The "Chart" menu bar category, contains the following items:

- Zoom
- Zoom In (Zooms in the both the vertical and horizontal axis by a percent)



- Zoom Out (Zooms out the both the vertical and horizontal axis by a percent)
- Zoom Fit (Zooms both the vertical and horizontal axis, so that all data are visible)
- Zoom In Horizontal (Zooms in only the horizontal axis)
- Zoom Out Horizontal (Zooms out only the horizontal axis)
- Zoom In Vertical (Zooms in only the vertical axis)
- Zoom Out Vertical (Zooms out only the vertical axis)
- Pan
- Left (Moves the charts ,left)
- Right (Moves the charts, right)
- Up (Moves the charts, up)
- Down (Moves the charts, down)

Tool Bar



The toolbar contains some useful tools. These tools are described below, ordered by their corresponding number in the picture above.

1. New File
2. Open File
3. Save File
4. Copy Data
5. Zoom In
6. Zoom Out
7. Zoom Fit

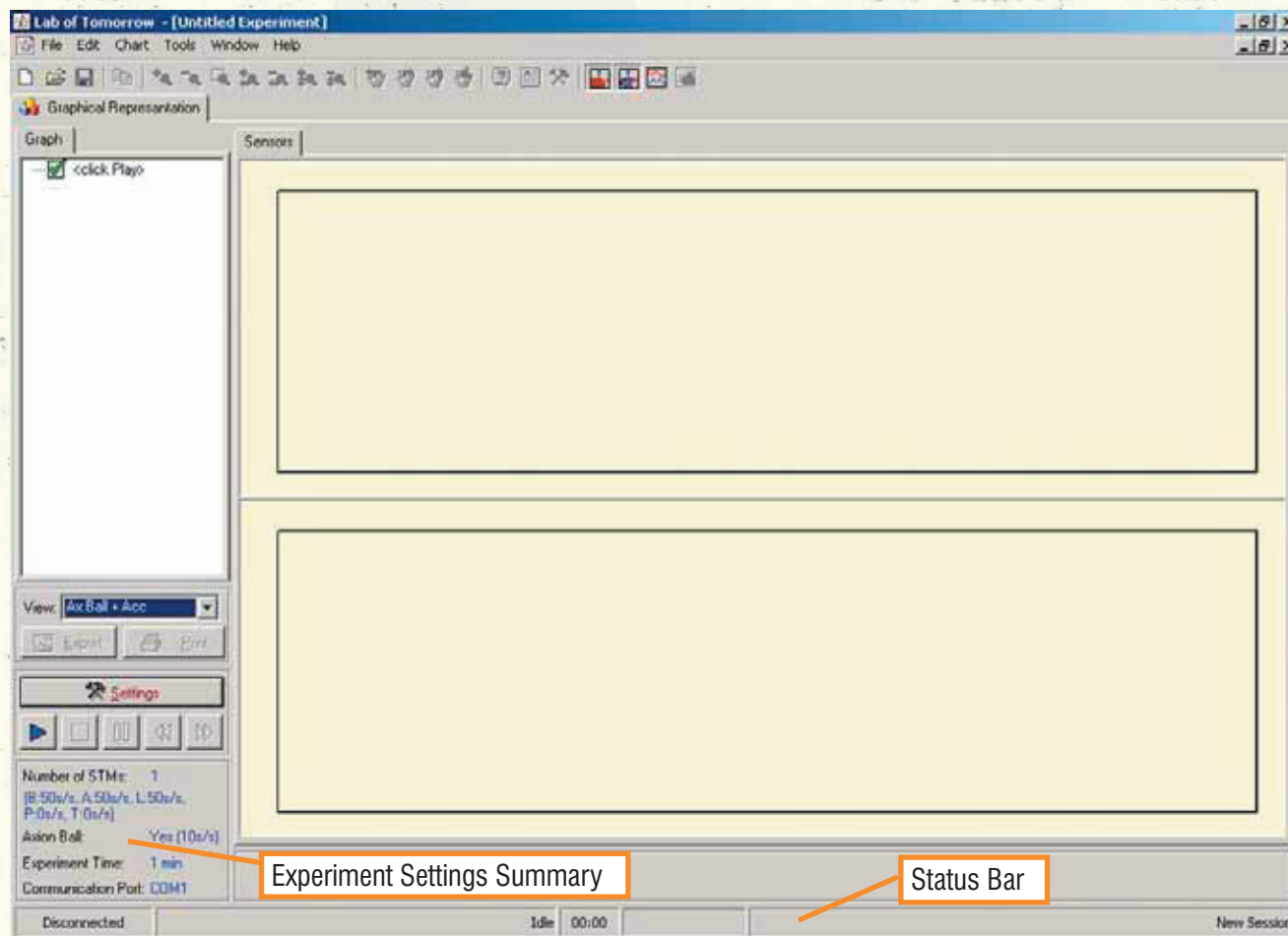
8. Zoom In Horizontal
9. Zoom Out Horizontal
10. Zoom In Vertical
11. Zoom Out Vertical
12. Pan Left
13. Pan Right
14. Pan Up
15. Pan Down
16. Help
17. Courses
18. Settings
19. Axion Ball Chart (Shows or hides the axion ball chart if the current experiment contains one)
20. Sensvest Accelerator Sensor Charts (Shows or hides the chart that contains accelerator sensor data)
21. Pulse, Temp Chart (Show or hides the chart that contains pulse and temperature data)
22. LPS Chart (Show or hides the LPS Data Chart)



2.6 Using the LOT User Interface

Creating a new Experiment

The user can create a new experiment, by clicking the "New" button in the toolbar, or selecting File->New->New Session File, or by selecting the "Start New Experiment" option in the Quick Launch Form. The following form appears:



Clicking on the settings, button will show the Experiment Settings form where all experiment settings are configured. When done, the Play button, will start sampling data from the base station. At the time the sampling is over, all chart and data manipulation functions are enabled, and the experiment can be saved as a file, for later viewing.

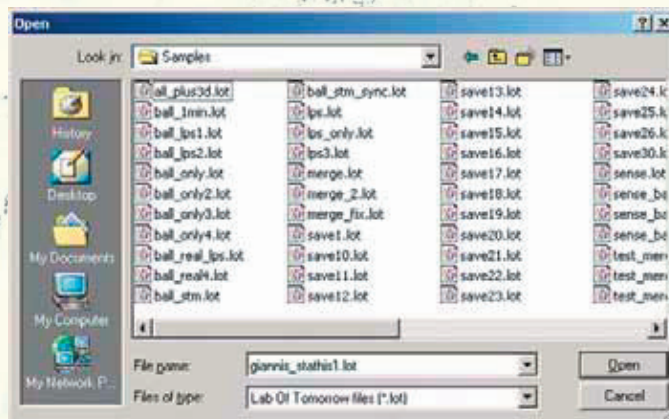


Attention:

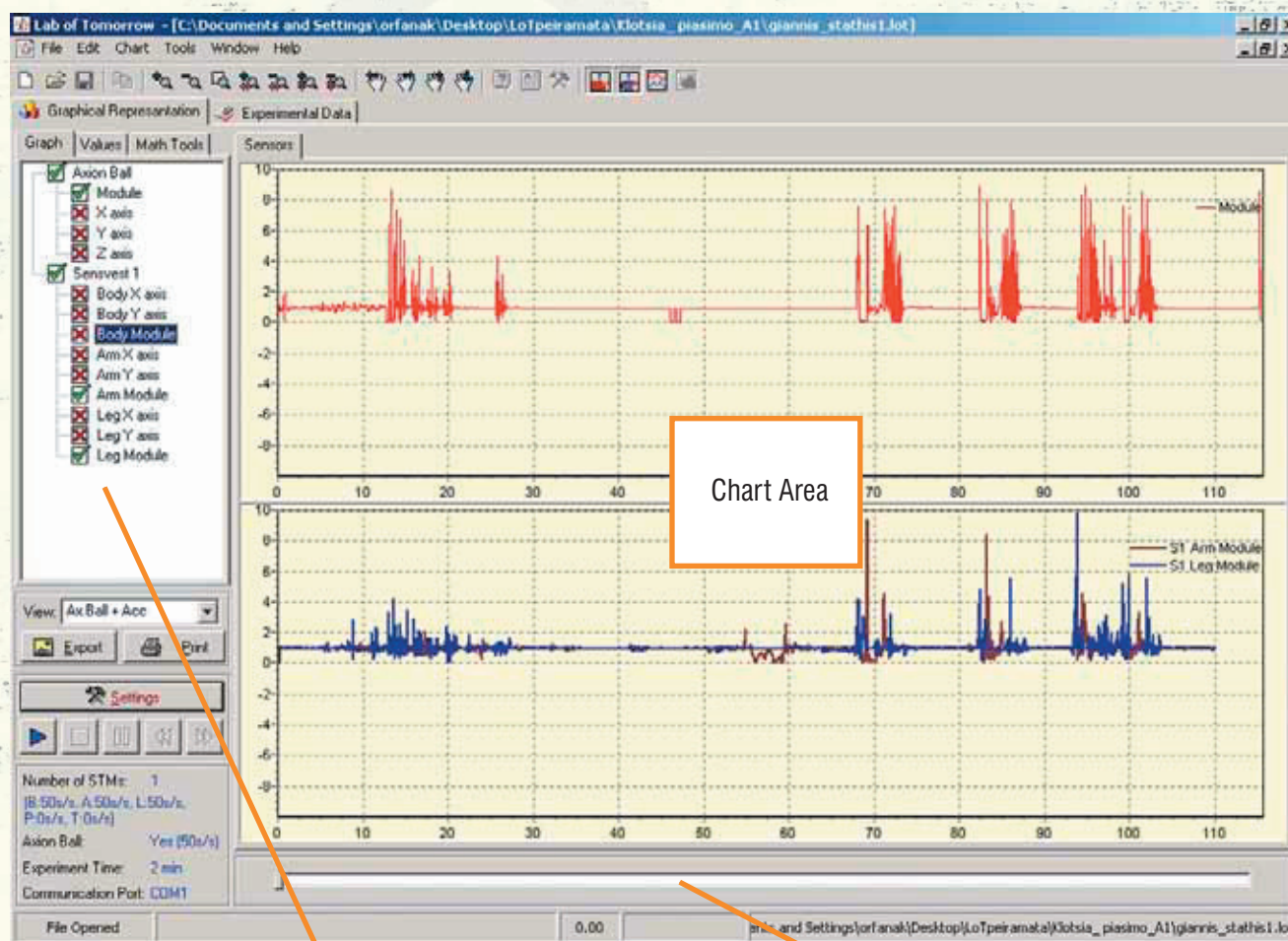
Please notice that every time you start new experiment you have always to configure the experiment settings again.

Opening An Experiment

This is very simply done, by just selecting the file you wish to open. The Open Experiment dialog, can be enabled by clicking the Open button in the toolbar or by selecting File->Open



Selecting a file, will result in the file being opened. In the next Screenshot you can see an experiment opened as a file, and a short description for every visible section of the form.



Shows or hides the clicked sensor data. This Tick icon represents a visible sensor, while the X icon represents a non visible one.

Timeline Slider

Saving an Experiment

By selecting File->Save or by clicking the Save button in the toolbar, the current experiment is saved under the name you choose. If the current editing file, was saved before, then all changes are save under the same name. If you select File->Save As, then the current file is saved under a new name, even if it was saved before.

Importing LPS Data

Choose

File->Import LPS.

The following form appears:

Import Data

LPS

Grab File

Summary

Number of Samples: Date And Time of Capture:

Total Length:

Sensors

LoT File:

Summary

Experiment Time: Axion Ball: Sensvest:

Synchronisation Data: LPS:

Date And Time Of Experiment:

Session Name: Supervisor:

This form, contains of two discrete sections. The "LPS" section, and the "Sensors" section. In order to import or merge LPS Data, you must click on the Browse button of the LPS Section. A valid *.mdb (Microsoft Database) file, containing LPS data must be selected. If the file contains LPS information, then the Import LPS button is enabled, and at the Summary



frame of the LPS section, you can see a brief description of the LPS file data. For an example file the form will look like this:

A screenshot of a Windows-style dialog box titled "Import Data". It has two main sections: "LPS" and "Sensors". The "LPS" section contains a "Grab File" text box with "grab.mdb" entered, a "Browse" button, and a "Summary" area with labels for "Number of Samples:", "Date And Time of Capture:", and "Total Length:". The "Sensors" section contains a "LoT File:" text box, a "Browse" button, and a "Summary" area with labels for "Experiment Time:", "Axion Ball:", "Sensvest:", "Synchronisation Data:", "LPS:", "Date And Time Of Experiment:", "Session Name:", and "Supervisor:". At the bottom are three buttons: "Cancel", "Import LPS:", and "Merge Files".

LPS	
Grab File	grab.mdb
Browse	
Summary	
Number of Samples:	Date And Time of Capture:
Total Length:	

Sensors		
LoT File:		
Browse		
Summary		
Experiment Time:	Axion Ball:	Sensvest:
	Synchronisation Data:	LPS:
Date And Time Of Experiment:		
Session Name:	Supervisor:	

CancelImport LPS:Merge Files

Finally, click on the Import LPS button, choose the name for the new Lab of Tomorrow file that will contain the LPS data, and a message will inform you about the success of the function.

If you wish to merge LPS data with an existing Lab of Tomorrow file, then you must select that file, by clicking the Browse button of the Sensors section. By doing so, the Open File dialog appears, and upon completion, the Summary of the file's parameters and settings appears at the Summary frame of the Sensors section.

If the Lab Of Tomorrow File, contains synchronization data , then the Merge File button , is enabled. If clicked, then the two files are merged into a new one. The application takes no action to prevent merging of files that are time unrelated. You must, choose the correct files (the Date And Time reports are very helpful for this manner). Selecting unrelated files, can have unexpected results when viewing the file at a later time.

For the above reasons it is suggested, that experiments containing sensor and LPS data, should be conducted in the following manner:

First, the LoT software starts sampling data from the sensors. A few seconds later, the LPS can start sampling data, but the process must be stopped BEFORE the LoT software has stopped sampling.





2.7 Using the Video Grabber Software

The video grabber programme is the software used for gathering the LPS camera frames and for creating the database of measurements. In order to use the video grabber successfully it is suggested that you will follow the following steps:

1. Start the software "Video Grabber"

2. Choose the video scale

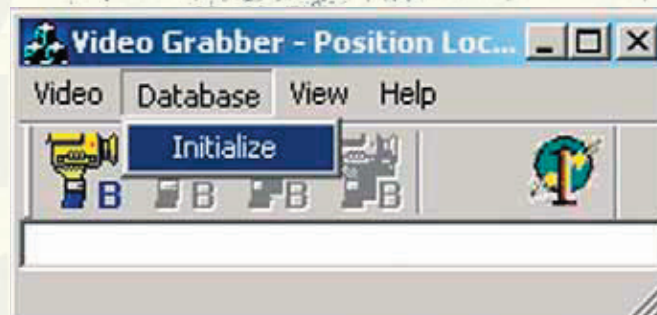
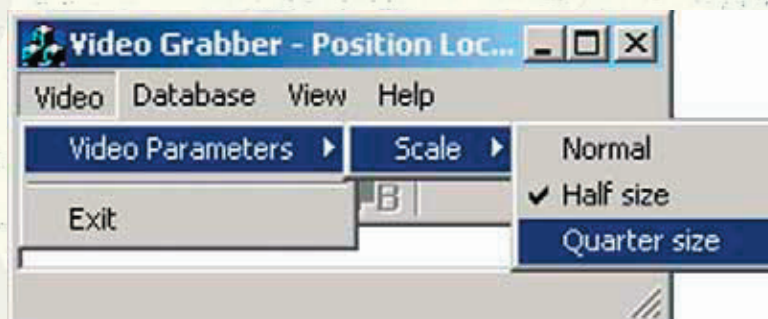
(recommended: half size)

3. Initialize database

(erase previous data)

4. Creating videos

4.1. Button overview

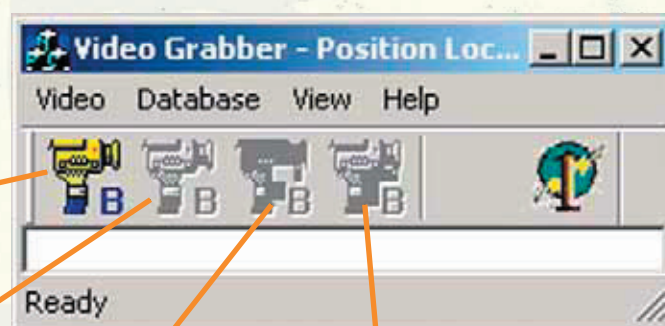


open camera

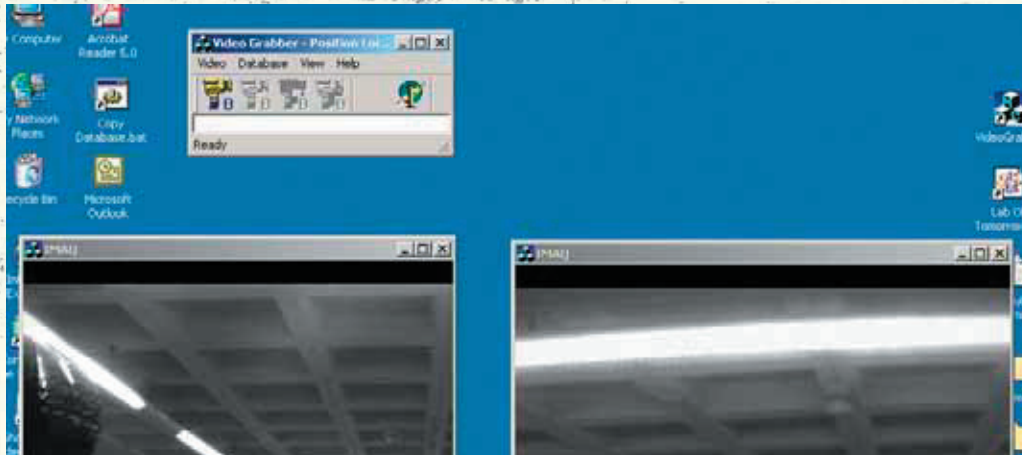
close camera

start recording

stop recording



4.2. "Open camera"



Use this button to open the two video windows and to control the position of the object(s) to be recorded.

The buttons "close video" and "start recording" are enabled.

"Close Camera"

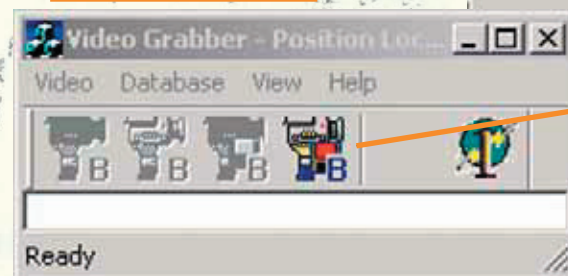
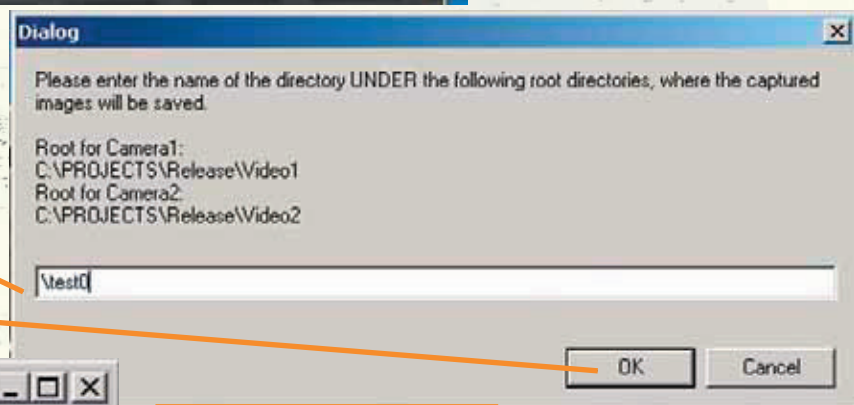
The two video windows disappear

4.3. "Start recording"

press the button

enter a name for the experiment

then start recording by pressing "OK"



only the "stop recording" button is enabled now

4.4. "Stop recording"

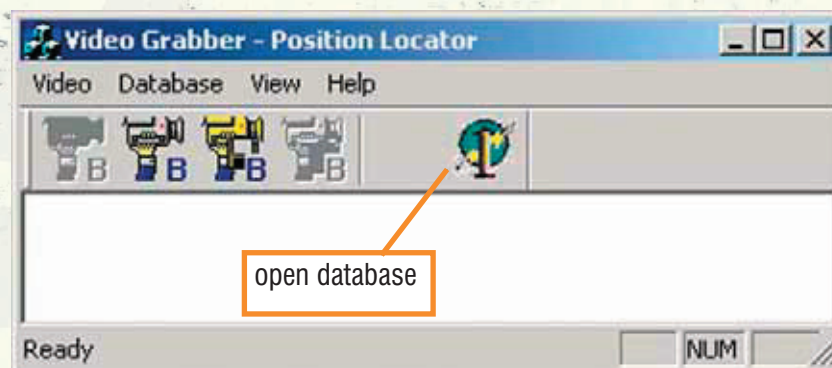
Press the button, when the movement you want to record has finished



5. Analysing the videos

5.1. Press the button

"open database"

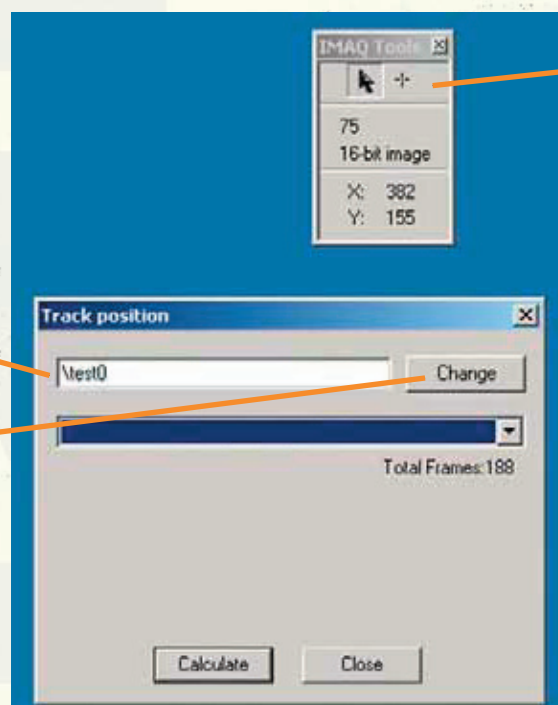


5.2. Choose the experiment and the tool

enter the name of
the experiment

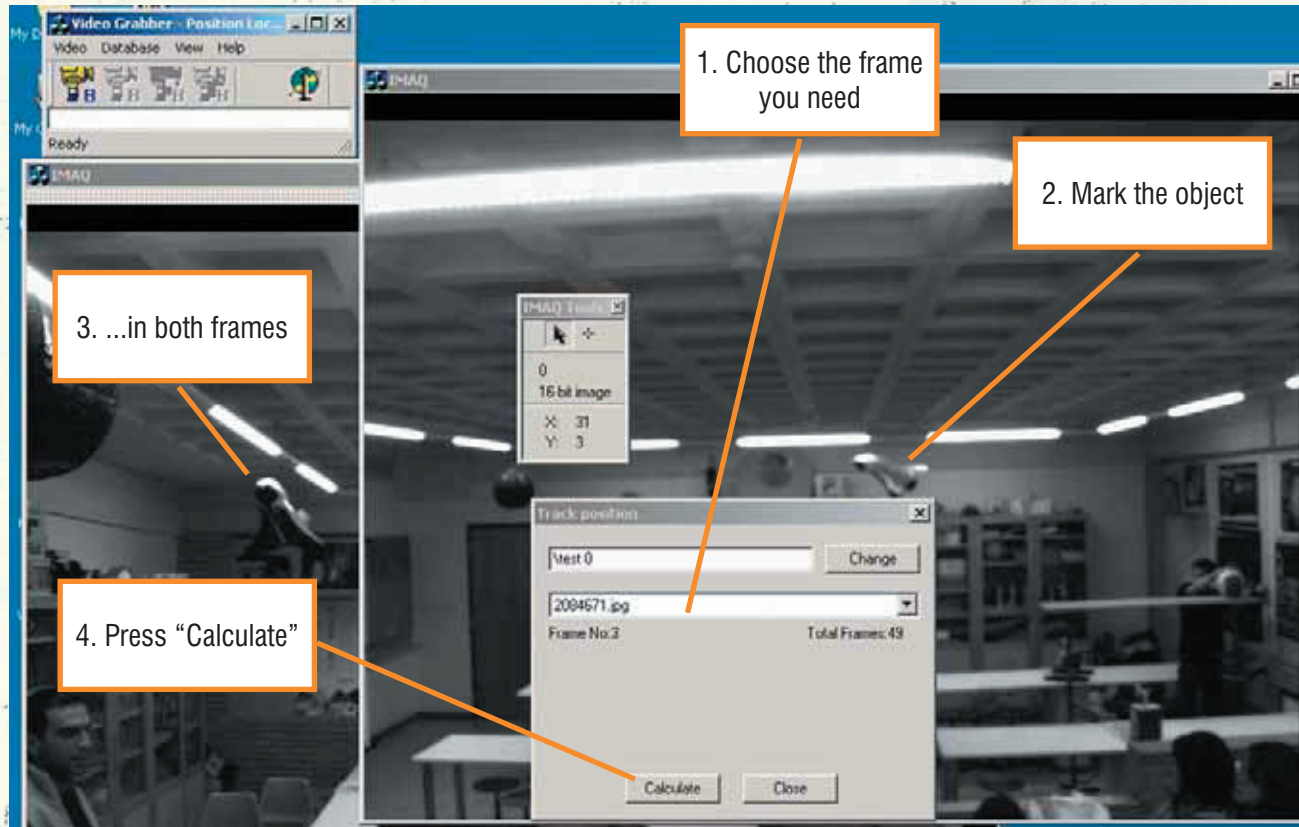
press the button
"Change"

choose the tool
for marking



The video frames will occur.

5.3 Mark the object in each video frame



Repeat steps 1 - 4 until the whole movement has been analysed, then press "Close"



6. Transferring the data

6.1. An MS-Access™ - file ("grab.mdb") has been created automatically, where the x-, y- and zcomponent of the positions and the assigned time ("tick") is stored:

Microsoft Access - [Points : Table]					
File Edit View Insert Format Records Tools Window Help					
X Y Z DateDone Tick					
	590,97	690,15	149,81	5/2/2004 2:37:34 µµ	2086234
	664,36	691,5	149,96	5/2/2004 2:38:44 µµ	2086281
	648,36	689,12	151,36	5/2/2004 2:39:20 µµ	2086343
	632,39	689,43	148,67	5/2/2004 2:39:44 µµ	2086406
	621,49	689,65	149,69	5/2/2004 2:39:57 µµ	2086453
	610,08	691,53	148,61	5/2/2004 2:40:11 µµ	2086515
	592,53	691,83	143,03	5/2/2004 2:40:36 µµ	2086562
	578,96	692,06	141,17	5/2/2004 2:40:56 µµ	2086625
	571,97	690,62	136,66	5/2/2004 2:41:14 µµ	2086671
	560,53	690,84	127,1	5/2/2004 2:41:27 µµ	2086734
	534,18	692,78	96,87	5/2/2004 2:41:46 µµ	2086843
	526,42	690,75	83,7	5/2/2004 2:42:09 µµ	2086890
	505,81	691,84	46,96	5/2/2004 2:42:40 µµ	2086953
	499,43	694,04	22,23	5/2/2004 2:43:55 µµ	2087015
*	0	0	0		

6.2. There it can be merged into the LOT-software.





Chapter 3

Good practice with “Lab of Tomorrow”

3.1 Using the Lab of Tomorrow tools in real classroom conditions

Lab of Tomorrow aims at upgrading science teaching in secondary education. This is achieved with the introduction and utilization of advanced technologies in the teaching and learning process. This gives the opportunity to redesign the school science laboratory expanding its experimental capabilities. The connection of science teaching with real life is essential while special effort should be put on motivating students to be engaged with science and exploratory learning in general. Lab of Tomorrow with the introduction of technological novelties in the classroom is believed to achieve the above goals by bringing a new era in the school science and experimentation teaching. This unit is giving essential information that concern the introduction of the Lab of Tomorrow tools in Science teaching and learning, the suggested initial experimental activities, useful information and hints on how you can successfully investigate specific aspects of Kinetics and Mechanics



3.2 Table of Contents and Lab of Tomorrow lesson plans

The Lab of Tomorrow “Table of Contents” presented below is a list of suggestions that takes into account the structure of the pedagogical framework as well as the advantages of the technical devices. Not all the topics of this list can be taught in school, but all taught topics should be located in this list. Within the following paragraphs several lesson plans guided by the teaching and learning principles that were introduced above, are presented. These lesson plans are designed to meet the needs of the implementation of the project in the school environment. The lesson plans are based on simple experimental activities with the use of the Lab of Tomorrow products so as for the new artefacts to be smoothly introduced in the science classroom. The lesson plans are designed to be complementary to the conventional physics lessons. Specifically the parts of the table of content that correspond to the project’s lesson plans are highlighted. The aim is at the future to improve the functionalities of the axion prototypes develop more extended and sophisticated case studies and thus increase the applications of the Lab of Tomorrow system’s components.

Table of Contents

Part I: Uniform Rectilinear Motion and Mechanical Energy

1) Units and quantities, space and time and trajectories

- a) Repetition of fundamental units and quantities
- b) Experiment: throwing of a ball (tennis ball), measure position with LPS
- c) Examination of data in multiple ways, e.g. different graphs of displacement (x, y, z) as a function
- d) of time, (x, y) as a function of time, x as a function of time, projection of motion into one plane
- e) Derivation of velocity as the ratio of the displacement to the time interval, average
- f) Velocity and instantaneous velocity

g) Those simple examinations should be particularly used to make the students acquainted with the User Interface

2) Uniform rectilinear motion

- a) Further examination the prior experiment’s horizontal component (the result should be:
- b) Horizontal velocity is nearly constant)
- c) Examination of similar but simpler, one-dimensional movements with LPS: rolling balls, pushed boxes or toy cars and also experiments with an air cushion rail
- d) One result has to be that for a motion with constant velocity the following laws are valid:
 $s = v \cdot t$, $\langle v \rangle = v(t)$, $dv/dt = 0$
- e) Minimizing friction leads to the assumption that without friction or other forces, every motion should “go on forever as a uniform rectilinear motion”; this leads directly to...

3) Newton's first law (also called "The Law of Inertia"):
"A free particle always moves with constant velocity."

4) Introduction of kinetic energy and momentum as additional, constant quantities for describing uniform rectilinear motion, based on the prior experiments; noticing, that the importance of these quantities will only become clear in the further course of the experiments

5) Interlude: springs (specific terms, force $F=k*s$, work and energy $E=1/2*k*s^2$) and potential energy ($E=m*g*h$)

6) Interaction of bodies in motion and springs

a) Experiments with LPS: e.g. moving body on an air cushion rail, stopped when upsetting a spring and set into motion again

b) First hint that energy may be conserved

7) Collisions I: elastic collisions in one dimension

a) Elastic collisions can only be realized using an air cushion rail

b) Experiments with colliding vehicles of different masses and velocities (LPS)

c) Result: energy and momentum are conserved

d) Reversal: conservation of momentum and energy are sufficient for predicting velocities

e) After collision, when initial velocities and masses are known

8) Collisions II: inelastic collisions in one dimension

b) these kinds of collisions can also be realized best with an air cushion rail, but with

c) Limitations (e.g. difficulty of changing masses and necessity of an exactly central collision) also with axion balls

d) Result: momentum is conserved, but energy is not

9) Collisions III: collisions in two dimensions

a) LPS and axion balls can be used for this more realistic kind of collisions

b) Validity of conservation of momentum is shown in a more complex context

Part II: Rectilinear Motion and Heat

1) Examination of a free falling axion ball as a prototype of a new kind of motion

a) Examination of graphs of velocity and displacement

b) Introduction of the following laws: $s=1/2*a*t^2$, $v=ds/dt=a*t$

c) $a=dv/dt$ as the new physical quantity acceleration

d) Description of the motion as "uniformly accelerated" ($a=constant$)

e) Introduction of the acceleration sensor

f) Comparison of data collected directly by the acceleration sensor and data derived from the

LPS

g) Momentum and energy are not constant



2) Re-definition of force as the changing of momentum

- a) $F = dp/dt$
- b) As the mass m should be constant, this means $F = m \cdot a$
- c) Newton's second law: "The time rate of change of momentum of a particle is equal to the force acting on a particle."
- d) Considering that momentum is a conserved quantity, you can hence Newton's third law from his second law: "When two particles interact, the force on one particle is equal and opposite to the force on the other."
- e) Other important forces, e.g. gravitational force ($F = m \cdot g$ with the above experiment, additionally $F(\text{gravitation}) = (G \cdot m_1 \cdot m_2) / r^2$)

3) Closer examination of energy in uniformly accelerated, rectilinear motion

- a) The accelerating force F has the same direction as the motion, hence work is done
- b) Comparison of $E(t=0)$, $E(t=T)$ and $W = F \cdot s = m \cdot a \cdot s$ with data from axion balls
- c) Conclusion: the work done on a particle is equal to the change of its kinetic energy; power as work done per unit time

4) Other motions of the same kind: car accelerated by a spring (repetition), body gliding on inclined planes etc., using LPS and accelerometer

5) Accelerated every-day motions

- a) Question: can they be described as uniformly accelerated?
- b) Examples of accelerated every-day motions: walking, running, riding on a bike, a car, a motorbike, inline-blades, hitting balls etc. (using LPS, accelerometers and sensor-vest)
- c) first intake to accelerated motions without constant acceleration

6) motions with negative acceleration

- a) Vertical throws of an axion ball
- b) car decelerated by a spring (repetition)

7) Complex systems of particles in motion:

- a) Structure of matter
- b) Kinetic energy of a system of particles
- c) Conservation of energy of a system of particles
- d) Collisions in a system of particles
- e) Velocity distribution in a system of particles
- f) Temperature as a quantity related to the average kinetic energy of the particles
- g) First law of thermodynamics
- h) "New" interpretation of pressure and expansion of gasses
- i) Repetition of basic laws of thermodynamics (heat capacity etc.)

8) "Realistic" uniform rectilinear motion

- a) Why is Newton's first law only an idealization; in other words: why do bodies, once set into motion, usually slow down
- b) Interpretation of the loss of momentum as an indicator of a force opposing the motion
- c) Identification of these forces as frictional forces (sliding friction, static and kinetic)
- d) Coefficients of friction, friction in fluids and gases)
- e) Measurement of coefficients of friction with moving bodies and inclined planes using LPS and accelerometer
- f) Work and frictional forces
- g) Atomistic interpretation of friction: where do momentum and energy go?
- h) Law of conservation of energy: "the sum of the kinetic energy and the internal potential
- i) Energy (or the proper energy) of an isolated system of particles remains "constant"

9) Friction and accelerated/decelerated every-day motions

- a) Friction as a limitation of acceleration and deceleration
- b) Examples of decelerated every-day motions: breaking with different vehicles using LPS, accelerometers and sensor-vest (bikes, cars, motor-bikes, toy cars) with special emphasis on questions of traffic safety

Part III: Superposition of Motion and Conversion of Energy

1) Introduction of the law of conservation of energy as an alternative to momentum and forces in describing/predicting motions, combined with a repetition of the basic motions already known

- a) Uniform rectilinear motion
- b) Free fall
- c) Sliding bodies on inclined planes
- d) Vertical throw
- e) Acceleration of vehicles

2) Examination of more complex motions as superposition of known motions with LPS and accelerometer; the user-interface will help to split the complex motions into the underlying simple components, which are stated in brackets

- b) Bouncing balls with no horizontal motion (free fall, collision, vertical throw)
- c) Horizontal throw (free fall and uniform horizontal motion)
- d) Bouncing ball with a horizontal motion (uniform horizontal motion and bouncing balls with no horizontal motion)
- e) Projectile motion without air resistance (vertical throw and uniform horizontal movement)
- f) Projectile motion with air resistance, using for example different kind of balls and
- g) shuttlecocks (vertical throw and accelerated horizontal movement)



h) Projectile motion with starting point and target on different latitude, including sport

i) Examples: long jump, putting the shot

j) Motion of a system of particles (motion of centre of mass and relative motion of a single particle)

k) Particles

3) Uniform circular motions

a) Example: spinning around an axion ball on a string of variable length

b) Measurements with LPS and accelerometers: angular velocity, period, frequency, angular acceleration, centripetal force

c) Angular momentum and rotational energy as a conserved quantities

d) Centripetal and “centrifugal” forces (measuring within an accelerated reference system, using the axion ball)

4) every-day circular motions, examined with LPS and accelerometers

a) (Toy) cars in curves

b) Banking of curves

c) (motor-) bikes in curves

5) Motion of rolling objects

a) Examination of different cylinders rolling down inclined planes with LPS (possibly using coloured spots)

b) Velocity and angular velocity

c) Potential, kinetic and rotational energy

d) Momentum of inertia

6) Oscillatory motion

a) Small axion ball on a spring as a prototype of a simple harmonic oscillator, also using LPS

b) Kinematics of, force and energy in and basics equations of simple harmonic motion

c) Small axion ball on a string as a nearly harmonic oscillator (also using LPS), kinematics, force, energy and basics equations

3.3 First lessons and basic experiments

Getting started with Lab of Tomorrow experiments

Lab of Tomorrow can be used by any user who wants to explore Science and Physics in a more exploratory manner i.e. connected closer to real life conditions. However, initially, Lab of Tomorrow has been designed to address the learning needs of students in secondary education. Thus, the analysis and the presentation of Lab of Tomorrow experiments in this chapter has been designed to meet the needs of students 15-16 years old. However, this doesn't mean that the content of this chapter is not useful for other categories of potential Lab of Tomorrow users. This paragraph indicates a minimum of competencies that are required for the user to possess so as to be able to use the LOT tools with success. The minimum competencies are in line with what 15-16 year old students have in science. Of course any one who has knowledge above this minimum, can very easily make and analyse experiments with Lab of Tomorrow.

In general, Students have different background in Physics and Science subjects respective to their age and the curriculum of the country they come from. National educational systems and curricula differ significantly from country to country and so students don't have the same knowledge in mathematics or physics. However some general conclusions on what is in general considered acquired knowledge or not can be derived.

In general it is considered that students:

- *don't know how to derive functions*
- *don't know how to work with an EXCEL spreadsheet*
- *only have basic skills in interpreting diagrams*

And they are considered to:

- *know how to draw diagrams when they have a table of measurements*
- *recognize a proportional relation between two physical quantities*
- *know how to make simple measurements (time with a stopwatch, length with a ruler, temperature with a thermometer, voltage and current with a multimeter)*

So the question is:

“What should students know or need to know to before they carry out experiments with the Lab-of-Tomorrow equipment?”



The answer is that students should:

- *have a detailed idea about how acceleration is defined and*
- *how position and velocity can be measured*
- *be able to draw correct s-t- and a v-t, a-t diagrams despite of the inaccuracy of measurement*
- *know the difference between average velocity and instantaneous velocity,*
- *be able to interpret an s-t-diagram and from this graph derive the*
- *average velocity as the slope of the linear graph and the*
- *instantaneous velocity as the slope of the tangent of the non-linear graph*
- *know that also the area under the graph has a special physical meaning*
(esp. area under v-t-diagram _ distance)

Teachers should have a general impression of which of the above topics their students know and feel comfortable to handle in physics and science lessons. These topics are listed in national curricula and considered basic knowledge and thus they are taught extensively in schools. However if the teacher realise that students need to have some additional exercise and support lessons the following sequence of lessons is suggested as an introduction into basic physical methods and knowledge and familiarisation with the Lab of Tomorrow tools.

3.4 Sequence of preparatory lessons

In general, a sequence of preparatory lessons and experiments are proposed in order for the students or the LoT users in general, to be familiarized with the way of “thinking” and “acting” within the framework of Lab of Tomorrow.

In case of a teacher who is about to implement Lab of Tomorrow in classroom, apart from the preparatory experiments the introduction of the Lab of Tomorrow may additionally include:

- *Worksheets in “Mechanics: Introduction into Kinematics”*
- *Worksheets on “Interpretation of diagrams” (1 - 2 lessons / homework)*
- *Worksheets on “Getting practice in measuring” (2 - 4 lessons)*

Choose worksheets depending on the time available and the general competence in science of the classroom.

Teams of students carry out several simple experiments and work out the results. Thus they learn about several methods of measuring, about discussing and presenting the results and about different types of movement.

Experiments with the “Lab of Tomorrow” equipment

As it was mentioned above the aim of these experiments is to get the students accustomed with handling the equipment and the software and with interpreting the graphs delivered by the software.

Carry out some of these tests with changing sample rates 10 - 100 Hz

Initial Experiments with the Ball

Let the ball lying on the Table

Orientate the ball in such a way, that the x- and y-axis deliver the value “0” and the z-axis delivers “1”.

Explain the reason!

How do accelerometers work?



Attention

The ball has embedded three one dimensional accelerometers combined in a way that the result is a three dimensional accelerometer. The important parameter in the measurements is that although we are referring to the sensors as accelerometers the actual measurement is **the force exerted on each sensor in the respective axis in a certain time**. Taking into account that the inertial mass of the sensor is constant then through the Newton's second law $F=m \cdot a$ you can have one to one correlation of force exerted on the sensor F and the a acceleration experienced by the sensor.

To avoid introducing any notional confusion to students it is suggested here to explain to them that what is measured by the accelerometers of the Lab of Tomorrow system is the **“the reaction force that the sensor feels at each moment”**. Do not forget that the same applies to the accelerometer sensors of the Sensvest accelerometer.

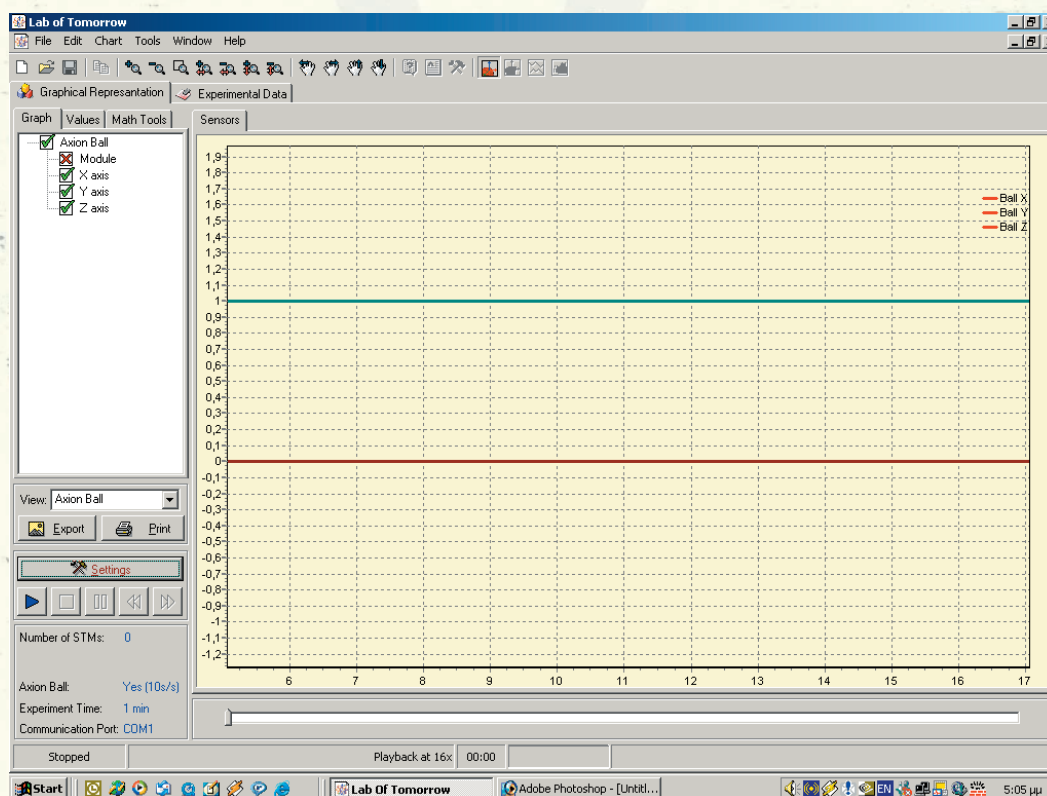


Figure 3.1 The ball is standing still on a surface

Conducting the experiment as it is prescribed above it will lead to results presented on the User Interface that are similar to the screenshot above.

The z axis will give back the value 1. This is because the only axis that feels any force is the z axis. This has to do with orientation of the accelerometers' axis of the ball shown on Diagram 1 and can be explained with the following simple argument. When the ball is standing still on the surface it acts force equal to its weight $B = m \cdot g$ to the surface and the surface reacts back with an equal and opposite force $N = m \cdot g$ according to the third Newton's law. The sensor measures what it feels and it feels only **reaction forces** so the feedback value is the value of **N**. Please notice that the reaction forces in the LoT User Interface are given in units of **g** (see the y axis of the screenshot). In this case what it is given back by the sensor is the force N which is equal with the weight of the ball, but in units of g and thus is 1 g. On the other hand the x and y axis accelerometers give back a zero value since they are orientated in the horizontal plane where no reaction forces are applied (no forces in general are applied in this case).

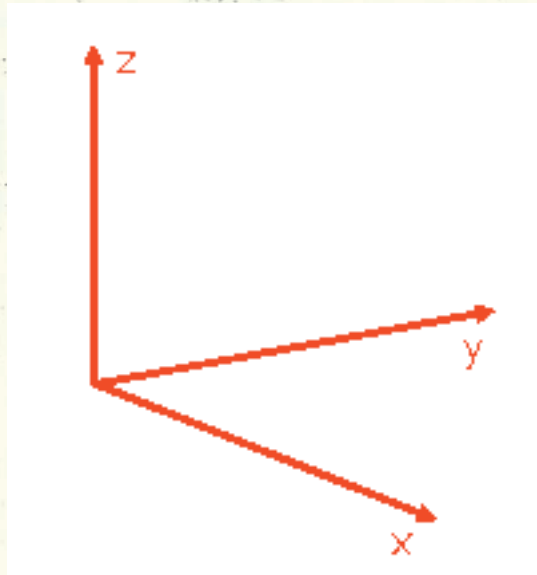


Diagram 1 Orientation of the accelerometers' axis of the ball

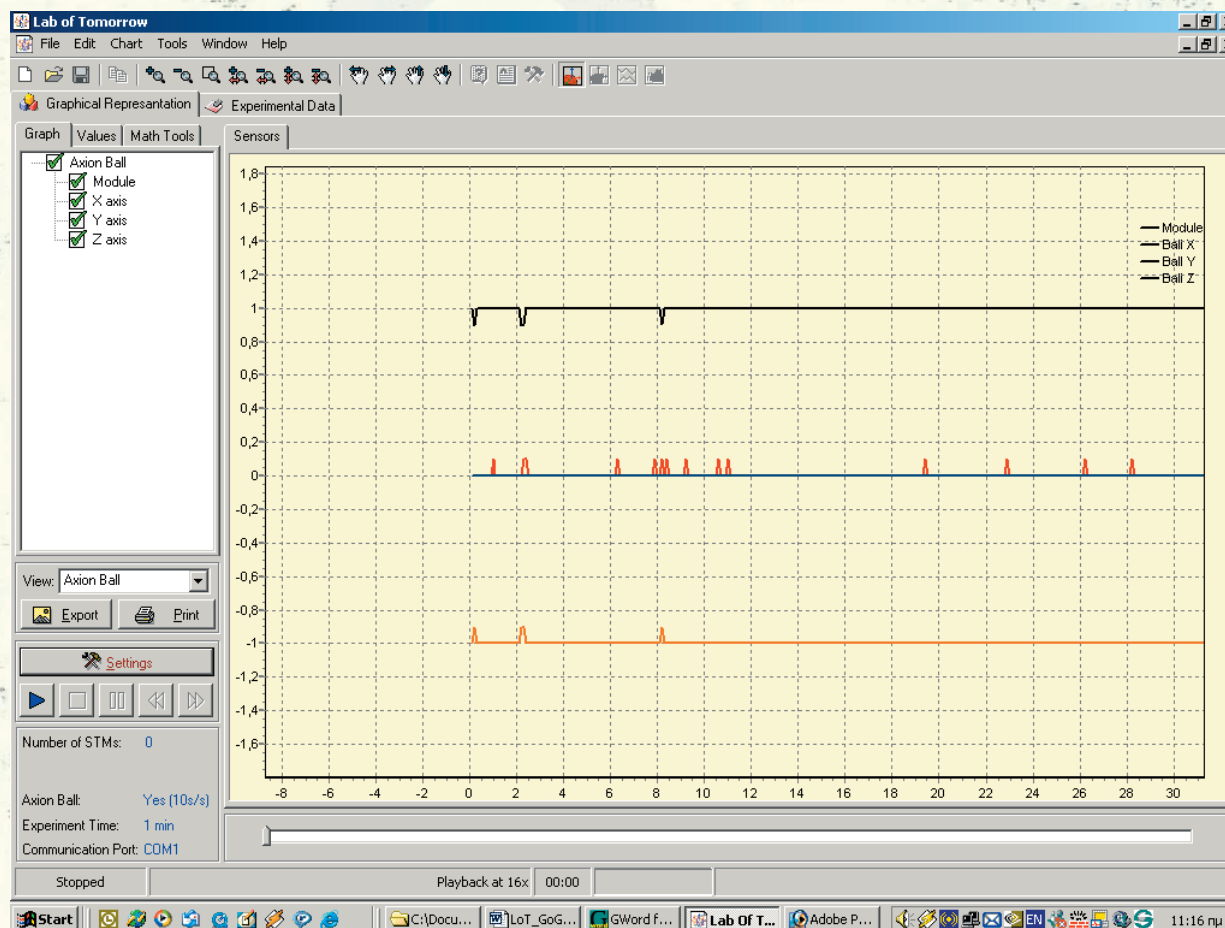


Figure 3.2 Ball standing still on a table with the positive z axis reversed.

If the orientation of the z axis of the ball accelerometer is reversed (Diagram 2) then the resulting graph is similar to Figure 3.2. You can note that this time the value of the z accelerometer is -1 while still the x and y are giving back zero.

Important

Notice that on the graph is also presented the module of the reaction force that is being sensed i.e the net value of all the reaction force coordinates x,y,z (the square root of the sum of the squares of the three coordinates).

The module, as it is a value of a square root, is always a positive number it is very useful for the presentation of data since can be understood more easily by the students. This is because the module is not a vector, is just the net value of the total force.

If we would like to study the x,y,z coordinates of the force sensed by the ball when hitting the surface we can always select the respective components from the option area of the User Interface at the left part of the screen. As you can see each sensor x,y or z experiences something different depending its orientation and can record negative values as well. However the module is the sum of these components and is always a positive number.

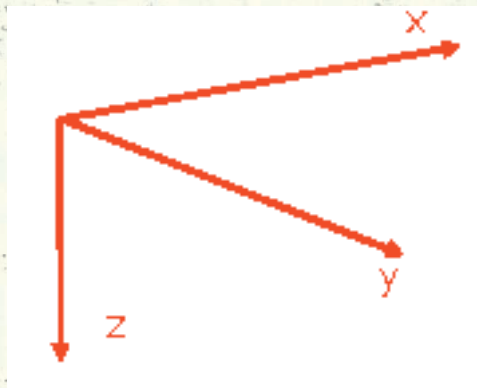
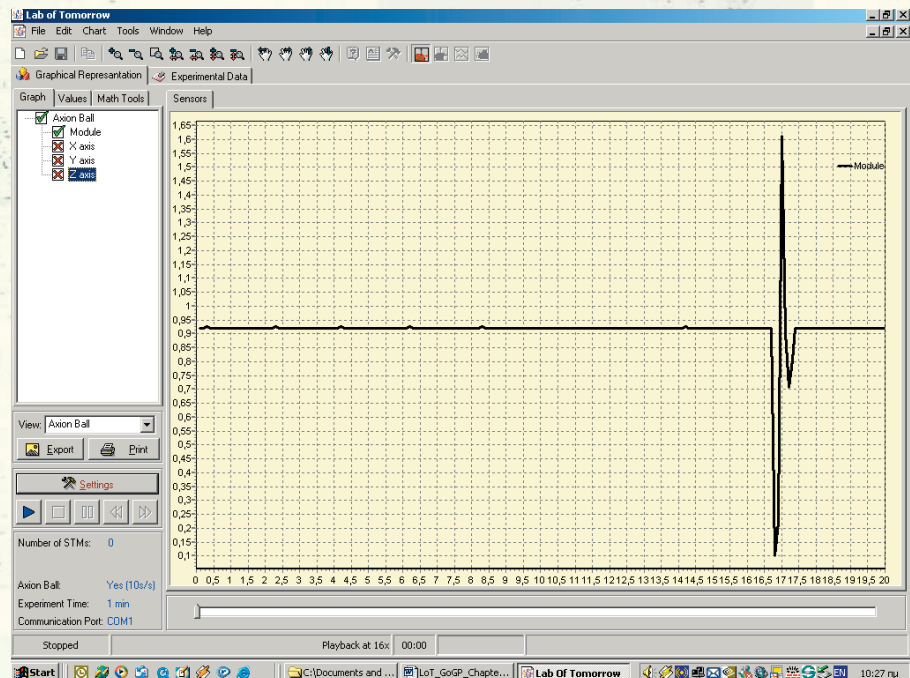


Diagram 2 Orientation with the z accelerometer axis reversed

Hit the table with your fist.

Figure 3.3 Hitting the table, module of the total force sensed by the ball





Hitting the table on which the ball is kept still will produce a graph similar to what is shown in Figure 3.3. The ball when the hand hits the table it almost loses contact (the force N is almost 0) with the surface of the table and thus for an instant the sensor gives us a value near zero as it is indicated with the arrow on the left. The next moment it hits on the surface again so the sensors feel the reaction force of this hit which refers to the peak indicated by the arrow on the right. Finally after a few instants the ball (the sensor actually) regains stability on the surface and the net value that it is given back by the system is 1 (the value of the force N). It has to be mentioned here that what it is presented on the graph is the result of the vibration that is “diffused” to the sensor indirectly via the surface of the table. What the sensor “feels” depends on the way we hit the surface, the material of the surface and its characteristics and the way that this vibration moves to the sensors. It is usual that you will not always take the same results in this experiment since there is not any force applied on the ball in a direct way.

Rolling the ball on the table

If possible, it should be orientated in such a way, that the z-acceleration is “0”.

Describe the graphs (x-, y-,).

Count the number of rotations.

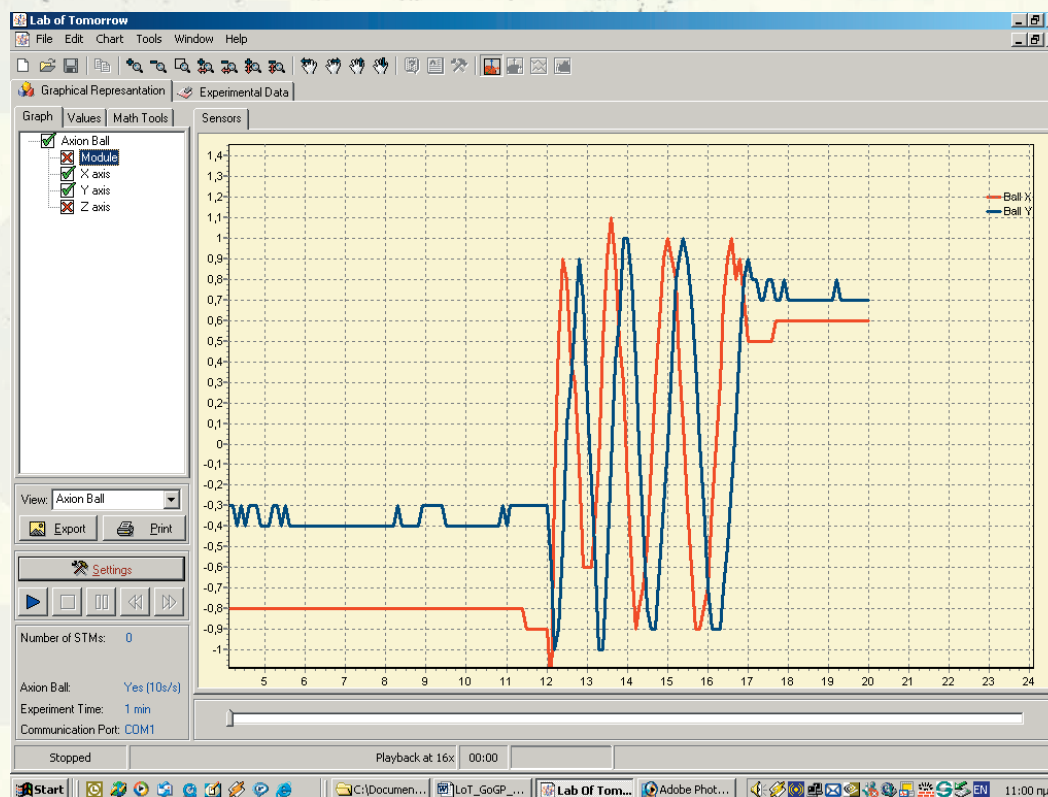


Figure 3.4 Rolling the ball

Conducting this experiment it will result to graphs like the one of Figure 3.4. The ball before starting rolling was roughly orientated in a way the the z axis accelerometer was horizontal and always giving back the value 0 (no reaction force is applied on the horizontal plane) while the x, y were orientated in vertical plane in a way that the initial values was approximately 1 for x accelerometer and approximately 0 for y axis.

As the ball starts to roll then progressively the value of x alters from 1 and becomes 0 and then -1 and so on. Something similar applies for y accelerometer, it's value changes from 0 to 1 and then 0 and -1 and so on. Each time that the accelerometers show their initial values, it means that the ball has completed one cycle while rolling and this is one simple way to count the number of rolls. Notice that the way the acceleration values of the sensors x, y, z are changing depend among others on the initial orientation of the ball.

Holding the ball

Move the ball upwards and downwards several times with alternating speed.

Explain the different heights of the peaks.

What does "module" mean?

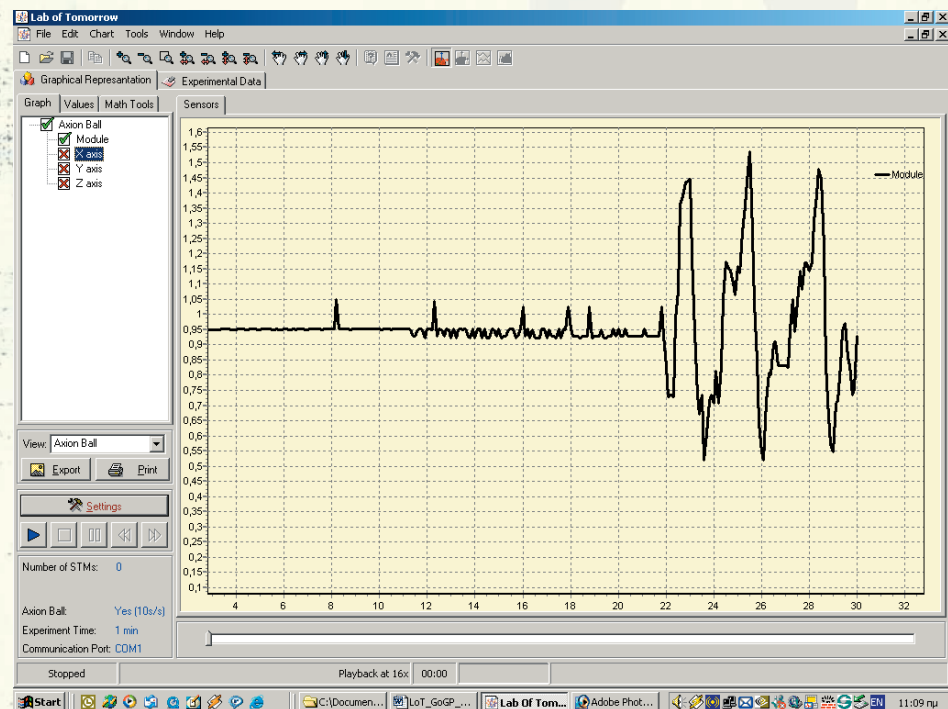


Figure 3.5 Holding and moving the ball with the hand



When someone is holding the ball the sensors record the reaction force exerted from our hand to the ball. This means that if we are not moving our hand at all, the reaction force N that we exert with our hand to the ball is equal to the weight of the ball. However almost always there is a light or less light trembling of our hand which can be also noticed at the left hand side of the Figure 3.5. Moreover when we move our hands, holding the ball, up or down, a force exerted on the ball is imposed by our moving hand and peaks like those that are presented on the right hand side of Figure 3.5 are observed. Note that the graph presents the values of the module of the force exerted on the ball in respect of time. Thus the peaks are always in the positive value part of the graph and each one of them can refer either to an upward or downward movement depending on the specific conditions of the experiment.

Throw the ball vertically upwards several times and catch it in an alternating manner

How long does the free flight last?

Explain the different heights of the peaks when catching the ball.

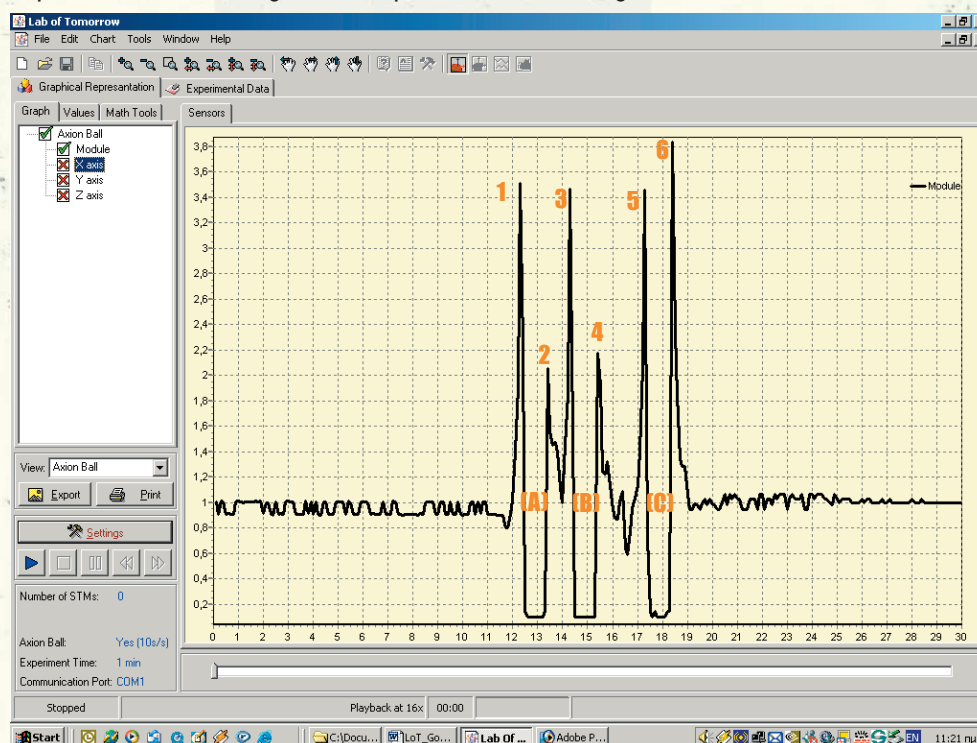


Figure 3.6 The ball is thrown up

When the ball is thrown up and is moving on the air it loses contact with other objects and thus no reaction forces are applied to it. The net force shown on the graph by the sensors is zero. Initially however, our hand threw the ball upwards by exerting instantly a force to the ball. This reaction force is observed and refers to peaks numbered 1, 3, 5. This is the case since in the experiment presented in Figure 3.6 the ball has been thrown upwards three times in the row. The peaks 2, 4 and 6 refer to the three times that the ball was caught again by the hands while the letters A, B and C refer to the time slots when the ball was on the air.

Using the Sensvest

As it is mentioned elsewhere the sensvest consists of three two dimensional accelerometers, one heart pulse meter and one body temperature sensor. There is a large variety of experiments that include LoT user's participation in activities that can be studied with the new tools. The following paragraphs aiming at providing some hints on what can be studied and analysed with the sensvest or what can be studied with the combined use of the sensvest, the ball and the LPS.

Sit down and stand up.

Put on the sensvest components; wear the belt and the arm and leg sensors. After setting up the system and before started taking measurements sit on a chair.

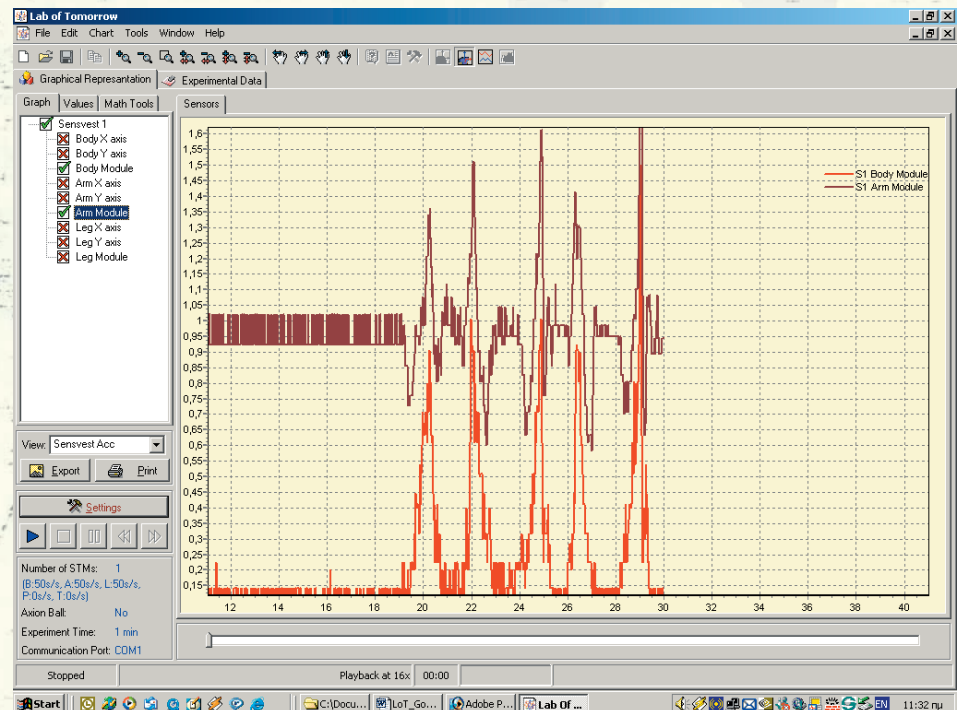


Figure 3.7 Sitting and standing while wearing the sensvest



Proceed to an experiment where the user of the sensvest is sitting and standing several times in the row. If the motion of the leg is neglected and one focus to the body module and the arm module of the acceleration values that are given by the sensvest, then the resulting graph is similar to Figure 3.7. Each time that you stand up or sit down a peak is produced in the positive section of the graph referring to the modules of the arm and body acceleration.

Walk around.

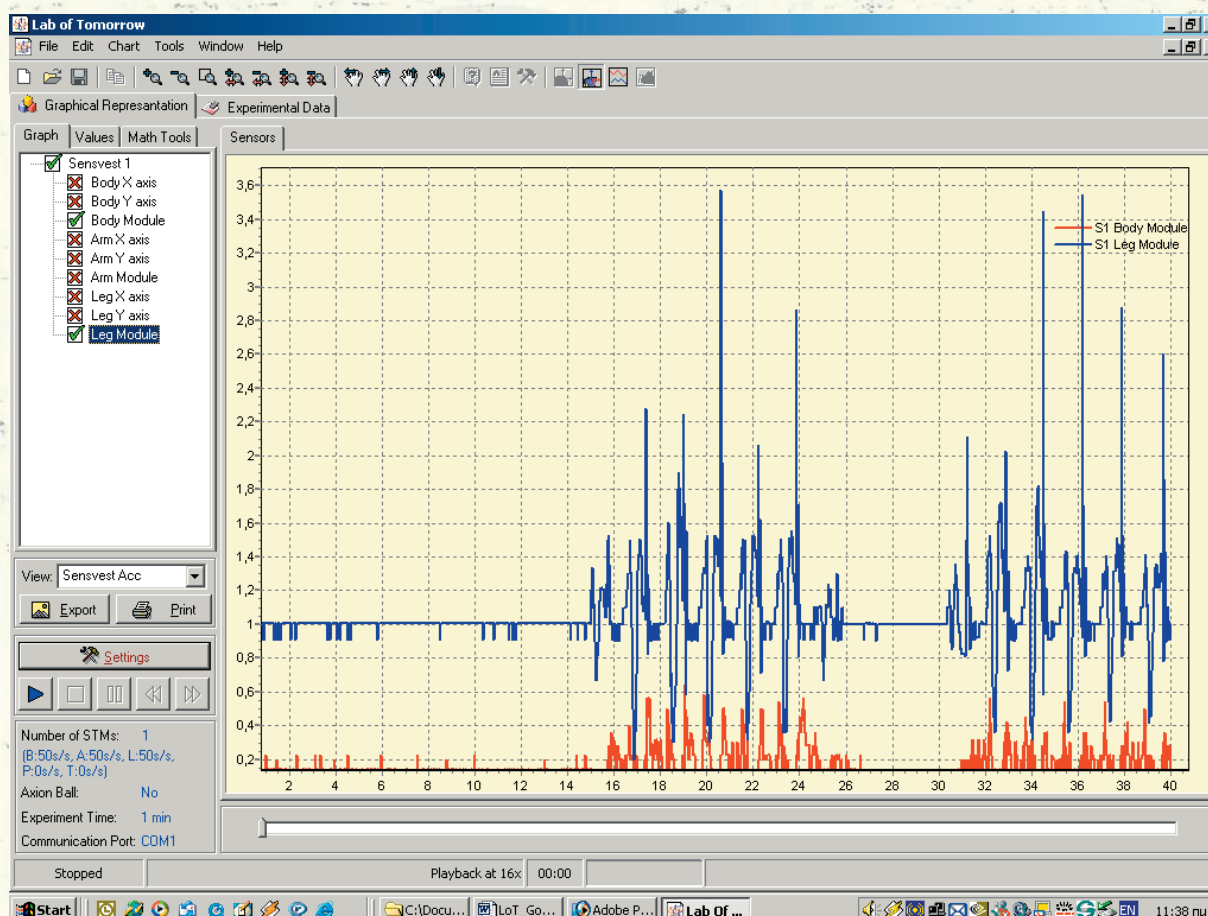


Figure 3.8 Walking around while wearing the sensvest

Walking around while wearing the senvest gives back graphs similar to Figure 3.8. This time the attention is focused to the leg and body acceleration modules. The interest is in the number of the peaks which refer to the number of the steps that are made by the user. Moreover it can be noticed that each time that a step is made there is a respective reaction force that is sensed by the body accelerometer sensor. However the force values recorded by the last sensor is not as high compared to the forces sensed by the leg sensor which is reasonable since the body is not moving or vibrating so much as the leg does in a step.

Jump.

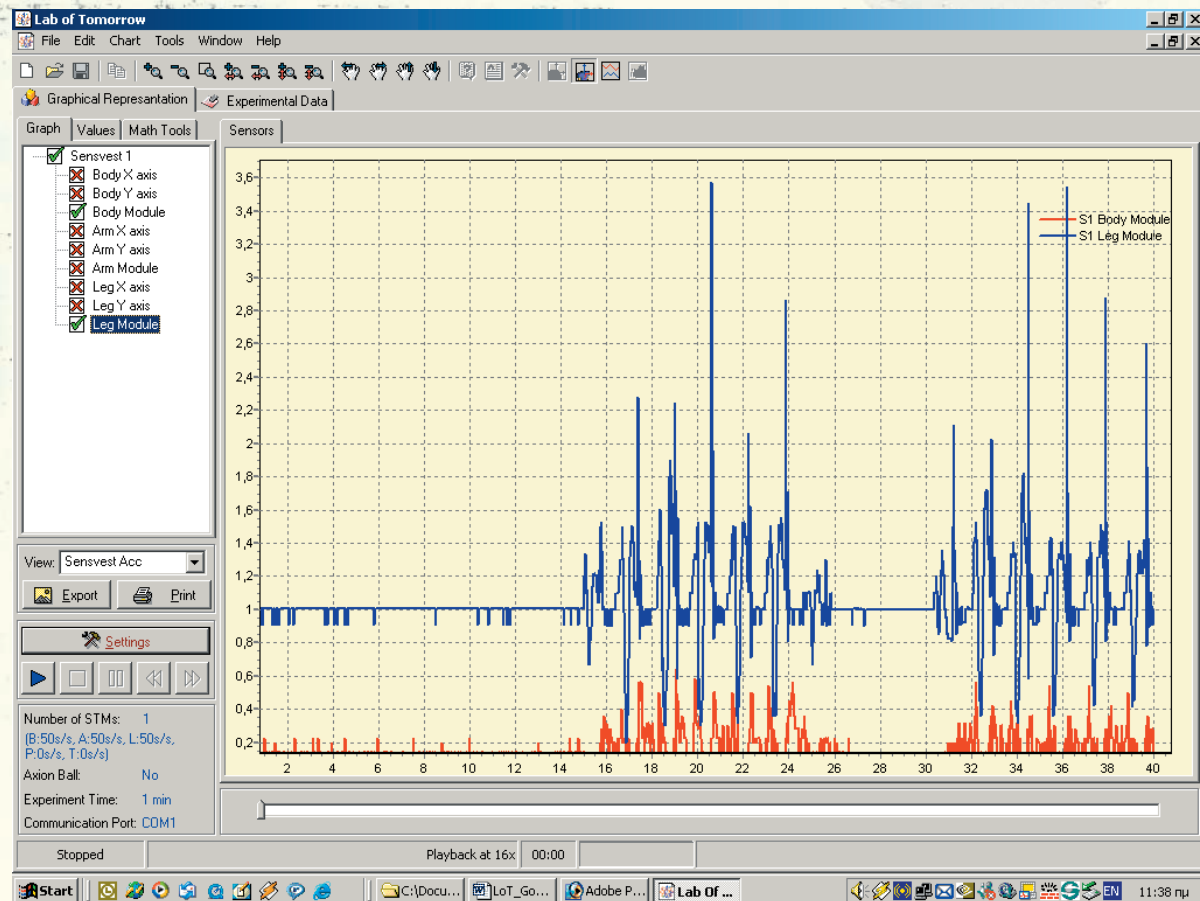


Figure 3.9 Jumping while wearing the sensvest



When jumping while wearing the sensvest the resulting graph is similar to Figure 3.8 qualitatively but the values of the peaks are higher. This is something that is expected since the forces when we hit the ground are stronger than when we walk. In Figure 3.9 we can discriminate three pairs of peaks. The first peak of each pair refers to the force exerted on the leg and the body when jumping upwards while the second refers to the forces when hitting the ground.

3.5 School practice with Lab of Tomorrow

Apart from the above initial experiments there is a variety of other experiments that can be conducted with the LoT tools. There is a series of experiments that are in accordance with national school curricula and can be used for the verification of the basic laws of Mechanics. In this paragraph several examples of this kind are presented and guidelines are given on how can be smoothly introduced in everyday classroom practice.



Free Fall

The following is a lesson plan providing information and material concerning the experimental study of free fall motion with the use of the axion ball.

Specific experimental activities are presented and several questions, exercises and tasks are proposed to assist consolidation of the acquired knowledge.

Figure 3.10a Free Fall

Duration:

- i) Classroom lesson 1x45min
- ii) Experimental Activities 25min

Vocabulary

free fall, linear motion, acceleration of gravity, air resistance

Tools and Materials

Axion Ball, LPS



Aims and Objectives

The students:

- to be able to describe acceleration as the rate of velocity.
- to report free fall as a special case of rectilinear motion with constant acceleration.
- to find out that the acceleration of gravity is the same independently of the object's mass.
- to distinguish accelerating motion - decelerating motion (in case of upwards vertical throw)
- to be able to describe verbally, mathematically and graphically the laws of the basic physical quantities for the free fall motion.

Student's usual Misconceptions

- Heavier objects reach the earth earlier than lighter ones
- Bigger objects reach the earth earlier than smaller ones

Implementation

a. Stimulation

Duration ~20min

- Presentation of selected pictures or videos of different objects falling
- Short discussion on the presented material
- Track student's misconceptions as far as objects' motion is concerned
- Draw up a list on the blackboard with these misconceptions without any comments.



Figure 3.10b Free Fall with the Axion Ball

b. Experimental Activities

I) Ball is left to fall free by student's hand.

The axion ball is left to fall free from student's hands. Data are recorded by the base station and are presented to the students with the User Interface. The LPS system can be used additionally or in parallel to record frames that represent the motion of the ball, so as to have a two fold verification of the theoretical data.

II) Alternative-Additional Experiments

As alternative experiment the following can be proposed:

- The upwards vertical throwing of the ball to study decelerating motion as well

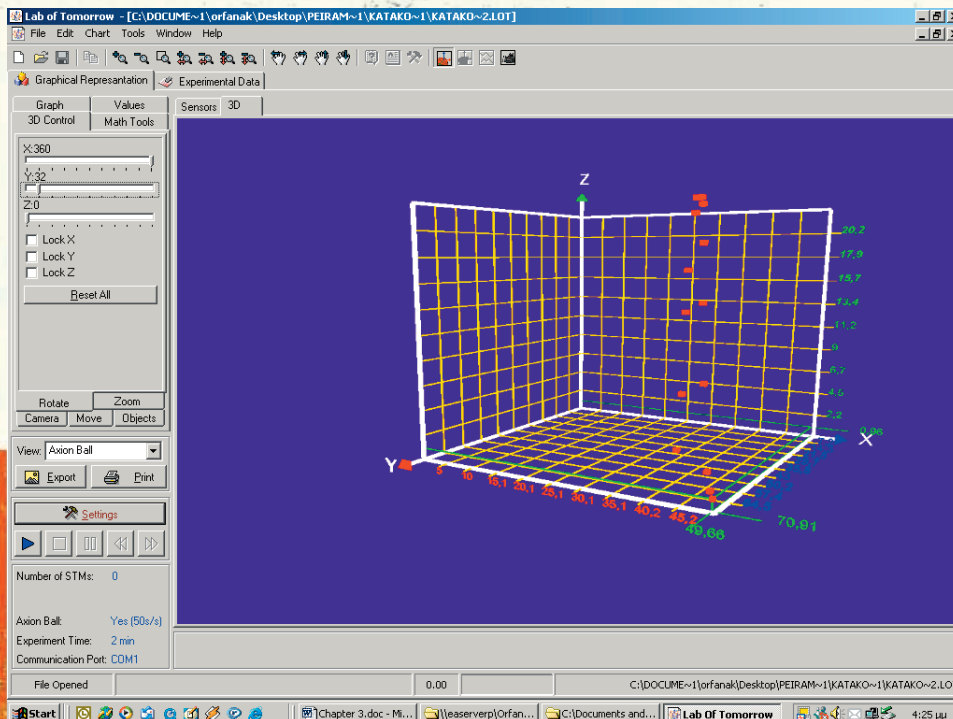


Figure 3.11 LPS data of a Vertical Throw experiment

The vertical throw experiment will have similar results and diagrams with the free fall experiment if one conduct it with the axion ball. It is very interesting though to analyse this motion with the use of LPS by studying diagrams like the one presented in Figure 3.11



c. Observation - Discussion

- Theory and experiment comparison
- Comparison with the ideal theoretical case of each motion case
- Examples deriving from daily activities to start a discussion on the misconceptions

d. Conclusion Drawing

- Free fall time is the same for every object regardless of mass variations
- Physical Quantities, mathematical laws, graphical representations
- Experimental calculation of the acceleration of gravity using the initial height of fall or the time of flight of the ball

e. Consolidation

Questions, exercises and tasks aiming at consolidation of the

acquired knowledge.

In Figure 3.12 which is a typical diagram of a free fall of the axion ball, the area A refers to the time of flight of the ball while the peak 1 refers to the force that is exerted on the ball when it hits the ground. The time of flight can provide the height of the fall experimentally. If the height of the fall is known then the acceleration of gravity can be experimentally calculated by the time of flight.

The rest of the peaks and time of flight period that are shown in the same figure represent the consequent bouncing of the ball.

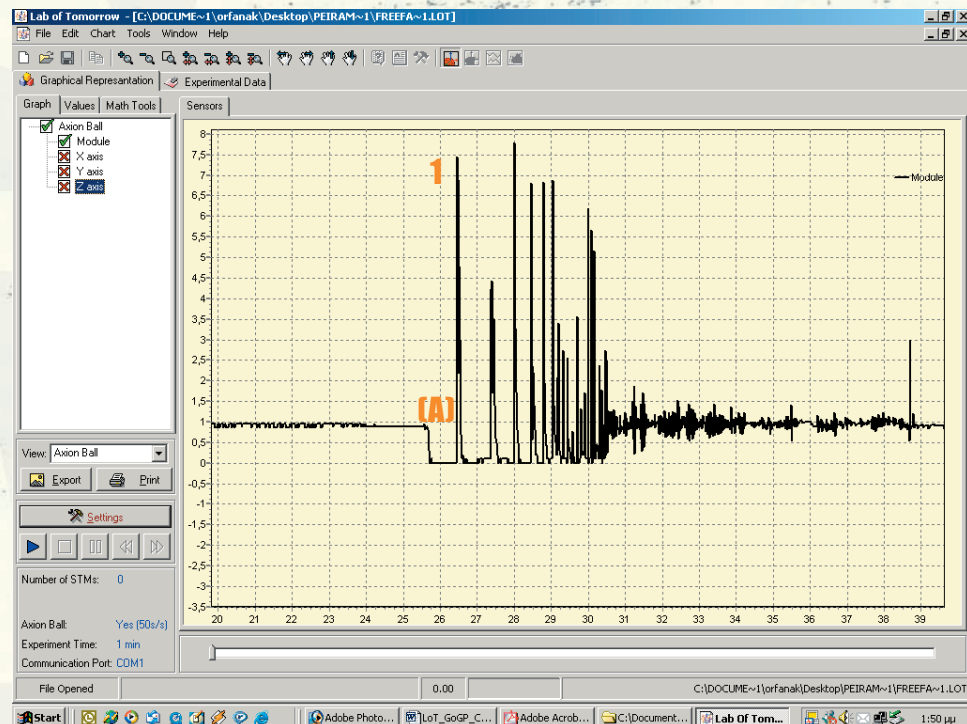


Figure 3.12 The axion ball data during Free Fall

Horizontal Throw

This lesson plan provides information and material concerning the experimental study of horizontal throw motion using the LPS. Specific experimental activities are presented and several questions, exercises and tasks are proposed to assist consolidation of acquired knowledge.

Duration:

- i) Classroom lesson 2x45min
- ii) Experimental Activities 25min

Vocabulary

horizontal throw

Tools and Materials

Axion Ball, LPS, plane surface exalted

Aims and Objectives

The students should:

- be able to distinguish that the motion as a whole can be analyzed in other independent, separate motions
- be able to distinguish the two simple motions (free fall, rectilinear with constant velocity) that constitute horizontal throw.
- be able to describe verbally, mathematically and graphically the laws of the basic physical quantities of the horizontal throw

Student's usual Misconceptions

- there are difficulties for the students to comprehend that horizontal throw is a complex motion
- In horizontal throw, the applied force e.g. by a hand, continues to act on the object (e.g. on the ball) even if the object is no longer in touch with the hand

Implementation

- a. Stimulation

Duration ~20min

- Presentation of selected video of the motion



- Short discussion on the presented material
- Track student's misconceptions as far as objects' motion is concerned
- Draw up a list on the blackboard with these misconceptions without any comments.

b. Experimental Activities

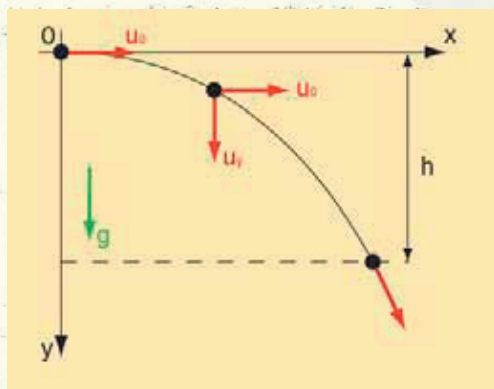


Figure 3.13 Horizontal Throw

I) Horizontal Throw.

A ball is thrown horizontally from an exalted surface. Data are recorded with the LPS

and the exact trajectory of the ball

is constructed afterwards by the User Interface.

The mathematical analysis is done by exporting the data to an excel sheet

II) Alternative-Additional Experiments

As alternative experiment the following can be proposed:

- to repeat the activity with different initial velocities



Figure 3.14 Horizontal Throw, camera frames of the LPS

A characteristic dataset that can be obtained by the LPS during the Horizontal Throw experiment is shown in Figure 3.15. The data presented have been already exported to an excel spreadsheet and have been normalised to the initial conditions(x_0, y_0, z_0) of the experiment.

Χρόνος (s)	X-X ₀ (cm)	Y-Y ₀ (cm)	Z-Z ₀ (cm)
0	0	0	0
0,047	-26,61	1,35	0,15
0,109	-42,61	-1,03	1,55
0,172	-58,58	-0,72	-1,14
0,219	-69,48	-0,5	-0,12
0,281	-80,89	1,38	-1,2
0,328	-98,44	1,68	-6,78
0,391	-112,01	1,91	-8,64
0,437	-119	0,47	-13,15
0,5	-130,44	0,69	-22,71
0,609	-156,79	2,63	-52,94
0,656	-164,55	0,6	-66,11
0,719	-185,16	1,69	-102,85
0,781	-191,54	3,89	-127,58

Figure 3.15 Horizontal Throw data set

The analysis with the mathematic tools of the excel can result the following diagrams

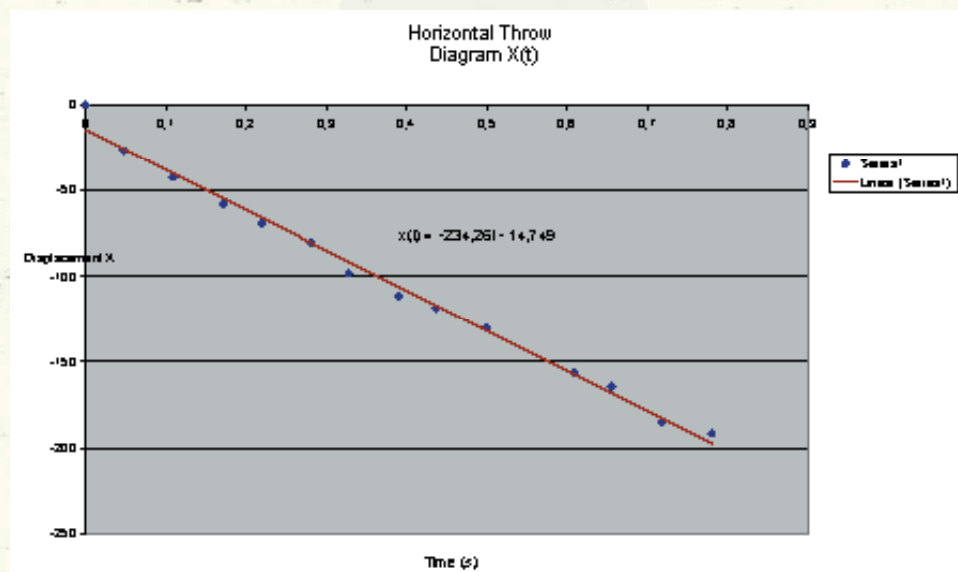


Figure 3.16 Displacement in x axis over time

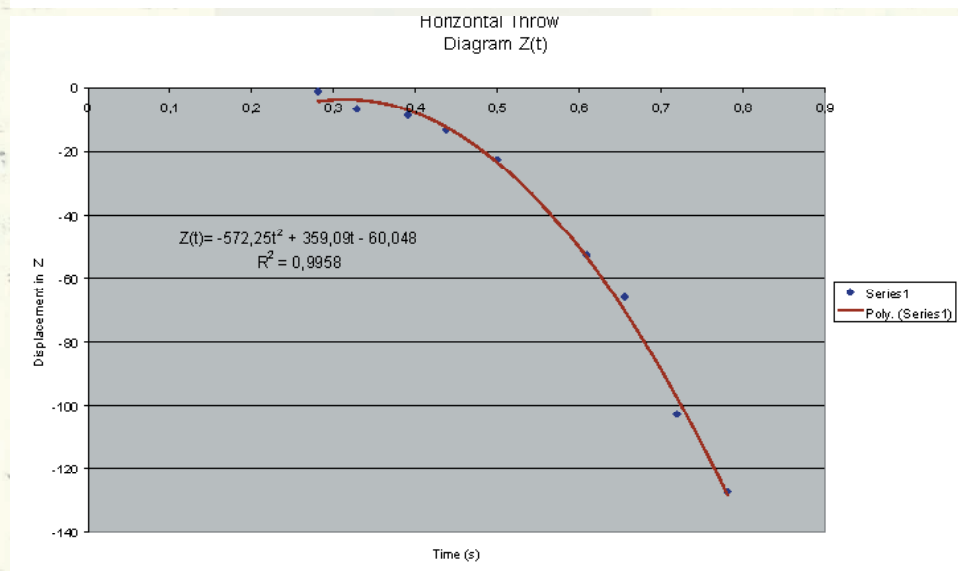


Figure 3.17 Displacement in z axis over time

The analysis of these diagrams can reveal plenty of information and can provide an alternative way of calculating the value of g experimentally.

c. Observation - Discussion

Discussion of theoretical issues arising from the experimental activities.

- Theory and experiment comparison
- Comparison with the ideal theoretical case of each motion case
- Examples deriving from daily activities to start a discussion on the misconceptions

d. Conclusion Drawing

- Motion can be analysed in other separate independent motions
- the falling time of the objects in horizontal throw it is dependent only on the height and it is independent on object's mass and initial velocity
- Physical Quantities, mathematical laws, graphical representations

e. Consolidation

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

Volleyball game

Side Throw

As an example of a more complex situation for the use of the axioms, the following volleyball lesson is given below. This Lesson plan is a proposal for a sequence of lessons in which students can apply their physical knowledge.

It is considered that they already know

- physical quantities
- laws of uniform rectilinear motion
- laws of accelerated rectilinear motion
- superposition of motions
- evaluation of graphs and measurements
- the students know how the axioms work



Duration

i) Conventional Lesson

2x 45 min to evaluate and to discuss the data, verify laws, find new relations between physical subjects

ii) Experimental Activities

45 min in the sports hall

Vocabulary

curvilinear motion

superposition of motions

trajectory

Tools and Materials

- Accelerometer at the player's wrist (part of the sensvest)
- Accelerometer in the ball
- Camera system (LPS) for Video analysis of the ball's motion

Aims and Objectives

- shift physics-lessons out of the classroom into everyday-learning environment
- integrate Lab of Tomorrow Equipment
- verify Newton's laws of motion
- let students apply their physical knowledge
- enable introduction of new principles
- allow students to develop their own experimental ideas

Student's usual Misconceptions

As these lessons takes place, when Newton's laws have already been derived, there should be no misconceptions concerning the laws of motion. But:

- it might be that the students have wrong ideas about the influence of air resistance

- students will think that the higher developed our equipment is the better should all experimental data from different tools fit together.

Implementation

a) Stimulation

For example: Movie of a volleyball match

Task: Examine, whether the physical laws of motion are useful to describe the motion of an ordinary object like a volleyball.

Students can split up that task into several detailed questions, e.g.:

- Measure the initial velocity
- the initial angle of the volleyball by video analysis or by analysing data from the accelerometer.
- Measure the horizontal range of the ball's flight
- ... in terms of the initial angle and
- ... in terms of the initial velocity.
- Compare those data with theoretically derived values and in that way confirm the laws of motion.
- Regard the x- and the y- component of the velocity,
- ... verify that the y-velocity derives from accelerated motion like a vertical throw
- ... and the x- velocity derives from uniform motion
- Describe the difference between theoretically and experimentally acquired data,
- ... estimate the influence of the air resistance.
- Calculate forces and momenta
- If possible, examine other influences, e.g. spinning of the ball.

b) Experimental Activities

students perform single volleyball

tosses like

- underhand serve

- overhand serve
- forearm pass
- overhand pass

wearing the sensor vest.

Other students film those activities with a video camera.



Figure 3.18 Volleyball analysis with LoT tools

c) Observation – Discussion

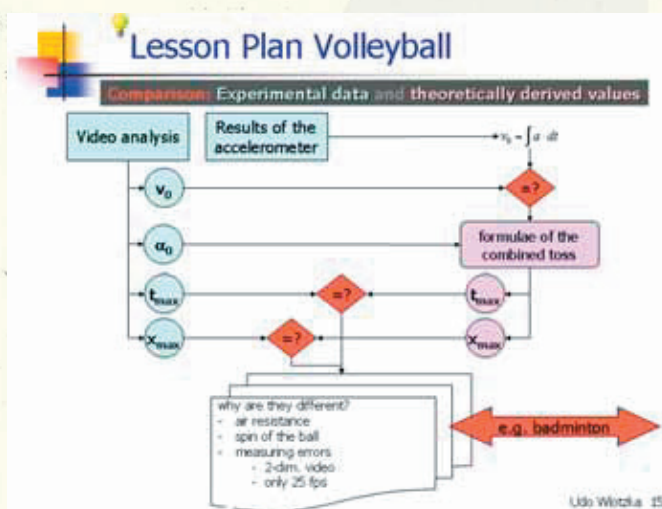


Figure 3.19 Teaching strategy

d) Conclusion Drawing

The motion of a volleyball is nearly a parabola, so it can be described with Newton's laws of motion; especially

- the horizontal range
- the maximum height
- the time of flight can be pre-calculated using the equations of the curvilinear motion, provided that the initial velocity and initial angle are known.

The initial velocity

- can be taken from video analysis
- or by integrating the acceleration (ball and/or body accelerometer)

The results of the three measurements vary a lot. The superposition of motions can be confirmed when x- and y components are regarded separately.

Evaluating the decrease of the horizontal component of velocity the influence of air resistance can be estimated.

It is rather small for a volley ball.

e) Consolidation

Questions

- how can the experiments be improved?
- is there an influence of other aspects, e.g. the spinning of a ball

Exercises

Integration with other subjects

- flight of other objects as cannon balls (see lesson plan "horizontal throw")
- theory of air resistance
- why does the trajectory of a long-range projectile like an intercontinental ballistic missile differ from a parabola (it is more an elliptical path)?



Physics in Sports

A qualitative approach with the use of sensvest

This lesson plan provides information and material concerning the experimental study of simple sport activities utilizing the sensvest axion developed in the lab of tomorrow framework. The main aim is to reveal the basic underlying physical and biologic concepts that govern such activities. Specific experimental activities are presented and several questions, exercises and tasks are proposed to assist consolidation of the acquired knowledge.

Duration:

- i) Classroom lesson 2x45min
- ii) Experimental Activities 25min

Vocabulary

Heart rate, pulse rate, step rate, temperature, acceleration, velocity

Tools and Materials

Axion Sensvest

Aims and Objectives

General Aims

The students should:

- be able to estimate the quality of physical measurements
- be able to make qualitative statements about the precision of a measurement
- to find out the qualitative relationship between physical laws and biology laws

Specific Aims

The students should:

- be able to find out experimentally that the velocity and acceleration of a person who is either moving at a constant speed or is accelerating and then is making a 180° turn, are zero at the exact moment of the turn.
- be able to find out experimentally that pulse rate increases with exercise
- be able to find out experimentally that body temperature varies slightly with exercise
- be able to recognize specific body activities (like a jump or a ball kick) in the peaks of an a-t diagram

Student's usual Misconceptions

- Everything can be determined “exactly” by physical methods
- The acceleration and velocity of a constantly moving body during a 180° turn is not -at any moment of the motion- zero.
- There is significant variation in body temperature during body activity
- There is energy consumption only in intense physical activities

Implementation

a. Stimulation

Duration ~20min

- Presentation of selected video of an athlete on a lab during ergometric tests.
- Short discussion about physics in sports and human physiological parameters in various sport activities, discussion on what could be measured during these tests and why.
- Track student's misconceptions arising from the previous discussion
- Draw up a list on the blackboard with these misconceptions without any comments.

b. Experimental Activities

1) Walk to one direction, turn around and walk backwards

A student wearing the sensvest walks in one direction

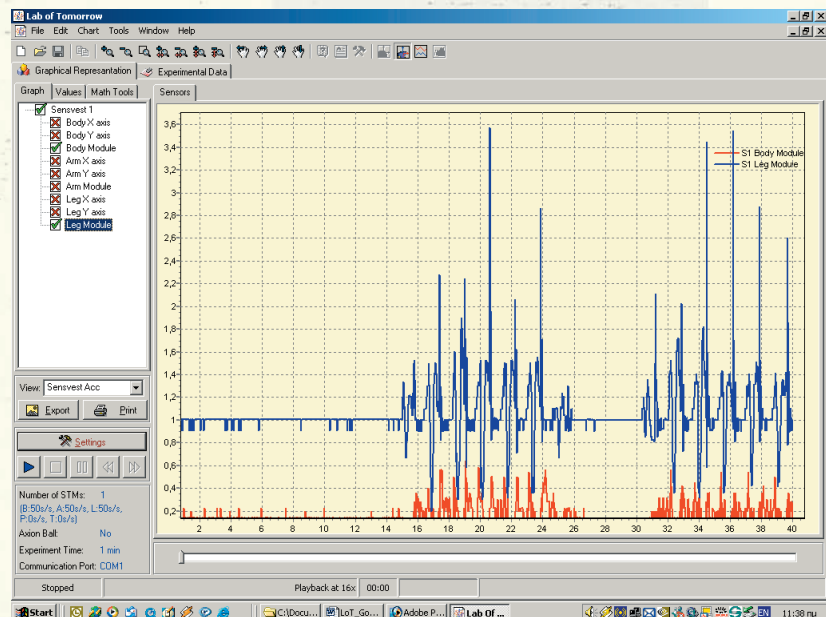
with approximately constant velocity, after some

meters walk, turns around to continue his walk back to

his starting point. Data from the sensvest (body acceleration,

pulse rate, temperature) are recorded.

Figure 3.20 Walking forward and backwards





II) Accelerate in one direction, turn around and accelerate backwards

A student wearing the sensvest accelerates in one direction and after a several meters run, turns around to continue running back to his starting point. Data from the sensvest (body acceleration, pulse rate, temperature) are recorded.

III) Jumping repeatedly with different rates

A student wearing the sensvest starts jumping repeatedly on the same spot for a several seconds.

The physiological parameters of the student (pulse rate, temperature, body acceleration) as well as the jumping rate are recorded. The experiments is repeated with different duration and jumping rate.

IV) Combined movements

A student wearing the sensvest is making more complex moves while wearing the sensvest. Figure 3.21 presents a typical diagram of its kind when the student sits and stands up, walks, runs and jumps.

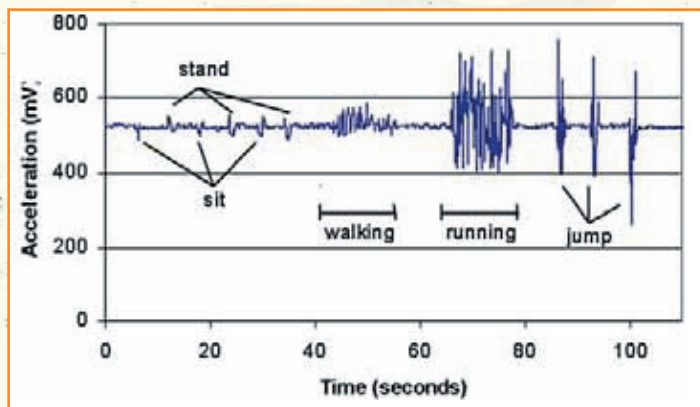


Figure 3.21 Analysing combined movements with the sensvest

V) Alternative-Additional Experiments

As alternative experiments the following can be proposed:

- Repeat the former experiments with male, female students and teachers to record possible differences
- Repeat the former experiments with different degrees of effort and speed

c. Observation - Discussion

Discussion of theoretical issues based on the experimental activities.

- Theory and experiment comparison
- Examples deriving from daily activities to start a discussion on the misconceptions

d. Conclusion Drawing

Students write down the conclusions from their experimental activities and the relevant discussions.

- Nothing can be determined “exactly” by physical methods
- There are significant variations in several physiological parameters during physical activities.
- There is energy consumption of human body during any physical activity.

e. Consolidation

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

Kicking and catching the ball

A qualitative approach with the use of sensvest

This lesson plan provides information and material concerning the experimental study of simple sport activity utilizing the sensvest and the ball axions. The main aim is to verify experimentally the validity of the third Newton's Law. There are not many experiments in the conventional school laboratory that allow the study of the third Newton's Law and thus this experiment has special added value.

Duration:

- i) Classroom lesson 1x45min
- ii) Experimental Activities 25min

Vocabulary

Action-reaction

Tools and Materials

Axion Ball, sensvest

Aims and Objectives

The students:



- to be able to understand action and reaction law
- to be able to report that action and reaction do not result to a total zero force value
- to find out that gravity is the only force that is applied on the ball when it is on the air



Figure 3.22 Kicking and catching the ball

Student's usual Misconceptions

- there are difficulties for the students to comprehend that kicking is a complex motion
- In kicking like horizontal throw, the applied force e.g. by the leg or the hand, continues to act on the object (e.g. on the ball) even if the object is no longer in touch with the leg or the hand

Implementation

a. Stimulation

Duration ~20min

- Presentation of selected video of a football game or penalty kicks
- Short discussion on the presented material
- Track student's misconceptions as far as objects' motion is concerned
- Draw up a list on the blackboard with these misconceptions without any comments.

b. Experimental Activities

1) Kick and catch the ball

One student is wearing the leg accelerometer and kicks the ball towards another student who wears the arm accelerometer.

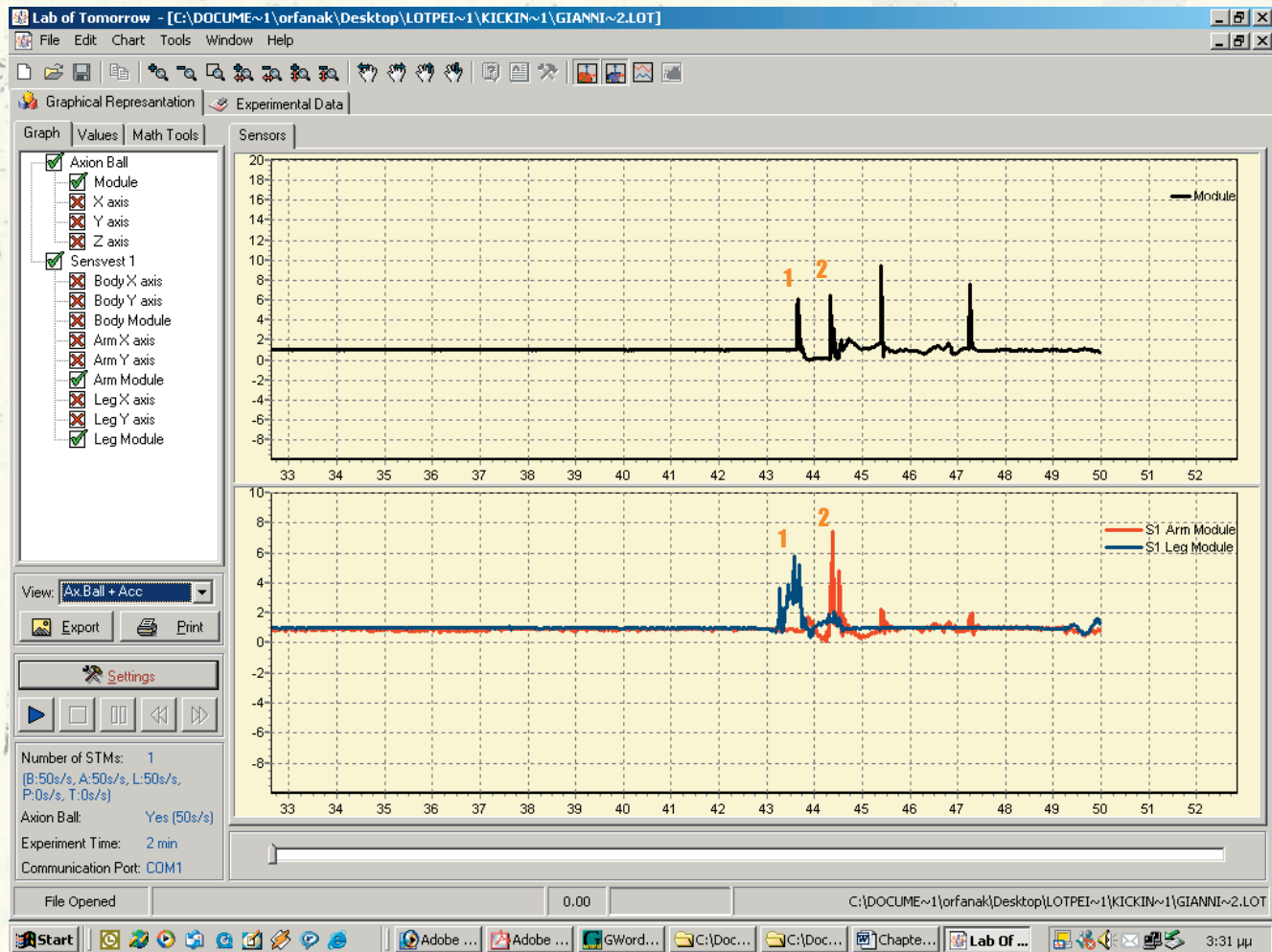


Figure 3.23 Data of kicking and catching the ball experiment



Figure 3.23 is a very characteristic example of the verification of the 3rd Newton's law and the qualitative analysis of a complex activity like kicking and catching a ball. The black line refers to the total reaction force that is exerted on the ball while the blue and red lines are the reaction forces sensed by the leg and arm sensors respectively. At instant 1 a peak is presented in the diagram both for the leg and the ball. The values of the peaks are almost identical which represents the verification of the 3rd law. The peaks of the leg sensor before instant 1 represent the motion of the leg while the ball at the same time is still on the ground not moving.

The 3rd law is again verified at the instant 2 which represents the instant that the ball is being caught by the other student's hand. Again the two reaction force peaks of the ball and the arm have almost the same value.

The time interval between instants 1 and 2 represent the time of flight of the ball.

V) Alternative-Additional Experiments

As alternative experiments the following can be proposed:

- Repeat the former experiment with male, female students and instead of catching the ball kick it against the wall.

c. Observation - Discussion

Discussion of theoretical issues based on the experimental activities.

- Theory and experiment comparison
- Examples deriving from daily activities to start a discussion on the misconceptions

d. Conclusion Drawing

Students write down the conclusions from their experimental activities and the relevant discussions.

- Nothing can be determined "exactly" by physical methods
- Action has its reaction
- The only universal force on earth is gravity

e. Consolidation

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



Chapter 4

Evaluation of Lab of Tomorrow

4.1 Introduction

While modern technology occupies a major part in everyday life and is commonly available in schools of today, the technology itself does not provide support of the development of scientific concepts: To many students working in a science laboratory is limited to manipulating equipment instead of manipulating ideas. This is because of two reasons: on the one hand modern technological equipment is seldom designed and developed with pedagogical aspects in mind; on the other hand are pedagogical concepts seldom well-adjusted to the special features and possibilities modern technology offers.

Therefore the basic idea of the Lab of Tomorrow project is to develop innovative pedagogical and technological approaches and to integrate them into a specifically designed learning environment, in which the students shall be enabled to use technical equipment to reach the level of interpretation of observed phenomena in a shorter time and without needing mathematical competences which are beyond their capabilities.



4.2 Project's Evaluation Scheme

The evaluation of the Lab of Tomorrow project is based on three aspects:

- Evaluation of students' learning. In assessing students' learning, students' engagement in science as inquiry is going to be primarily examined. It is assumed that the activity of designing projects and experiments provides a powerful way for students to be involved in scientific inquiry
- Evaluation of the pedagogical framework. The major theoretical issue underlying the project asks whether the implementation of the technology is able to offer a qualitative upgrade of science teaching at high school level. In such a case the introduction of technology would not act as a substitute of the conventional teaching but rather as an addition that has to justify its introduction in everyday school practice.
- Ethnographic evaluation. The project will take advantage of the different school environments across Europe and is going to investigate the attitudes of students and teachers of different cultures to the implementation of ICT in education.

As stated above the evaluation scheme concerns three aspects. Consequently for each of the three aspects specific research goals and methodologies have to be selected that basically represent the respective aspect.

Research targets

Regarding the evaluation of students' learning the students' performance after attending the Lab of Tomorrow lessons needs to be assessed first. Another important aspect in the evaluation of students' learning is the actual course of the students' learning processes. Since the learning processes in a technology based learning environment like the Lab of Tomorrow mainly depend on the students' abilities in the usage of the technological equipment, it is important to evaluate the students' attitude and aptitude using modern technology. Therefore the following research targets can be formulated as to the evaluation of the Lab of Tomorrow:

- Students' performance before and after attending Lab of Tomorrow lessons
- Students' learning processes
- Students' attitude and aptitude regarding modern technology
- Lesson implementation

The evaluation of the pedagogical framework is tightly related to the actual lesson implementation.

- School background

To correlate different results to different ethnographical situations, background information about the respective school is needed.

The ethnographical evaluation has to be based on the different participating schools. That is, the above characteristics of the evaluation of students' learning and the pedagogical framework have to be compared in this aspect.

Methodology

The evaluation of students' performance in an international project like the Lab of Tomorrow project requires an assessment tool that is able to cope with the different national conditions of the participating countries; namely language, school curricula and culture. A reliable questionnaire accomplishing these qualities has been used in the scope of TIMSS. The items of the TIMSS questionnaire are Rasch-scaled, which allows the comparison of different topics and countries on a large scale related to students' performance. To allow an attribution of the actual test results to the specific Lab of Tomorrow lessons the evaluation will be organised as a pre-post-evaluation with treatment and control groups in one country.

One method for the empirical analysis of learning processes is video documentation. Since the structure of the project and its large extent is not suitable for a detailed analysis of learning processes, only essential key elements of the lessons are taken into account.

To assess students' attitude and aptitude regarding modern technological equipment an ICT questionnaire is used. An extensive literature survey concerning ICT questionnaires showed that surprisingly few studies deal with this topic. Additionally most existing questionnaires are often used without further evaluation and are not taken up, modified and re-evaluated by others. Also a lot of questionnaires are considerably out of date. Since it seems inefficient to develop a wholly new instrument, the questionnaire in line with the Lab of Tomorrow evaluation will be constructed from several questionnaires thereby balancing their weaknesses. While this still allows comparability to some degree it may also be a contribution to the development of a well-evaluated instrument for assessing student's attitude and aptitudes concerning ICT.

The results of the treatment group of Ellinogermaniki Agogi will be compared with a control group. The results of the international TIMSS score may serve as an additional control group especially with a focus on students' performance.



The evaluation of the pedagogical framework is strongly connected with an analysis of the implementation of the lessons. To obtain information about major characteristics of the lesson implementation a teachers' questionnaire will be used. Additional information like for example the lessons superficial structure, students' time-on-task or the teachers' actual education aims can be achieved by analysing the video documentation.

As discussed in the preceding section the ethnographical evaluation will be based on a school-wise comparative analysis of the above results. To gain detailed information about the specific school background a questionnaire will be prepared containing questions regarding the school situation. That questionnaire should be completed by the headmasters of the participating schools.

The following assessment tools are selected to assess data concerning the research targets as specified:

Students performance after attending Lab of Tomorrow lessons	TIMSS Questionnaire
Students learning processes	Video Documentation
Students attitude and aptitude regarding modern technological equipment	ICT Questionnaire
Lesson characteristics	Teachers Questionnaire
Lesson implementation	Video Documentation
School background	School Background Questionnaire

TIMSS Questionnaire

The general idea and structure of the "Third International Mathematics and Science Study" (TIMSS) was described in great detail in the fifth pedagogical report. Therefore it will not be further discussed here.

For the Lab of Tomorrow evaluation the "TIMSS population II test" will be used. It is designed for students at the age of 15 and suitable for the Lab of Tomorrow evaluation because its content matches with the content of the curriculum of the participating countries and the content of the project. In pre- and post-test different booklets will be used to avoid recognition effects. Because of the TIMSS international studies' rotation design pre- and post-tests will still be comparable.

Video Documentation

The use of video documentation provides the possibility of an international comparison but also requires a high standard for that purpose. As a consequence strict video guidelines have to be applied.

The video material is prepared by the partners. For their help two guidelines have been developed where they will find information for high quality video shooting:

- Documentation of the IST-project Lab of Tomorrow
PART I: Checklists for video-taping
- Documentation of the IST-project Lab of Tomorrow
PART II: Guidelines for video-taping

The video material is digitalised and coded by the partners before they send it to the evaluation team; for that purpose a coding seminar is offered. The video documentation thus is carried out once for every lesson. Later it is analysed in respect to the different research targets.

ICT Questionnaire

The ICT questionnaire was constructed of two evaluated assessment tools: the „Computer Attitude Scale“ (CAS), which examines computer anxiety, computer confidence, computer liking and computer usefulness and the „Level of Computer Familiarity“ of TOEFL Examinees.

Teachers Questionnaire

The teachers' questionnaire is supposed to provide an overview in broad outline of the lesson implementation. It contains questions regarding the number of students, the topic of the lesson, the type of experiments carried out, which modules of the “Lab of Tomorrow” system have been used and the estimated learning outcome.

School Background Questionnaire

The school background questionnaire is most important to assess specific school characteristics. The questionnaire consists for example of items concerning the size of the city, the schools' educational profiles, activities, social background, its number and distribution of teachers as well as co-operations.

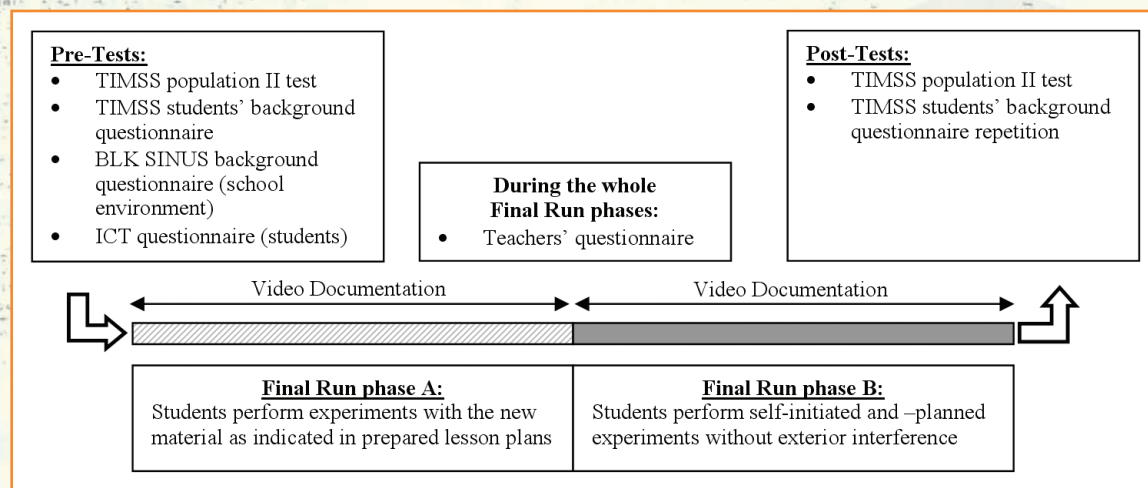


4.3 Evaluation

The evaluation sample regarding the evaluation of students' learning consists of all available students in the physics courses that were either using the Lab of Tomorrow system or were chosen as control group. The following table gives an overview of the participating schools:

School		Country	Type	Age (yrs.)	Students
Bundesgymnasium und Bundes-Realgymnasium Schwechat	BGS	Austria	Treatment	15	30
Helene Lange Gymnasium	HLG	Germany	Treatment	17	20
			Treatment	17	25
Phönix-Gymnasium Hörde	PHX	Germany	Treatment	17	22
Ellinogermaniki Agogi	EA	Greece	Treatment	15	25
			Control	15	24
Technical Senior Secondary School "G. B. Pininfarina"	PIN	Italy	Treatment	15	21

The evaluation of the Lab of Tomorrow was planned as follows: After a preceding test run a final run should follow in two phases. Just before phase A of the final run the TIMSS pre-tests would be carried out. At the same time ICT tests would be performed. In phase A of the final run students then would perform experiments with the Lab of Tomorrow system according to the lesson plans. Phase A is followed by phase B in which the students would be supposed to perform self-planned experiments based on the Lab of Tomorrow system. Both phases would be accompanied by video documentation according to the video guidelines and teachers questionnaires, which the teacher would have to answer directly after every lesson. After completion of phase B the TIMSS post tests would be carried out. The following figure shows a time based overview of the evaluation scheme:



The following table provides the time on task at the respective schools:

School		Final Run Start	Duration of Final Run
Bundesgymnasium und Bundes-Realgymnasium Schwechat	BGS	Mid 02/2004	1.5 months
Helene Lange Gymnasium	HLG	Mid 11/2003	4.5 months
Phönix-Gymnasium Hörde	PHX	Mid 11/2003	4.5 months
Ellinogermaniki Agogi	EA	Mid 11/2003	4.5 months
Technical Senior Secondary School "G. B. Pininfarina"	PIN	End 11/2003	2.5 months

The indicated periods of time represent only the time covered by video recordings and teacher questionnaires sent by the schools.

Despite of that the evaluation scheme of the project has been realised as planned; that is, the TIMSS pre- and post-tests have been carried out before respectively after the scheduled final run period. The ICT tests have been carried out in the same period by the local teachers. Video documentation has been executed by the video groups implemented at the schools in line with the final run. Teacher's questionnaires were handed out to the teachers, who were supposed to fill out one questionnaire for each lesson performed with the „Lab of Tomorrow“ system. The school background questionnaires already had been carried out before the pre-test and final



run phases. All performed tests have been anonymous for privacy. Details of the evaluation procedure are discussed in the following.

TIMSS Questionnaire

As already mentioned the TIMSS questionnaire has been carried out in a pre-post-design. The following table provides information about when the pre-test (1st Run) and post-test (2nd Run) have been carried out at the participating schools. In each case the number of students that performed the test is given in parentheses.

School		Type	1st Run (n)	2nd Run (n)
Bundesgymnasium und Bundes-Realgymnasium Schwechat	BGS	Treatment	10/2003 (30)	4/2004 (25)
Helene Lange Gymnasium	HLG	Treatment	11/2003 (20)	4/2004 (18)
		Treatment	11/2003 (25)	4/2004 (24)
Phönix-Gymnasium Hörde	PHX	Treatment	11/2003 (22)	4/2004 (17)
Ellinogermaniki Agogi	EA	Treatment	10/2003 (25)	3/2004 (22)
		Control	10/2003 (24)	3/2004 (24)
Technical Senior Secondary School "G. B. Pininfarina"	PIN	Treatment	10/2003 (21)	3/2004 (21)

As can be seen from the provided dates, there have been only about 6 months between the two runs. Since this is about half of the originally planned final run duration, differences of 15 year old students' performance between classes may no longer be detected by the TIMSS questionnaire, but of course differences between pre- and post testing. According to former longitudinal studies by means of TIMSS-testing an increase of one standard deviation can be expected as result of a one year instruction. Thus TIMSS questionnaire results may show no differences of performance increase although the Lab of Tomorrow technical and pedagogical implementation still may have induced different learning processes. Since the development of such an evaluation instrument requires consideration of content and time, it was not possible to respond to this problem in the short time left after the change of schedule and the begin of the final run. Additionally different students missing in the 1st and 2nd test run and problems with making the data anonymous (for different reasons students sometimes couldn't apply the same procedure twice), which partially averted a connection between individual 1st and 2nd run results, limit the data analysis.

Moreover the reports of the executing staff about the test procedure showed great differences concerning the discipline of the classes while performing the tests – especially in some cases the tests were not performed individually. Consequently a comparison between schools cannot be done in most of the cases and has to be handled very carefully.

Video Documentation

For the video documentation video groups should have been trained at each school. These groups were supposed to document the lessons of Lab of Tomorrow according to the two guidelines for the work of the video groups, the “Video-Checklists” and the “Video-Rules”.

It has been decided to classify the videos available by three categories: videos documenting an introductory lesson (Type A), videos documenting a lesson in which students perform simple experiments initiated by the teacher (Type B) and videos documenting a lesson in which students perform complex experiments initiated by them (Type C).

The following table lists the availability of the three video types per school; where „C“ means the video has been recorded according to the guidelines and is comparable in this regards, „N/A“ means the video is not available and „N/C“ means, that the video has not been recorded according to the guidelines and therefore is not comparable. Unfortunately no video of type C has been provided by PHX.

School		Type A	Type B	Type C
Bundesgymnasium und Bundes-Realgymnasium Schwechat	BGS	C	C	C
Helene Lange Gymnasium	HLG	C	C	N/A
		N/A	C	C
Phönix-Gymnasium Hörde	PHX	C	C	-
Ellinogermaniki Agogi	EA	C	C	C
Technical Senior Secondary School “G. B. Pininfarina”	PIN	N/C	N/C	N/C



ICT Questionnaire

The ICT questionnaires as well as the TIMSS questionnaires have been completed well before the start of the project. They have been carried out by the teams at the schools and sent back to the evaluation team. The following table gives an overview of the numbers of the participating students:

School		Type	ICT
Bundesgymnasium und Bundes-Realgymnasium Schwechat	BGS	Treatment	30
Helene Lange Gymnasium	HLG	Treatment	20
		Treatment	25
Phönix-Gymnasium Hörde	PHX	Treatment	22
Ellinogermaniki Agogi	EA	Treatment	25
		Control	24
Technical Senior Secondary School "G. B. Pininfarina"	PIN	Treatment	21

Teachers Questionnaire

The teachers' questionnaires were supposed to be answered directly after the respective lessons in which the Lab of Tomorrow system was used. An analysis of the questionnaires leads to the assumption that this applies only to a small number of lessons. Moreover the number of the teachers' questionnaires differs from class to class (see the following table) and we have some hints that some reports are not filled immediately after the lesson but at once some time later. That means that no reliable comparison of the teachers' questionnaires can be established. Consequently the analysis of the pedagogical framework will be completely based on the analysis of the video documentation.

School		Type	Teachers Questionnaires	Video Documentations
Bundesgymnasium und Bundes-Realgymnasium Schwechat	BGS	Treatment	4	4
Helene Lange Gymnasium	HLG	Treatment	25	6
		Treatment	4	4
Phönix-Gymnasium Hörde	PHX	Treatment	0	0
Ellinogermaniki Agogi	EA	Treatment	11	3
Technical Senior Secondary School “G. B. Pininfarina”	PIN	Treatment	7	7

School Background Questionnaire

The school background questionnaires were sent to the schools’ headmasters in course of the final run and have been received back after an appropriate time from all schools but HLG.



4.4 Results

This section provides a discussion of the project evaluation results.

TIMSS Questionnaire

In a first step the TIMSS questionnaires have been coded and processed according to the TIMSS international studies coding instructions. That included in a first step a professional translation of non-German questionnaires with respect to the items requiring free answers. In a second step the electronically processed data has been verified by the International Association for the Evaluation of Educational Achievements Data Processing Centre (IEA DPC) located in Hamburg. In a third step the IEA DPC computed individual scores for mathematics and science items per student according to the TIMSS95 scoring routines. Finally the computed scores have been Rasch-scaled to allow a comparison between the participating classes.

Math and Science Items

The following tables list the mean average values of the pre-test (1st run) and post-test (2nd run) along with the differences and standard deviations per school for the math and science results; significant differences are marked with an asterisk (*).

Science Results						
School	Type	N	1 st Run	N	2 nd Run	Difference
			Mean (Standard Deviation)		Mean (Standard Deviation)	
BGS	Treatment	30	609 (64)	25	614 (77)	5
HLG	Treatment	45	629 (59)	42	668 (61)	*39
PHX	Treatment	22	651 (66)	18	654 (49)	3
EA	Treatment	25	629 (59)	22	625 (60)	-4
	Control	24	588 (71)	24	599 (89)	11
PIN	Treatment	21	579 (85)	21	510 (66)	*-69



Math Results						
School	Type	N	1 st Run Mean (Standard Deviation)	N	2 nd Run Mean (Standard Deviation)	Difference
BGS	Treatment	30	619 (66)	25	586 (69)	-33
HLG	Treatment	45	610 (76)	42	631 (70)	21
PHX	Treatment	22	629 (85)	18	661 (75)	32
EA	Treatment	25	618 (77)	22	587 (74)	-31
	Control	24	600 (62)	24	605 (81)	5
PIN	Treatment	21	534 (79)	21	487 (58)	* -47

The only significant increase in students' performance concerning science took place at the HLG (17 years of age!). On the opposite the students' performance at PIN shows a significant decrease in both math and science. According to reports from the staff executing the TIMSS questionnaires on-site, this may be the result of a seemingly low students' motivation to perform the questionnaires. Furthermore – though not significant – a comparison of treatment and control group at the EA demonstrates even better results for the control group. Thus a correlation between the use of the Lab of Tomorrow system and pedagogical framework and an increase in students' performance can not be stated regarding scientific literacy as measured by the TIMSS-test. As mentioned before this may be related to the shorter duration of the final run, since minor effects on the increases of learning outcomes can not reliably be measured with the applied methodology. A comparison to the respective countries TIMSS international achievement has been turned down, because of those achievement scores being about 10 years old and the resulting incomparability of populations.

Since the students at the HLG were from a higher grade, it might as well be concluded that the Lab of Tomorrow system could induce a higher effect when used in higher grades. But this can not be confirmed by the students' results at the PHX. Thus it would need further evaluation.

Background Items

Background items in the TIMSS questionnaire were supposed to provide further explanation of differences in math and science results not induced by the project implementation but different private students' profiles. The background items have been correlated with math and science results. First, items not correlating with both – math and science results – have been eliminated from further analysis. In a second step a one way analysis of variance has been performed on the remaining items. Items where significant differences between the participating classes have been found are provided in the table "TIMSS Questionnaire Background Details" in the appendix. The table provides the items grouped by "general", "science" and "math". For each item only significant differences between classes are listed, while a positive value stands for a higher agreement, frequency, et cetera.

In the group of general items it has to be noticed first, that the students' year of birth is significantly lower at PHX and HLG compared to all other participating schools. That would have been expected from the table on page 14 and thus indicates a valid analysis process concerning background items. Moreover has to be noticed, that students at PIN aim for a lower education level than students at BGS, EA, HLG and PHX. That may be related to the PIN special education focus as a technical school. An additionally interesting aspect seems to be a higher security at BGS, EA, HLG and PHX, which is expressed by significantly lower events like stealing or anxiousness of being hurt. This indicates fundamentally different social backgrounds of the students at the participating schools.

Concerning math and science items a demonstrative difference between EA and all other classes can be stated: students at EA receive a significantly higher amount of extra lessons in math and science.

This peculiarity might explain why no significant math or science performance differences could have been observed for students at EAT and EAC. Both groups had obviously the same amount of extra lessons. Other remarkable distinctivenesses concerning math and science background items are: Students at BGS and PIN like math significantly less than students at PHX and EA, and additionally students at BGS like science significantly less than students at all other schools except PIN. This may account for the bad results at PIN and the missing significant changes at BGS. Obviously computers are used more often in math lessons at PIN – in fact significantly more often than at any other participating school. This will have to be kept in mind when analysing the ICT questionnaires in detail.



So basically it can be assumed that a different social and educational background holds the responsibility for missing math and science performance increases and even performance decreases. Moreover may the results of the ICT questionnaire provide more information about whether increases or no increases in students' performance may be related to the students' attitudes and aptitude regarding computer technology.

Video Documentation

The prepared videos of the lessons have – as explained above – been classified in three different categories:

- Type A: Introductory lesson, in which the teacher explains the Lab of Tomorrow system.
- Type B: Lesson with simple experiments, in which students perform experiments with the Lab of Tomorrow system initiated by the teacher.
- Type C: Lesson with complex experiments, in which students perform experiments with the Lab of Tomorrow system initiated by themselves.

For the purpose of the analysis of the recorded lessons a set of categories has been developed by the evaluation team and a video workshop has been held. In the course of the workshop coders from the participating countries were trained (even though limited) in the use of the category system and subsequently coded the videos from their respective countries.

Since the category system for the video analysis will be described in detail in the pedagogical report, only a rough overview will be provided here: Concerning the analysis of the actual lesson implementation, e.g. teaching methods used, a set of categories regarding the superficial characteristics of lessons (Category Set A) has been compiled from the extensive category system Reyer (2003) developed for the analysis of apparent and deep structure of lessons. To receive information about the ICT related activities of students a set of categories regarding computer use and learning physics has been developed (Category Set B). For the analysis concerning educational aims and content-related actions two more category sets have been created based on the work of Reyer (2003): Categories regarding learning physics and modelling (Category Set C) and categories regarding application and transfer of the acquired knowledge (Category Set D). The video documented lessons at hand have been split into coding intervals of 20 seconds. Each interval has been coded with the above mentioned category sets. The analysis of the video documented lessons according to these category sets will be described in the following.

This analysis is mere descriptive and exclusively related to the video documented class. By no means may conclusions be drawn for the respective school or country.

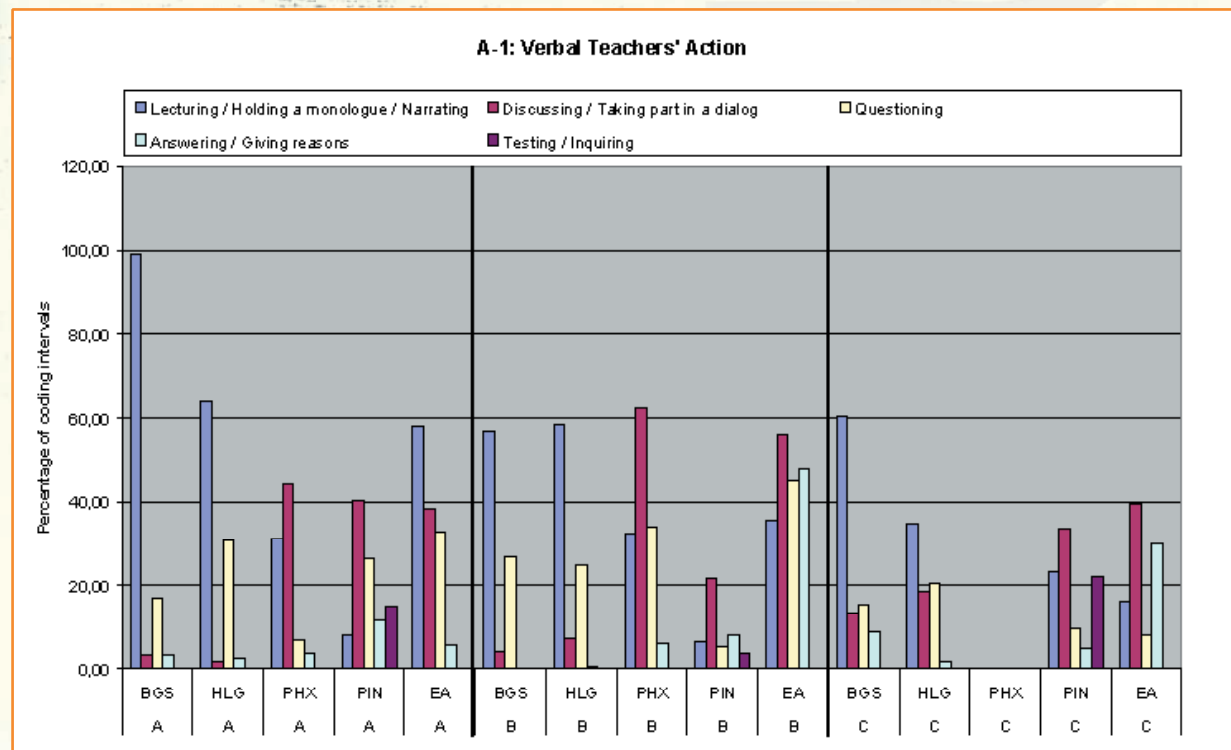
Superficial characteristics of lessons

The description of superficial lesson characteristics allows the creation of profiles regarding the actual lesson implementation in line with the “Lab of Tomorrow” project. The chosen category set contains the following categories:

- Teachers’ verbal action - Teachers’ manipulative action - Teachers’ media	- Students’ verbal action - Students’ manipulative action - Students’ media
- Interaction types - Activities in classroom discourse - Activities in students’ working phases	

Each of these categories conceives between 4 and 7 items, which provides a detailed description.

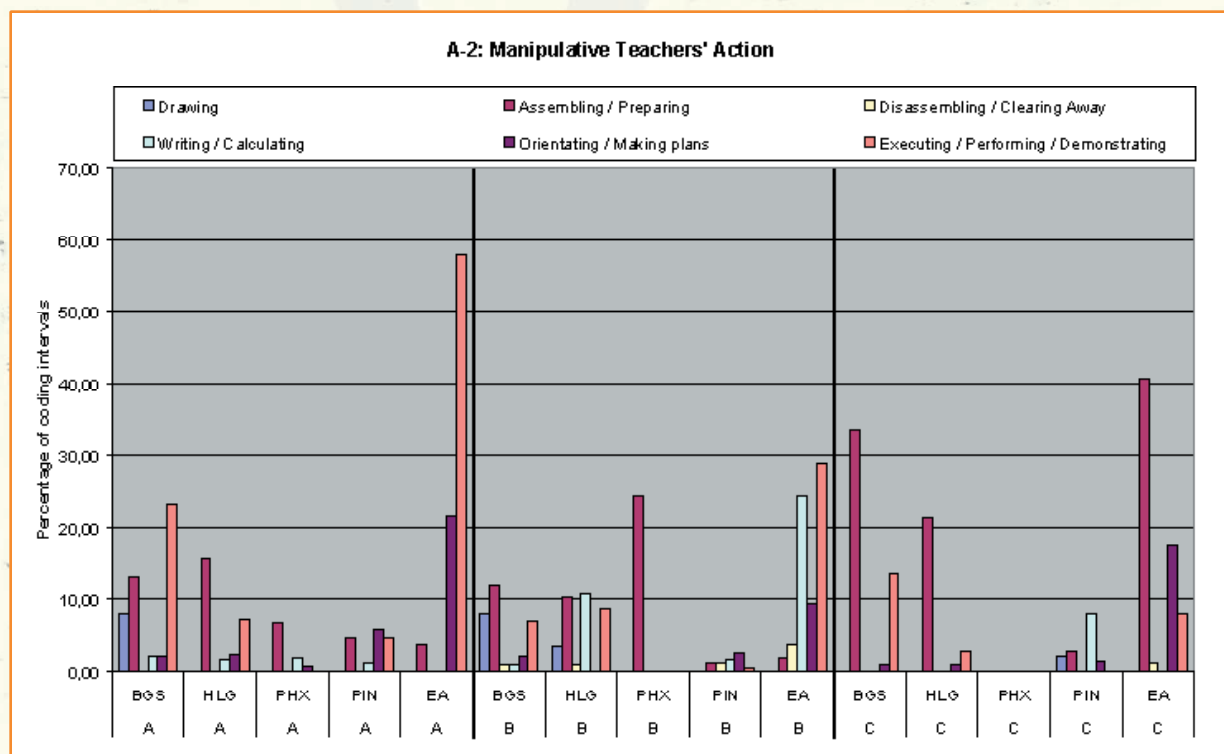
The following figure shows the teachers’ verbal action for the participating schools the video documentation could be analysed – grouped by lesson type (Figure A1):





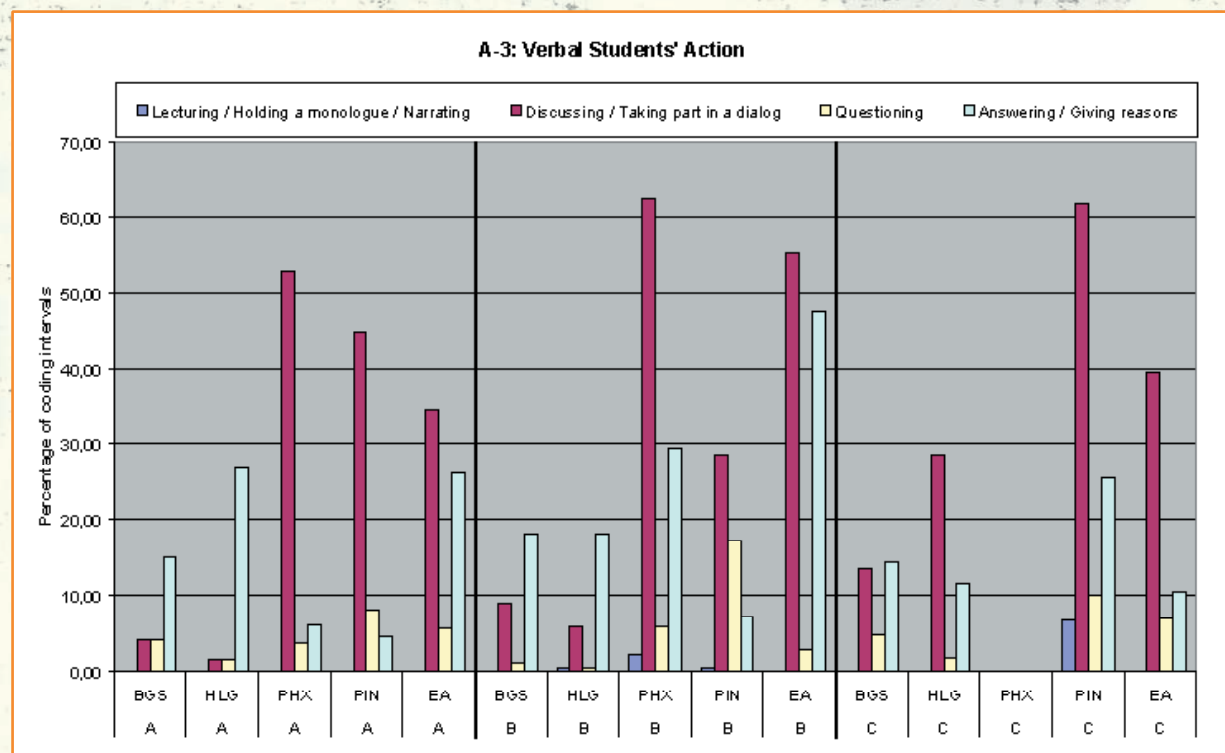
Obviously the teacher's main activity is Lecturing – especially in course of type A lessons. The small shares of *Lecturing* at PIN can be explained by the specially cut video data, which misses for example introductory phases at the beginning of the lessons and explanations of the teacher. In addition lecturing amounts decrease from lesson type A to lesson type C. This confirms expectations, considering that lesson type A is mostly introductory while lesson type C involves the students in an autonomous way. Interestingly the teachers at BGS and HLG in opposite to PHX as well as EA and PIN only show small amounts of *Discussing*, though those amounts grow slightly from type A to type C. The amount of *Questioning* seems to remain nearly constant from lesson type A to lesson type B and to decrease to lesson type C. Again, that was to be expected, since the students do a lot more autonomous work in lesson type C. *Answering* contributions are low for all schools and lesson types except EA where *Answering* takes place a lot in lesson types B and C. Testing could not be observed for all schools but for PIN, where obviously a considerable amount of testing takes place for all lesson types.

Figure A-2 shows the teacher's manipulative actions - again for all schools grouped by lesson types.



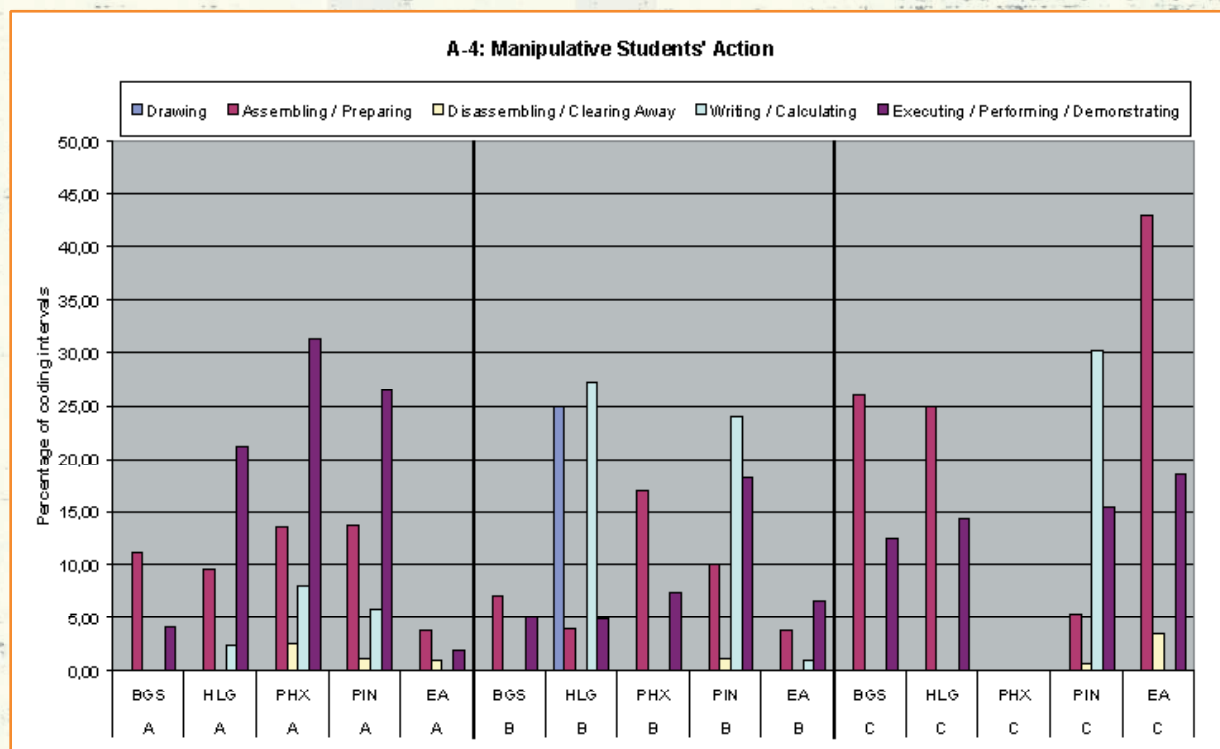
Noticeable amounts of *Assembling and Executing* can be observed for all schools. In case of *Executing* mostly in lesson type A, in case of *Assembling* mostly in lesson type C. Lesson type B seems to be a transition in this regard. The shares for PIN are low in comparison, which applies for all PIN manipulative teachers' actions. Although *Assembling* occurs in a considerable amount, *Disassembling* can not be observed besides very small amounts in lesson type B. *Orientating* respectively *Making Plans* can be considered important only for EA lessons.

Verbal students' actions are shown in Figure A-3.



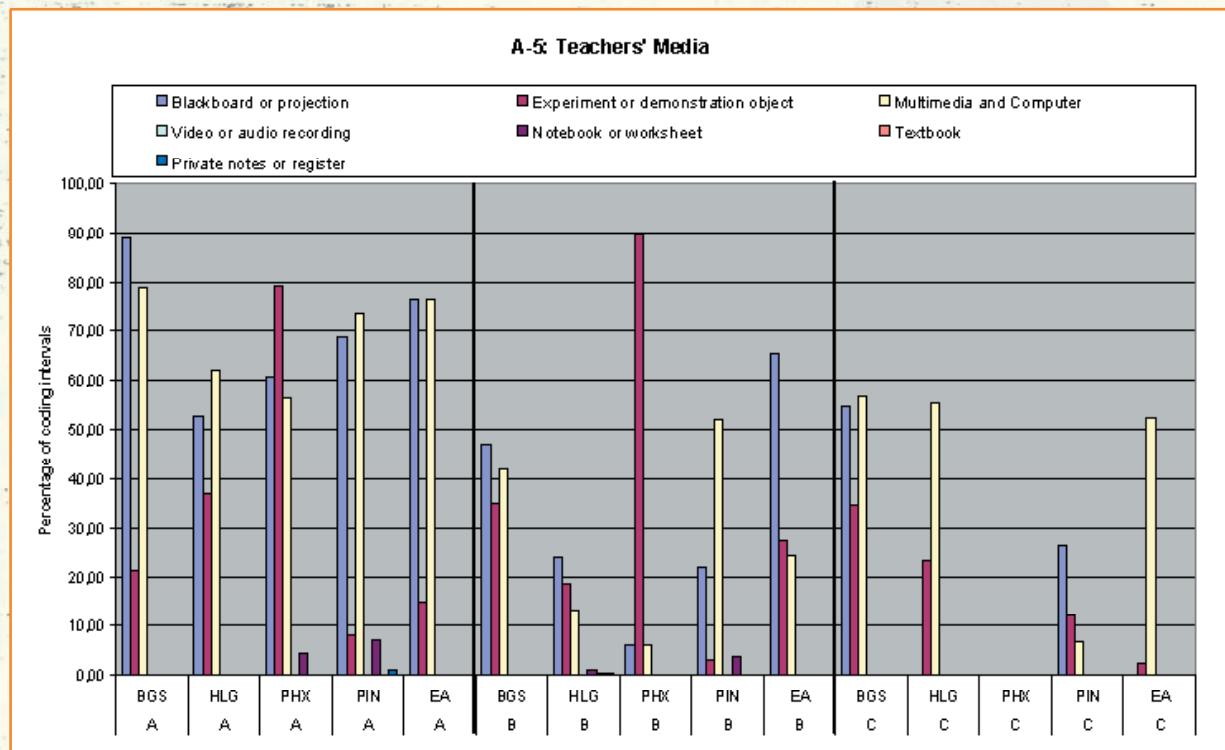
While no noticeable amounts of *Lecturing* can be observed, again high amounts of *Discussing* are revealed at PHX, EA and PIN for all lesson types and the smaller amounts at BGS and HLG in lesson type A still increase to lesson type C. Large amounts of *Answering* and still considerable amounts of *Questioning* can be stated for all schools and all lesson types. Although those do not follow a special scheme, this complements the respective verbal teachers' actions. Thus the observed verbal students' actions fit well with the observed verbal teachers' actions.

Figure A4 presents manipulative students actions.



While Assembling shares are quite low for lesson types A and B, they increase in lesson type C. That seems plausible considering that in self-organised group work more *Explaining* and thus *Drawing* would be needed, as often used in scientific explanations. The high shares of *Executing* for lesson type A, which decrease to lesson type B and C are irritating. They may be explainable if *Executing* is interpreted as a direct consequence of a teachers' directive. The amounts of *Drawing* and *Writing* at HLG in lesson type B and *Writing* at PIN in lesson types B and C seem to indicate that special lesson implementations have been carried out.

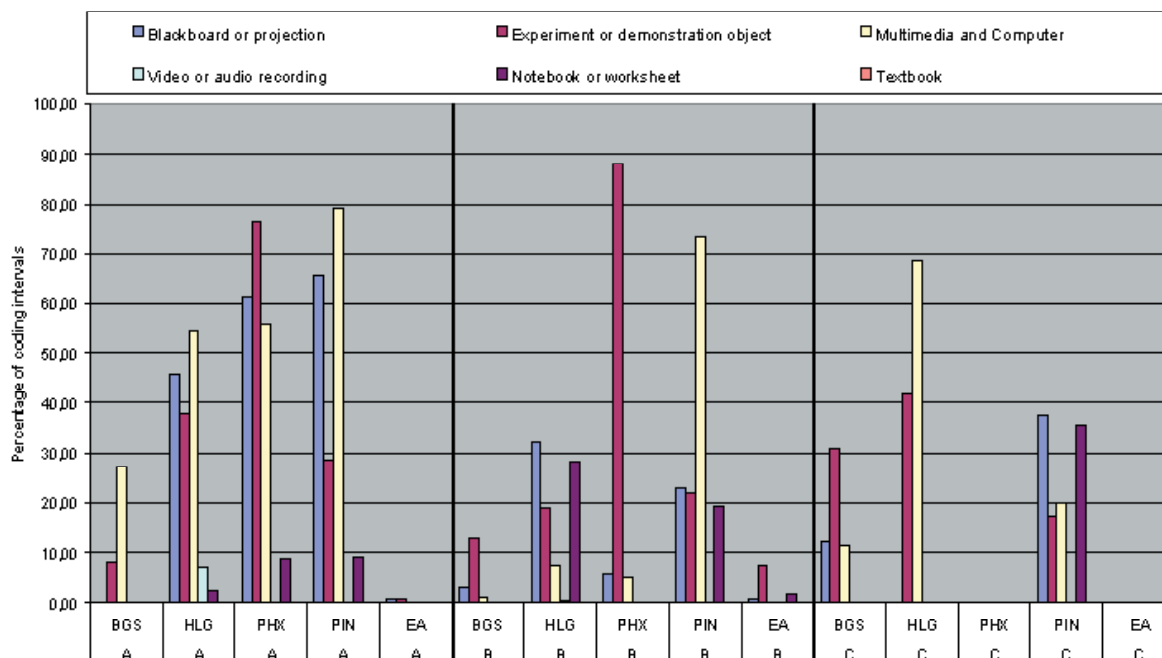
Teachers and students use of media are presented in Figure A-5:



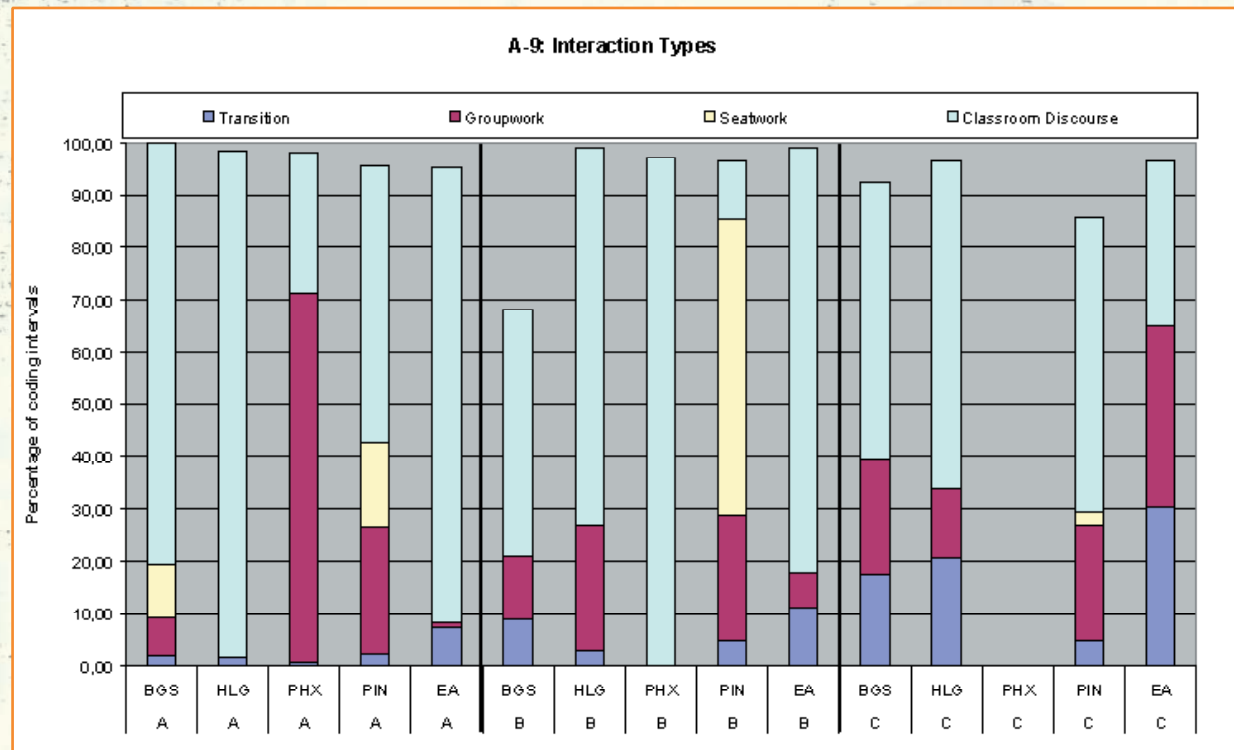
Obviously the teachers only used three out of seven media: *Blackboard* (or projector), *Experiment* (or demonstration object) and *Multimedia* (including computers). In all lessons of type A the blackboard is used at least the second most. This is the same in lesson type B for BGS, HLG and EA, although the absolute amounts decrease. The large shares of *Blackboard* at BGS and PIN in lesson type C, which contradict the lesson type, may be related to the teachers using a projector along with multimedia or a computer, while at HLG and EA only the computer may have been used. This is in particular the case for the HLG which owns a mobile computer lab containing notebooks, so that the students can follow the teacher by means of their own media. Otherwise – for the use of experiments – no special scheme or profile can be identified. The remarkable use of experiments at PHX and Multimedia at PIN in lesson type B again points to special lesson implementations.



A-6: Students' Media



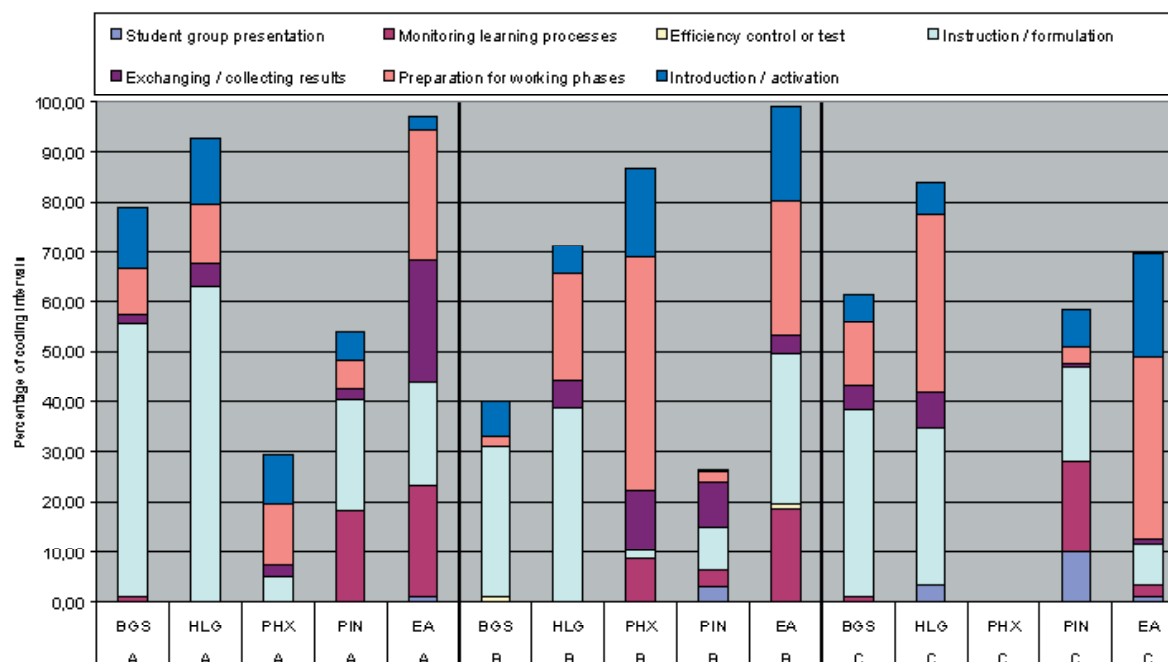
The distribution of students' media (Figure A6) gives a slightly different picture. Although again *Blackboard*, *Experiment* and *Multimedia* seem to be the most used media, other media can be observed in a noticeable amount. Especially in lesson type B where HLG and PIN students use Notebooks or Worksheets in a sensible amount. This may be related to the teachers' actual methodological approach.



The analysis of the video documentation with respect to interaction types (Figure A9) shows large percentages of classroom discourse for all lesson types, except for PHX and PIN. In the case of the latter this has to be explained again by the character of the video data, which did mostly contain students' working-phases. Still, shares of *Classroom Discourse* decrease from lesson type A to C as one would have expected. Correspondingly, the amounts of group work and transition increases. For PHX the before mentioned indication of a special lesson implementation can be confirmed here. Besides, just BGS as well as PIN show any shares of seatwork in a lesson of type A. Obviously all other teachers did not use seatwork as a teaching method.

Since *Classroom Discourse* and Transition takes most part of the actual lessons, the activities in those phases are presented in the following Figure A8.

A-8: Activities in Classroom Discourse or Transition

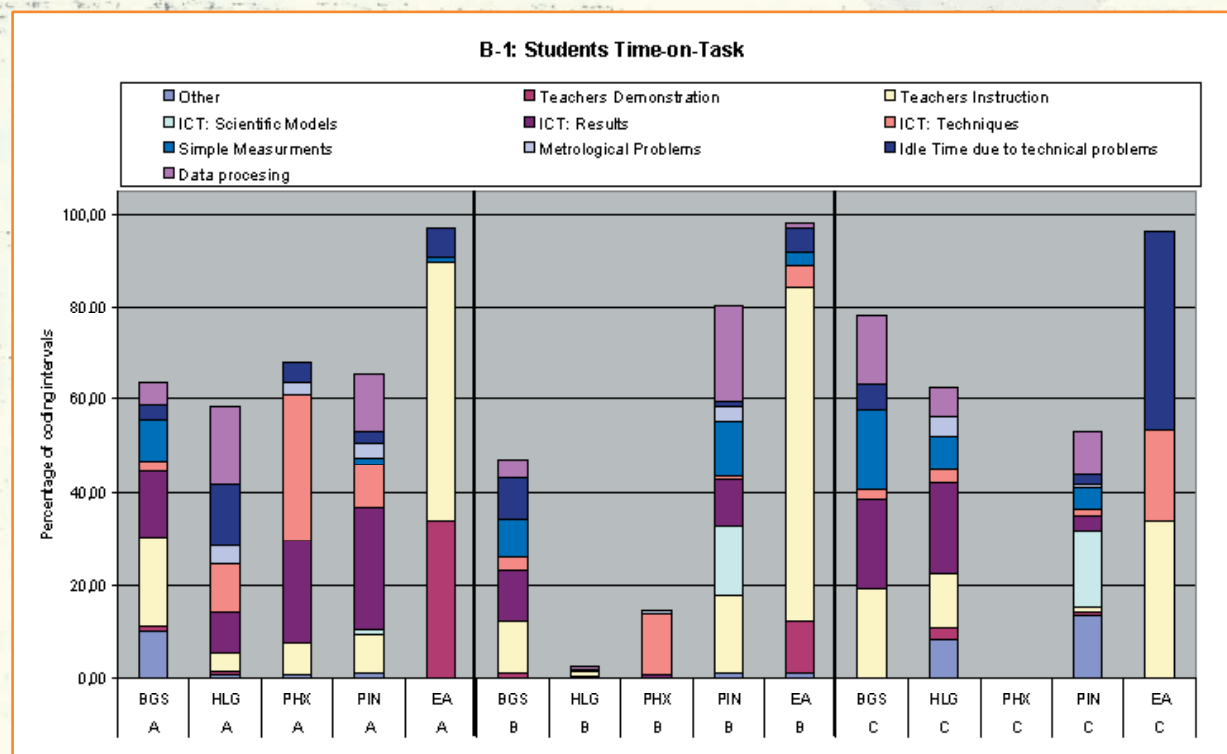


High amounts are accounted for Instruction, which can be related to classroom discourse phases, and preparation for working phases, which can be related to transition phases. In comparison to PHX, EA and PIN, the BGS and HLG schools show higher shares of instruction. At EA and PIN the missing percentages can seemingly be accounted for a monitoring of the learning processes by the teacher – at PHX especially Introduction and Preparation are favoured. Small amounts of the exchanging or collecting of results as well as introduction or activation can be observed for the majority of lesson types and schools. Efficiency or control tests on the other hand did not take place.

Computer use and learning physics

To obtain an overview of teachers' and students' activities with respect to the use of ICT equipment as well as the association between the use of ICT equipment and physics learning, two category sets have been recently developed: students' learning related actions while working with technical equipment (*students' time-on-task*) and teachers support related to students' actions (*teachers' learning support*).

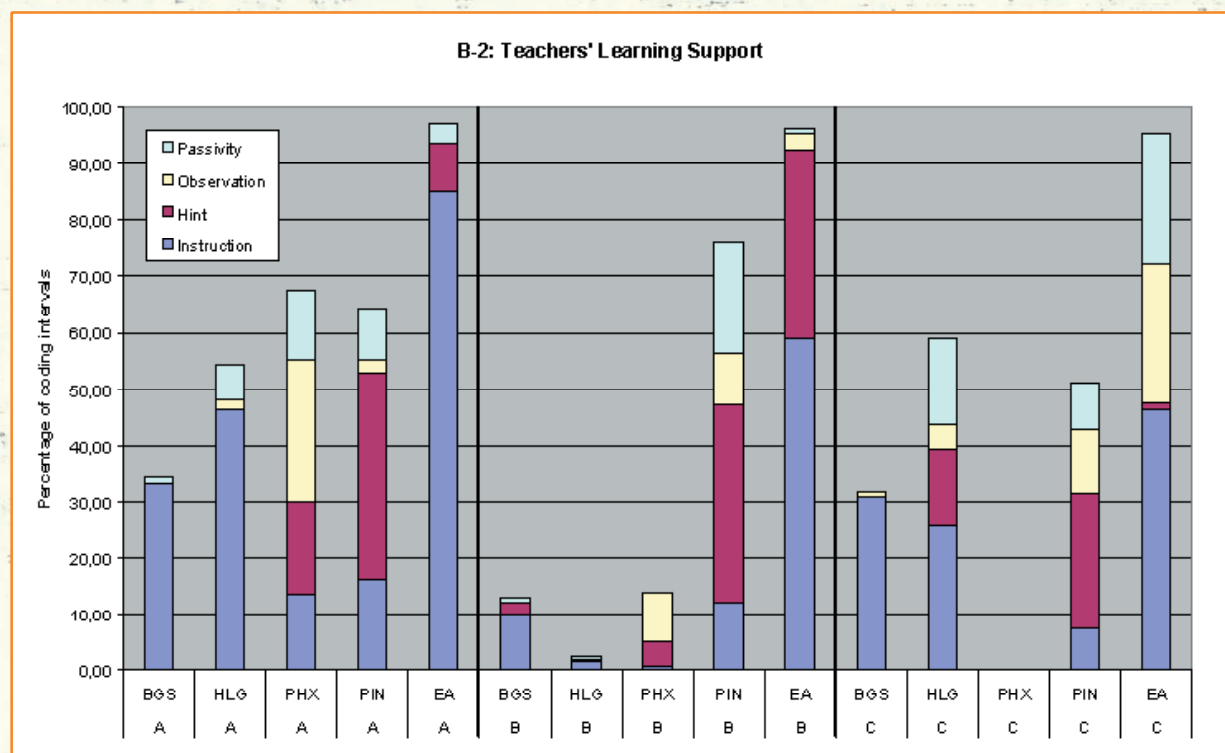
The following two figures provide an overview over the students' time-on-task (Figure B1) and the teachers' learning support (Figure B2) during lesson phases with use of ICT:



While for BGS and HLG the distribution of tasks over time is very differentiated, EA shows a high amount of *teachers instruction* and *teachers demonstration* in lessons of type A and B as well as large amounts of *teachers instruction* concerning lesson type C. Additionally for lesson type C a considerable amount of *idle time due to technical problems* could be observed. According to the teachers report this is because in the lesson of type C at EA teacher and students actually left the classroom to perform some real life sports while using the Lab



of Tomorrow equipment. The total amount of students' *time-on-task* in lesson type B at HLG and PHX is surprisingly low. A detailed analysis of the underlying video data revealed that in both cases special lessons took place: simple experiments have been developed and performed by the teacher with help from the students. The teacher handled the ICT equipment in both cases, so there were only small numbers of students working with ICT equipment and thus respectively low amounts of students *time-on-task*. Overall the amounts accounted for the different category items can be rated as sufficiently distributed, though larger amounts of tasks concerning ICT related physics would have been desirable.

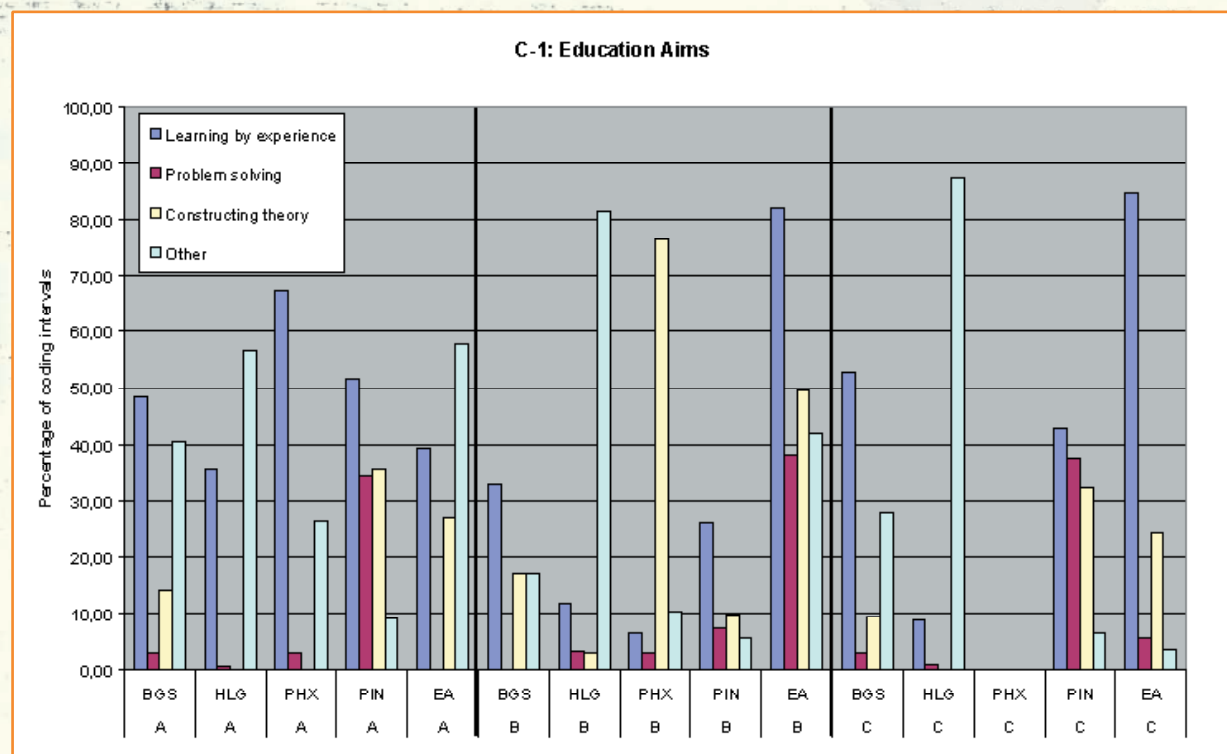


More than half of the teachers' learning support is made up of *instruction* at all schools – except for PHX and PIN, which in case of the latter may once again be related to the specific character of the video data. In lessons of type B and C the shares of instruction decrease in favour of hints for lessons of type B and additionally observation and passivity in case of lessons of type C. For HLG and PHX the above mentioned observation of low amounts of *students' time-on-task* in the course of the lesson are affirmed by low amounts of teachers' learning support. This can again be traced back to a special lesson implementation.

Learning physics and modeling

As described in section 2.2 the Lab of Tomorrow pedagogical framework and derived lesson plans have been developed along certain education aims, like for example learning by experience. To retrieve information about the actual education aims of the teacher in course of the accomplished lessons, the video data has been coded into categories related to education aims considered most important: *learning by experience*, *problem solving*, *constructing theory*. The remaining education aims have been summarised in a category “Other”.

The following Figure C1 shows the analysis of the education aims by lesson type and school:



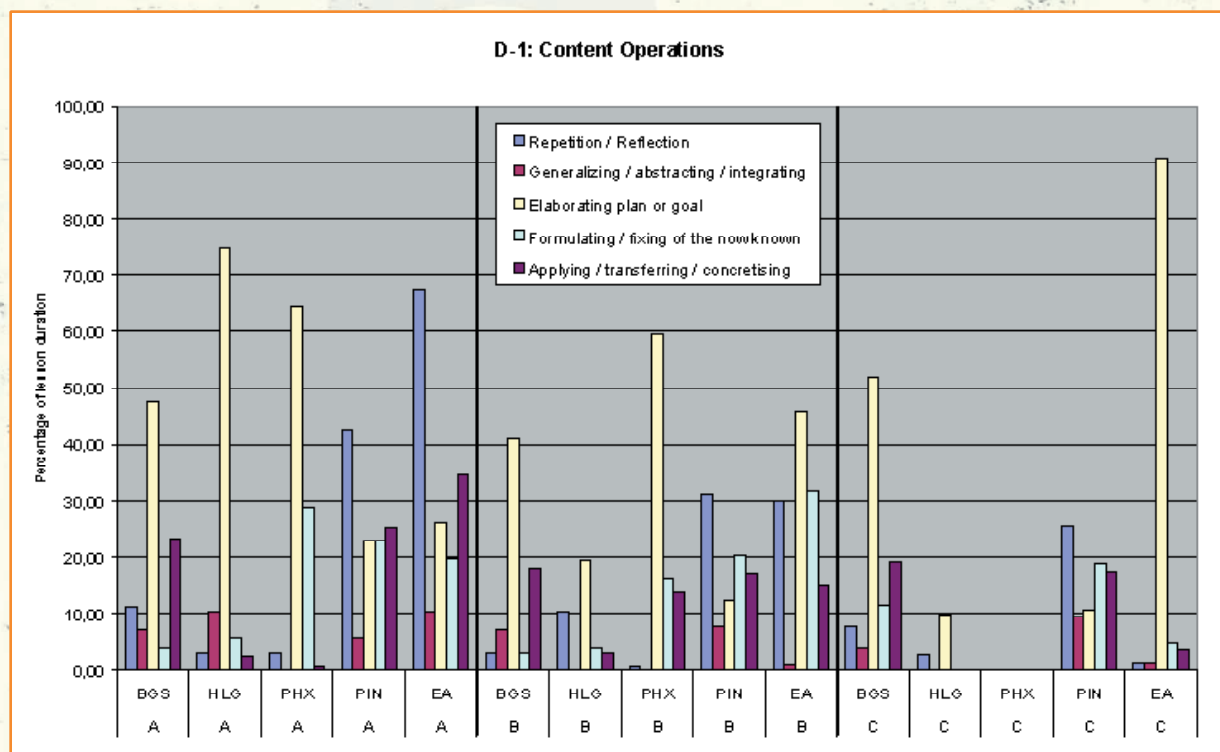
Obviously *learning by experience* and *other* education aims are pursued most of the time. Problem solving does not occur in noticeable amounts at BGS, HLG or PHX at all, and for EA only in lessons of type B. It is observed in perceptible amounts for lessons of type A and C at PIN, which can not be explained by the character of the PIN video data since the shares of other education aims remain the same. For *constructing theory* higher amounts can be observed mostly for EA and PIN in comparison to BGS and HLG for all lesson types – and for PHX in



lesson type B. Therefore BGS and HLG mainly pursue *learning by experience* and *other* education aims, while EA and especially PIN prefer the education aims classified as important within the Lab of Tomorrow project. Due to the missing data of lesson type C no scheme can be constituted for PHX.

Application and transfer

To receive information about the application and transfer of acquired knowledge so called content operations have been coded. Content operations are noticeable characteristics of a lesson in terms of content related learning. The content operations have been coded in great detail to provide a maximum of accuracy and have been summarised in major categories later, as presented in the following Figure D1:



The content operation *elaborating plan or goal* is observable in a considerable amount for all lesson types at all schools. At BGS, HLG and PHX it makes up the major content operation in all cases while at EA and PIN

repetition takes considerable amount in lessons of type A, which contradicts the findings of figure C. Obviously the teachers' goals are not received by the students. Admittedly the amount of *elaborating plan* increases for EA from lesson type A to C, where it is accounted for almost the whole lesson. While *generalizing* occurs in relatively low amounts *applying* can be observed in higher amounts for all schools but HLG. *Formulating* does furthermore appear only at EA and PIN – and at BGS for lesson type C. Overall it seems that no special scheme of lesson type or per school can be finally and reliably determined.

Summary

As a result of the video documentation, lesson and school profiles with respect to the use of the Lab of Tomorrow system can be identified. Again it is to be noticed that these are individual profiles that are exclusively related to the respective class and teacher.

The analysed lesson types were: introduction into the Lab of Tomorrow system (A), simple experiments with the Lab of Tomorrow system (B) and self-planned experiments with the Lab of Tomorrow system (C). Therefore the confinement of the environment by teachers' instructions is reduced from type A to C, while students' participation should increase.

As described, the amount of lecturing by the teacher mostly decreases from lesson type A to C, while other amounts of verbal teachers' activity remain the same. The overall amount of verbal students' activity increases on the other hand (mostly *Disusing* and *Questioning*) although no special category based profile can be found. Regarding students' manipulative actions a decrease of *Executing* seems at first surprising. On the other hand if one assumes that *Executing* has been understood as a students' manipulative action following from a teachers' directive, the decrease seems reasonable. It includes a decrease in the use of the blackboard or projector and multimedia or computer as teachers' media. The distribution of interaction types shows as well a decrease of *classroom discourse* phases in favour of *group work and transition* phases.

Concerning *computer use* and *learning physics, learning physics and modelling* and the *application and transfer of knowledge* no lesson type profiles can be established. Nevertheless may lesson profiles be detected that correspond to the pedagogical framework, which is a matter of transeunt analysis.

Regarding school profiles the participating schools have been compared with each other: this reveals high amounts of teachers' activities in Lab of Tomorrow lessons for all schools. For example the teacher is still lecturing for about 60 percent of the lessons in all schools for all types of lessons. Moreover the teachers' manipulative actions consist mostly of making plans or drawing or writing. The above described development of interaction types during the different lesson types can also be observed for all schools – except for PIN, which has to be handled carefully in school-wise comparison because of the special nature of the provided video data.



The BGS shows the highest amounts of lecturing as teachers' verbal activities, whereas in comparison a considerable amount of questioning could be observed, too. In comparison to EA and PIN no other teachers' verbal activities occur in a noticeable amount. On the other hand only low amounts of students' verbal activities can be stated, while students' manipulative activities are mainly executing or performing. Together with a major amount of instruction in classroom discourse it seems that at BGS classroom activities are mainly teachers' activities while in other phases students carry out activities discussed or planned in the preceding classroom discourse. This again fits with the observation of a high amount of elaborating plan or goal as a content operation with respect to the application and transfer of knowledge.

At EA high amounts of questioning as a students' verbal activity could be observed. This is in accordance with an appropriately high amount of *answering* as a teachers' activity. Moreover, a relatively high amount of *constructing theory* can be observed as an important education aim. Obviously the interplay between the students' questioning and the teacher answering is a teaching method intended to lead to the construction of theory at EA. But this can not be confirmed by the results of the TIMSS questionnaire. For lesson type C a large amount of technical problems seem to have happened because of idle times in students' time-on-task and no observed executing or performing as students' activity. This reflects as a high amount of instructive teachers support. In combination with a high amount of teachers' instruction in students' time-on-task and high amounts of making plans and lecturing as a teachers' activity this conflicts with *learning by experience* as the major education aim – especially for lesson type C.

For HLG similar observations can be made as for BGS: High amounts of lecturing and questioning can be accounted for teachers' verbal activities, but less amounts of other verbal activities. Moreover high amounts of executing can be observed – regarding the lesson of type C as a special case with no executing. Classroom discourse consists mostly of instructions given by the teacher, too. Therefore, the same conclusion as for BGS can be drawn: classroom activities are mainly determined by the teachers while in other phases students carry out activities discussed or planned in the preceding classroom discourse. Again this is confirmed by a high amount of *elaborating plan or goal* as a content operation, which on the other hand decreases from lesson type A to C. That may lead to the conclusion that at HLG students work more independently in later lesson types. This assumption can be backed up by decreasing amounts of *instruction* in classroom discourse and in teachers learning support. Additionally the increase of *other education aims* may be interpreted in this context as follows: a high amount of different education aims may indicate that the learning environment is less confined. This is because a less confined learning environment needs the teacher to be more flexible in respect to pursued education aims in a given situation.

While PHX shows a similar distribution of teachers' manipulative actions like BGS and HLG, the teachers' verbal actions are in contrast formed by a large amount of *Discussing* in all lesson types. This is confirmed by students' verbal actions, which also consist mostly of *Discussing*. Teachers' and Students' *Media* are predominantly the

experiment which relates to the tight connection between the amounts of teachers' and students' discussing. The non profile behaviour at PHX concerning interaction types together with the above observations of similar lessons between type A and B leads to the assumption that both lessons have been carried out by the teacher in a very special way. This can be confirmed by the detailed analysis of the underlying video data performed in course of the analysis of students' *time-on-task* and the teacher's reports: a very special experiment (car jumping through a loop) has been developed and performed by the teacher.

Amazingly PIN is the only school in which testing has been observed as a teachers' verbal action. The very same observation holds for the occurrence of seatwork as an interaction type. Also less classroom discourse seems to take place, though this again may be related to the special nature of the provided video data. If one only considers students' working phases, which actually were available on the videos, a comparably less amount of teachers' instruction in favour of a higher amount of hints has to be stated. These observations may lead to the conclusion that basically different teaching methods are used at PIN in comparison to the other schools.

ICT Questionnaire

The ICT Questionnaire consists of two parts: the "Computer Attitude Scale" (part one) and the "Level of Computer Familiarity" (part two). These will be handled separately for analysis. Results will later be merged to establish per class ICT profiles.

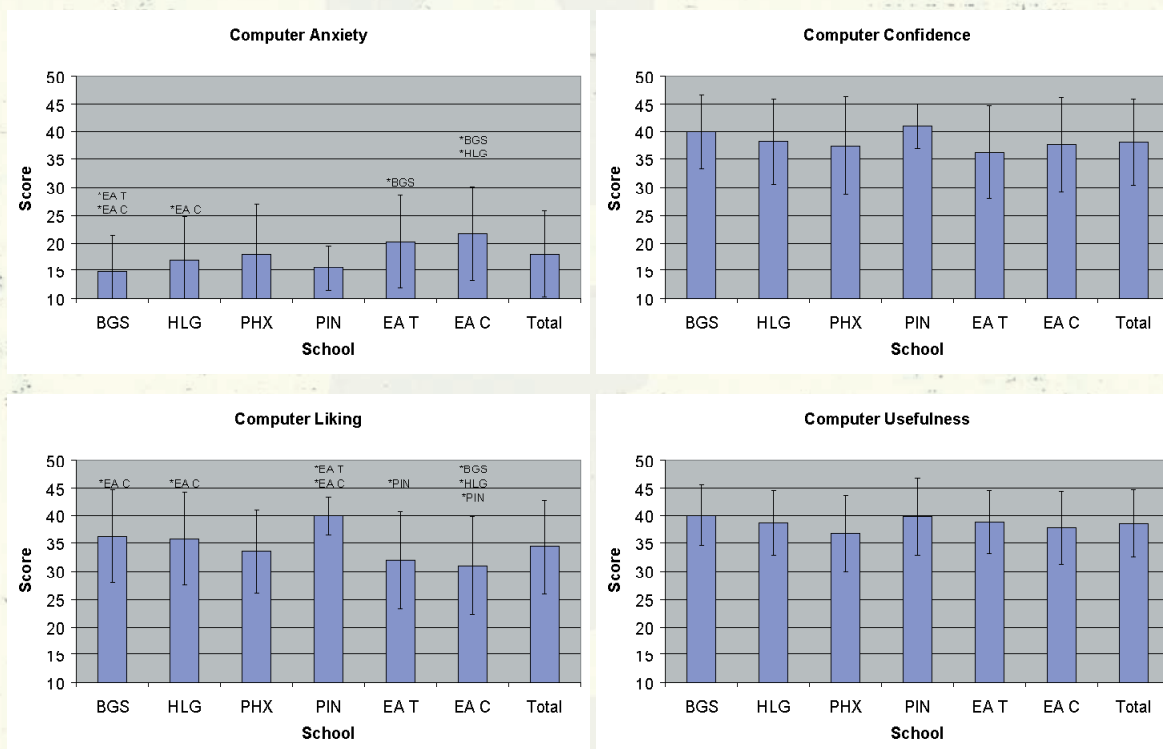
The first part of the questionnaire contained four different scales concerning computer attitudes: anxiety, confidence, liking and usefulness. Each scale was built of 10 items, where at a time five correlate positively and five negatively with the respective scale. Each item could be answered on a 5 level Likert scale. For analysis the ordinary values of 1 to 5 have been assigned to the answers of items correlating positively and the values of 5 to 1 for the items correlating negatively. That is, a value of 5 corresponds with for example a high computer anxiety. In a next step a factor analysis has been performed for an estimation of how each item contributes to the scale. The following table shows the number of factors for each scale and the respective reliability expressed through Cronbachs Alpha:

Scale	# Factors	α
Anxiety	2	0,8861
Confidence	1	0,895
Liking	1	0,8842
Usefulness	3	0,7949



Obviously *confidence* and *liking* scales are formed by only one factor with high reliability. The anxiety scale is formed by two factors with a reliability as high as for the confidence and liking scales. The largest number of factors can be observed for the *usefulness* scale, whereas the reliability can be considered high enough to assume one scale for all ten items. Therefore all four scales can be considered as correctly represented by the respective items.

In a final step a value per student has been calculated for each scale by summing up the values of all items contained by the respective scale. Through that an average per class has been calculated and an overall average of all classes. The following figures show the mean values per class for the four scales: anxiety, confidence, liking and usefulness (with a minimum of 10 and a maximum of 50). Significant differences have been determined by a one way analysis of variances and multiple comparisons in a post-hoc procedure. and marked with an asterisk (*) followed by the token for the respective class the results differ significantly from.



As can be seen, there are no differences regarding the computer *confidence* and the computer *usefulness* values between the classes. But significant differences can be stated for computer anxiety and liking: BGS shows a

significantly lower computer anxiety than treatment and control class at EA and HLG even shows a lower one compared to EA's control class. This corresponds with the results concerning computer liking, where classes at BGS and HLG show higher means as the EA control class. Moreover, students at PIN show a significantly higher rating of computer liking than both classes at EA, which corresponds to the higher use of computers in math lessons at PIN. It may be explained by the special technological profile of PIN. Overall it can be stated as a trend that classes at BGS, HLG and PIN show a lower anxiety and higher liking than classes at EA.

The second part of the ICT questionnaire was related to the "Level of Computer Familiarity". It consisted of 23 different questions about availability, usage and comfort of different IT-based technological devices – especially computers. Each question could be answered on a 4 level Likert scale. Following the above procedure the ordinary values of 1 to 4 have been assigned to the answers, whereas "1" corresponds with high and "4" with low familiarity, frequency, etc. In a next step mean values per item have been calculated for each class. The following table provides the list of items together with the respective mean value for each class.



	BGS	HLG	PHX	PIN	EA T	EA C
	N = 28	N = 39	N = 20	N = 6	N = 25	N = 25
Computer at home	1,0	1,1	1,2	1,0	1,4	1,1
Computer at school	1,3	2,0	2,3	1,5	2,8	2,4
Computer at work	2,9	3,1	3,7	4,0	3,5	2,2
Computer at library	2,9	2,9	2,8	3,7	3,4	3,1
Comfort w/ computer	1,6	1,7	1,7	1,5	2,0	2,1
Comfort w/ mouse	1,3	1,4	1,6	1,5	1,7	1,5
Comfort writing	1,7	1,6	1,9	1,4	1,9	2,0
Comfort test (TOEFL)	1,8	2,0	2,3	1,7	2,3	2,4
#exams on computer	2,7	2,6	3,2	2,5	2,9	3,2
Computer ability	2,2	2,4	2,5	2,0	2,3	2,2
Touch tone phone	1,9	2,6	3,4	3,0	3,5	3,2
Program VCR	3,2	2,7	3,0	2,8	2,3	2,0
Auto banking machine	3,4	2,8	2,4	3,8	3,3	2,8
Auto ticket machine	2,6	3,4	3,2	3,3	2,4	2,2
How often use computer	1,0	1,2	1,6	1,0	1,7	1,5
How often internet	1,2	1,5	1,7	2,3	1,9	2,0
How often e-mail	1,9	1,8	2,0	3,5	2,7	2,7
How often mouse	1,0	1,3	1,4	1,0	1,6	1,4
How often games	1,6	2,1	1,8	1,2	1,4	1,6
Word processing /own language	1,8	1,9	1,8	2,0	2,1	2,0
Word processing /English	2,6	2,9	2,5	3,2	2,8	2,4
Spreadsheets	2,5	2,8	2,5	2,8	2,8	2,8
Graphics	2,4	2,7	2,5	2,8	2,9	2,6

An analysis of the provided data reveals that classes at EA show a lower than average level of computer familiarity. The treatment class for example obtains only a higher than average result for programming a VCR, using an auto ticket machine and frequency of gaming. The control class of EA provides slightly more higher than average results, which is potentially related to the higher availability of computers (see results of the first four items). The means of both classes are lower than BGS and HLG for almost all items. Therefore the trend that has been identified in the questionnaires first part is confirmed by the analysis of the second part. It can be expected that

at least BGS and HLG perform better when handling technical equipment – especially computers – than EA. This is presumably due to a higher than average availability of computers for students at BGS and HLG and a lower than average availability for students at EA. This would be an explanation for the significant increase in science performance at HLG. Still there has to be another major factor to be taken into account since there is no significant increase in science or math performance of students at BGS; although those hold very good results with respect to the ICT questionnaire.

School Background Questionnaire

The school background questionnaire was taken from the German SINUS project, translated into English and sent to the headmasters of the participating schools. The returned questionnaires have been processed electronically. The data of the schools has been compared to find differences with respect to items with special importance for the Lab of Tomorrow project. HLG did not return the questionnaire. Items selected by this means are presented in the following table:

	EA	PIN	BGS	PHX
School Location	Large City	Town	Town	Large City
Number of male Students	339	928	345	336
Number of female Students	248	38	440	331
School Type	Private	Public ¹	Public	Public
Class levels available	7th to 12th	9th to 13th	5th to 12th	5th to 13th
Percentage of 15-year olds in..				
..course < 9th grade	0	0	78	,
..10th grade	0	59	7	,
..12th to 13th grade	100	0	15	,
Computers available..				
..at school altogether	70	250	40	28
..accessible for 15-year-olds	40	75	30	20
..accessible for teachers only	10	25	5	4
..accessible for administration only	10	35	5	4
..with internet access	70	250	40	20
..connected to local network	70	250	40	20
..per student	0,09	0,20	0,04	0,03



Particular educational profile..				
..mathematics	no	no	yes	yes
..biology	no	no	yes	no
..chemistry	no	yes	yes	no
..physics	yes	yes	yes	yes
..natural science	yes	no	no	missing
..science	yes	no	no	no
..new technologies	yes	yes	no	yes
Activities available to students..				
..mathematics/science field	yes	no	yes	yes
..mathematics/ science field (Number)	3	0	2	3
..mathematics/ science field (Participating)	50	0	20	30
..new technologies	yes	yes	yes	yes
..new technologies (Number)	1	0	10	2
..new technologies (Participating)	100	0	100	50
Teachers	60	115	60	31
Teachers per student	0,10	0,12	0,08	0,05
Teachers teaching..				
..mathematics	6	13	14	10
..biology	2	0	4	5
..chemistry	3	4	2	3
..physics	5	6	14	4
..natural science	0	3	0	0
Teachers having attended further education	10 %	0 %	20 %	30 %
Funding school gets from private Persons in the past year.				
..parents	0	0	0	15000
..private persons	0	0	0	5000
Funding from school activities	5000	0	2000	2000

Students assessed by				
..standardized tests	never	once a year	three a year	never
..tests or exams developed by teacher	four times a year or more	four times a year or more	four times a year or more	once a year
..assessment by teacher	four times a year or more	four times a year or more	twice a year	four times a year or more
..students' works	four times a year or more	four times a year or more	once a year	twice a year
..homework	four times a year or more	four times a year or more	once a year	four times a year or more

From the table above differences between the participating schools can be asserted on a general level as well as concerning the availability of computers and educational profiles that directly relate to the Lab of Tomorrow project. So has to be noticed that EA is the only private school while all other participating schools are public. With few exceptions students at PIN are male students, which has to be attributed to the schools' technical profile. That again holds responsible for the reduced amount of available class levels (9th to 13th).

Concerning the availability of computers PIN provides by far the best ratio of computers per students, followed by EA with a 1/10 ratio. All other schools are ranked far below with a ratio of 1/20 or less. Again this fits with a higher application of computers at PIN due to its special technological orientation.

Educational profiles also vary between the respective schools: while EA puts an emphasis on natural sciences in general, PIN concentrates on chemistry and physics. BGS uses an educational profile that is based on mathematics and the three classical natural sciences physics, chemistry and biology. At last PHX follows kind of a new technology approach based on a focus on mathematics, physics and new technologies.

The ratio of teachers per students does not vary widely, although PHX reveals a very low ratio with 1/20. The distribution of teachers teaching different subjects can be considered similar for all schools. Remarkable remains the fact that teachers at BGS and PHX attend further education more often than teachers at EA and PIN.



4.5 Conclusions

The objectives of the Lab of Tomorrow project were based on emerging new technologies. To foster students' learning a set of new educational tools and learning environments – based upon a pedagogical framework – was developed. The course of the project was accompanied by a detailed evaluation procedure to gather valuable information about implementation details and effects. The three basic aspects to be evaluated were from a pedagogical point of view: the students' learning processes, the pedagogical framework, as well as an ethnographic comparison.

As described in section 4.1 no general increase in students' performance and thus no enhancement with regards to students' learning outcomes measured by an internationally validated tool could have been verified. From this can not in the end be concluded that there was no effect – especially since the duration of the final run had to be cut down due to technical problems with the Lab of Tomorrow system. The TIMSS questionnaire used is able to measure Scientific Literacy on an internationally validated Rasch-scale, which allows in general comparing the related performance of different groups on a classroom level. But to compare the effect of a certain intervention, like the instruction in the Lab of Tomorrow classrooms has been, the increase (as effect of the intervention) has to be measured in a pre/post design. Clearly an increase of knowledge as an effect of an intervention is dependent on the duration of the intervention. Regarding international results, an increase of TIMSS-test results of 1 to 1.5 standard deviations can be expected as an effect of one year instruction. The results of the tests in the evaluation of LOT show a not significant increase of knowledge in most of the cases, but it is principally not possible to expect different increases dependent on different treatments as an effect of 3 month instruction. The absolute differences and the development of certain classes can be related to different social and educational backgrounds of the schools and the classes as could be derived from the background items of the applied TIMSS questionnaire.

As a result of the video documentation lesson profiles could be observed that clearly demonstrate that the lessons held in course of the Lab of Tomorrow project reduce the confinement of the learning environment. Thus the Lab of Tomorrow allows a higher participation and individual development of students. Additionally quite detailed school profiles have been established, though those could not be related to the schools' performance results.

An analysis of the ICT questionnaire revealed that classes at EA have a lower than average level of computer familiarity. In contrast classes at BGS and HLG endue higher capabilities when handling ICT equipment. This does on the other hand not generally lead to a better performance, as discussed above.

From the data assessed by the School Background Questionnaires several differences could be found between the participating schools, for example concerning educational profiles and computer per students rating. Al-

though these differences could neither be related to the students' performance results nor explain them. Still one particular aspect revealed by the school background questionnaire seems to be important: Since it is at least known for German schools that the regular funding (by the government) not sufficiently covers necessary expenses, from the amounts of additional funding it can be concluded, that the Lab of Tomorrow system at its current pricing will not be affordable for those schools. Therefore a module system should be taken into account to enable schools to split the acquisition of the LOT equipment up into several years.

As far as the teachers that participated in LoT are concerned, giving an overview about the implementation and testing in LoT schools, the picture has to be described as follows:

Generally the LoT tools were much valued by the teachers. The first evidence of the TIMSS evaluation analysis shows that there is no remarkable differentiation of the performance of students in physics.

The teachers' point of view is that this is reasonable since:

- *The number of schools and students in Lab of tomorrow classes was limited.*
- *The duration of the Final Runs was only a few months*

But clearly teachers believe that:

- *Students have high motivation to participate in the lessons*
- *Students can comprehend deeper phenomena and laws referring to complex theoretical issues (2D-3D motion, circular motion etc.)*
- *Students understand better the connection of physics with real life*
- *The learning by experience approach in Physics can have very positive results*

The teachers are very excited to use the LoT tools, since the environment of implementation does not represent a difficulty for them. This relates to the embedding within the curriculum, as well as the preparation of lessons for the students. Additionally they would see no technical equipment barrier for the use of the LoT tools within their classrooms.

Also they rate the motivational factor for the students as very high, which is an asset for their teaching. Approximately the same results were analysed with the questionnaire of the students. Still comments on the paper by students stated that for some students it might become boring after a while. This is a very common fact for multimedia products, but it also means that a motivational role is not taken off from the teacher.

Most of the teachers think that the LoT tools are very effective in helping the students to reach the learning goals accordingly to the lesson plans.



Chapter 5

How to use the LoT Equipment Quick Manual

5.1 Base Station

Power Supply.

The Base Station is powered by the power-pack provided. Just plug the power-pack into the mains supply (230VAC) and connect it to the Base Station.

Operation.

For proper operation place the Base Station on a table, at a height about one meter above the ground. The area near it should be clear from any obstacles. The Base Station is connected to the Work Station (a PC with LOT software installed) via the RS-232 cross-cable provided.



Figure 5.1 Base Station



Attention:

Use only the RS-232 cable provided. The Base Station will not work with a straight, PC-to-modem cable.



5.2 Student Set

The Student Set consists of the following modules:

- Belt Assembly (AN-BLA-V1.0).
- Arm Accelerometer Module (AN-AAM-V1.0).
- Leg Accelerometer Module (AN-LAM-V1.0).
- Heart Rate Measurements Belt (Polar Belt).
- Temperature sensor (BLATMP V1.0).
- Bracelets for Leg and Arm Accelerometers (3 sizes - small, medium, large).
- Battery charger (2 items).

The x, y axes orientation of the Leg, Arm, Body Accelerometers follow the conventional notation and are defined by the silk screen at the top of each device.

All accelerometer modules are factory calibrated and no additional procedure is required by the user.

Belt Assembly.

Power Supply.

The Belt Assembly is the main part of the student set. To switch the module on, open (de-strap) the belt and press the button (Figure 5.2) on the AN-STMBAN-V1.0 module for about one (1) second, until the LED flashes twice. This LED is included in the AN-CHTBA-V1.0 module (see Figure 6). Once the module is switched-on, the LED flashes every two seconds. To switch the module off, press the button, until the LED flashes twice.

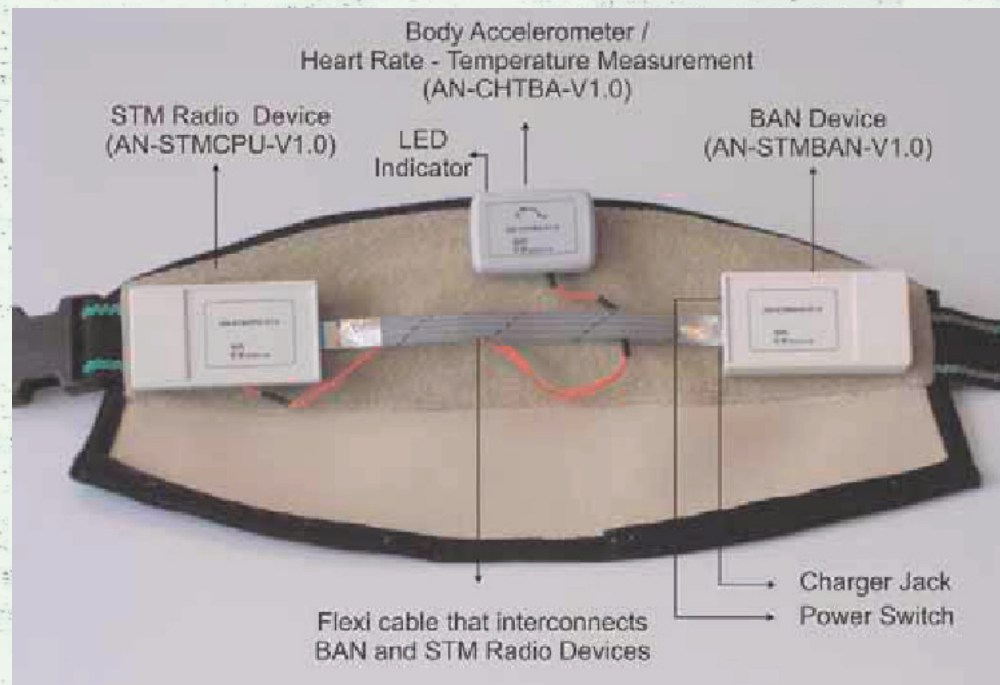
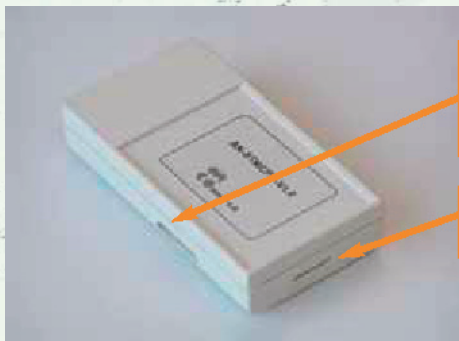


Figure 5.2 Belt Assembly

Operation.

The Belt Assembly consists of three main modules:

- The Student Set radio module (AN-STMCPU-V1.0), which establishes the radio communication with the Base Station Unit.

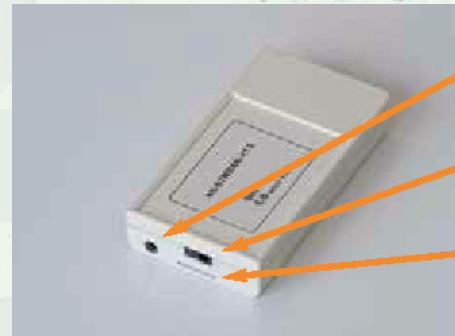


**Connection to
AN-CHTBA-V1.0**

Flexi Cable

Figure 5.3 AN-STMCPU-V 1.0

b. The Body Area Network radio module (AN-STMBAN- which collects wirelessly via the BAN all data from the Leg Accelerometer modules.

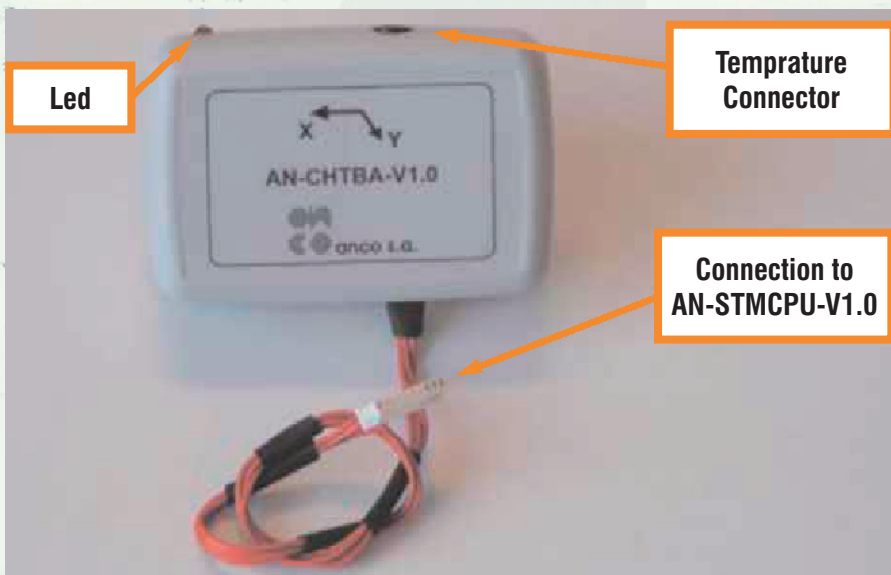


Button

**Charger
Connector**

Flexi Cable

Figure 5.4 AN-STMBAN-V 1.0



Led

**Temprature
Connector**

**Connection to
AN-STMCPU-V1.0**

c. The Heart Rate - Temperature - Body Accelerometer module

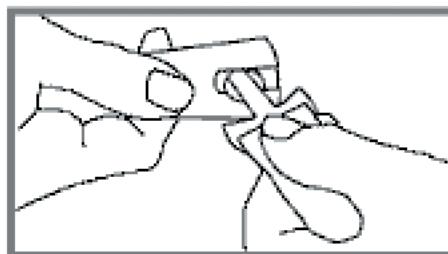
(AN-CHTBA-V1.0), which includes the heart rate receiver, the temperature connector and read-out circuit as well as the body accelerometer sensor.

Figure 5.5 AN-CHTBA-V1.0 module.

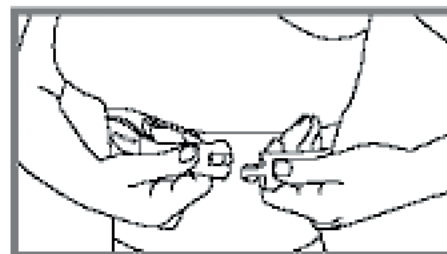
Temperature Measurements.

To conduct temperature measurements, connect the temperature sensor to the available connector at the AN-CHTBA-V1.0 module (Figure 5.6). The temperature sensor should be placed under the armpit, with the metal surface at the skin contact side.

To conduct heart-rate measurements, the student should wear the Polar belt, following the instructions in Figure 5.6.



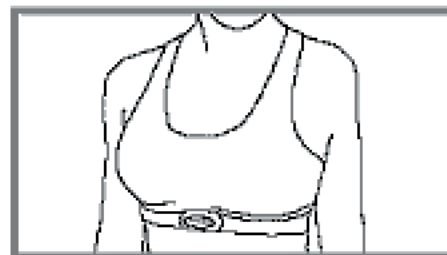
1. Attach the transmitter to the elastic strap.



2. Adjust the strap length to fit snugly and comfortably. Secure the strap around your chest, just below the chest muscles, and buckle it.



3. Lift the transmitter off your chest and moisten the two grooved electrode areas on the back.



4. Check that the wet electrode areas are firmly against your skin and the Polar logo is in a central, upright position.

Figure 5.6 Polar Belt Instructions.



Attention should be paid, so that the Belt Assembly is worn in the upright position, no more than 30 cm away from the Polar Belt. When an experiment with heart-rate measurements is in progress, the Belt Assembly LED flashes in accordance with the person's heart beat.

After the experiment has finished, carefully wash the belt with a mild soap and water solution; rinse it with pure water and dry it carefully with a soft towel. The belt should be stored in a clean and dry place.

Battery Charging.

The battery of the Belt Assembly is a state-of-the-art Li-Polymer type and can be charged at any time, without affecting battery life. To re-charge the battery, take-off the belt, switch it off and connect it to the charger provided. The battery becomes fully charged at less than two hours and provides power for about 3.5 hours of continuous operation.



Attention:

The module is not operational, when charging is in progress and it should not be turned on during this process.

Leg and Arm Accelerometers.

Power Supply.

The Leg and Arm Accelerometers have no power switch. They are switched on and off by the Belt Assembly, whenever an experiment starts and stops. The module will also switch itself off, if it is unable to communicate with the Belt Assembly for a long period of time.

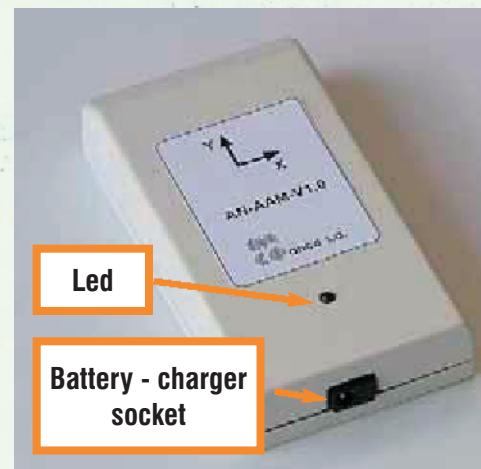


Figure 5.7 Leg and Arm Accelerometer.

Operation.

The student should wear the Leg Accelerometer at his/her leg and the Arm Accelerometer at his/her arm. When the Work Station issues an experiment start command, the student wearing the belt and the accelerometers must stand in such a way, that the y axis of both modules is vertical to the earth's surface. The student must remain in this position until the modules LEDs are turned on and remain lit. This means, that the activation signal has been received. After a while, the LED will switch off and start blinking. This means that the experiment has started and the sensors are gathering data. The LED will switch off permanently, when the experiment stops.



Attention:

All the Leg/Arm accelerometers, that are located in the vicinity of the experiment area and are not taking part in the measurements, should be placed in the horizontal position in order not to interfere with the working system.

Battery Charging.

The accelerometer modules have the same battery type as the Belt Assembly. The same charger is used to recharge these batteries. The battery becomes fully charged at less than two hours and provides power for at least 45 hours of continuous operation and for months, when in idle state.



Attention:

The module is not operational when charging is in progress.

Attention: When an Arm/Leg Accelerometer is in the horizontal position, it does not search for activation signals. For this reason, place the accelerometers horizontally when you store them for long periods, as this will extend battery life.



5.3 Ball Module

Power Supply.

To power-on the Ball Module, press the switch momentarily using a ball-point pen or a pencil. Do not use sharp objects to press the switch. Upon power-up, the LED flashes twice. When the Ball Module is powered up, the LED flashes every four seconds. When an experiment is in progress, the LED flashes every two seconds. To power off the Ball Module, press the switch once again.

Figure 5.8 Ball Module



Axes Orientation.

The x, y, z axes of the Ball module follow the conventional notation and are factory calibrated. When the ball is held with the LED indicator facing upwards and the air valve inlet to the right, then:

- The x, y axes are horizontal and the z axis is perpendicular to the x - y plane.
- The convention for positive direction is : x-axis to the right, y-axis forward and z-axis upwards.
- When in the above position, the actual values of the Ball module x, y, z acceleration components are:

$x=0, y=0, z=+1$.

Battery Charging.

The battery can be re-charged with the corresponding charger provided. The battery becomes fully charged at about 3 hours and provides power for about 4 hours of continuous operation.



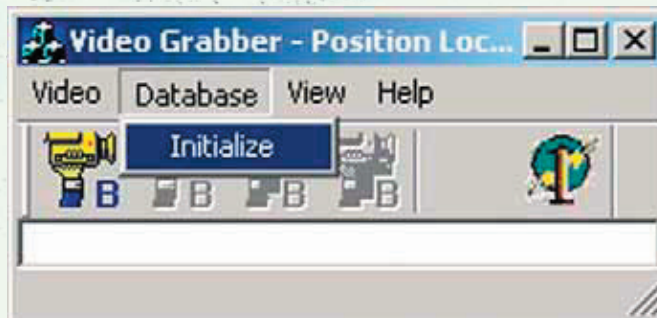
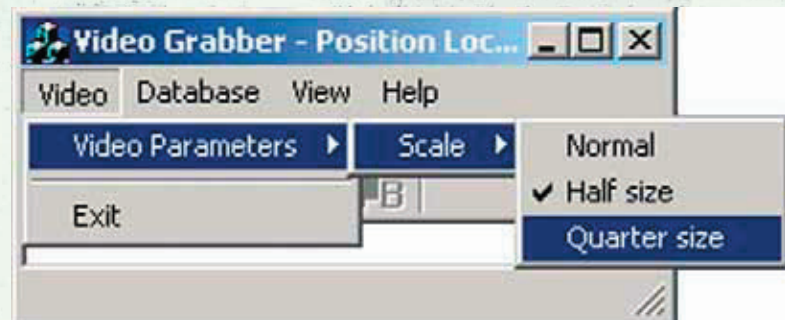
Attention:

When no experiment is executed, the Ball Module should not be left switched on, as this will consume the battery very quickly.

5.4 Using the Video Grabber Software

Student's User Manual

1. Start the software "Video Grabber"
2. Choose the video scale
(recommended: half size)
3. Initialize database
(erase previous data)



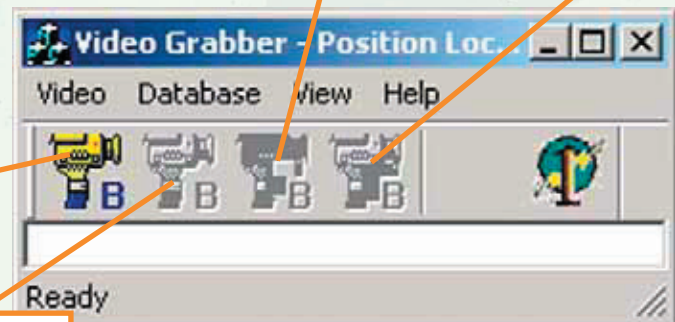
4. Creating videos
- 4.1. Button overview

open camera

close camera

start recording

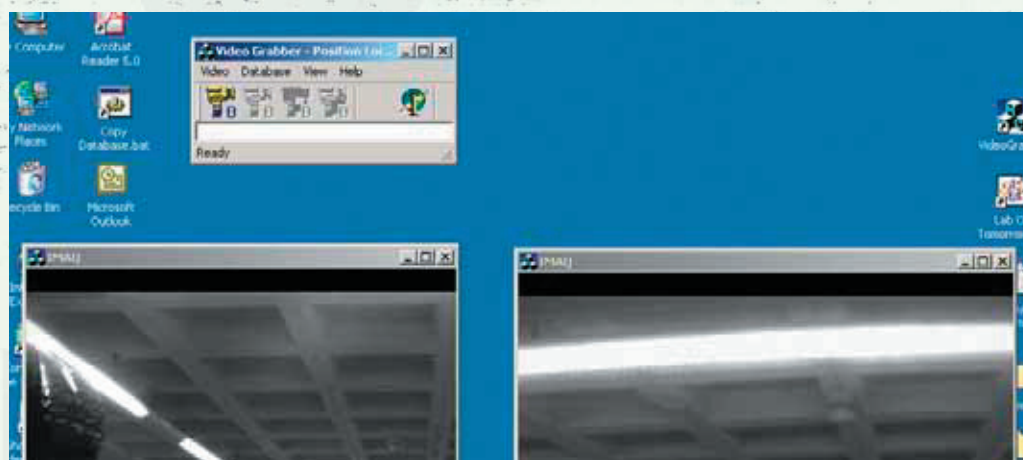
stop recording





4.2. "Open camera"

Use this button to open the two video windows and to control the position of the object(s) to be recorded.
The buttons "close video" and "start recording" are enabled.

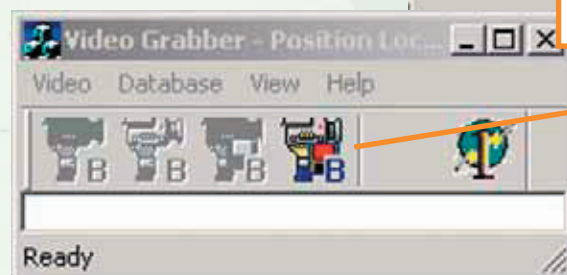
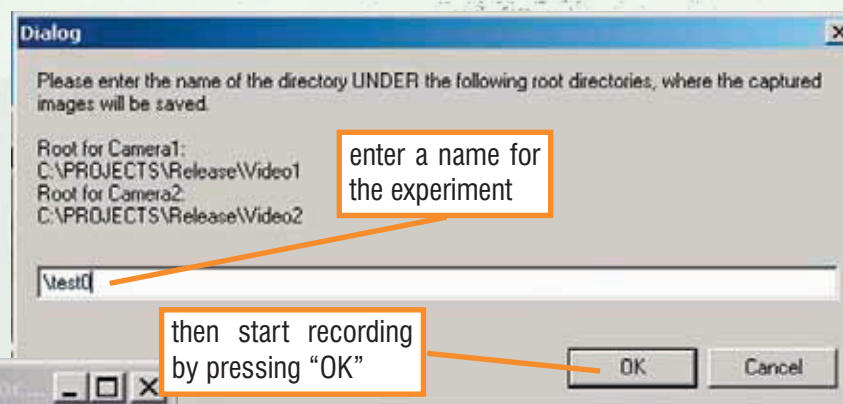


4.3. "Close Camera"

The two video windows disappear

4.4. "Start recording"

press the button



only the "stop recording" button is enabled now

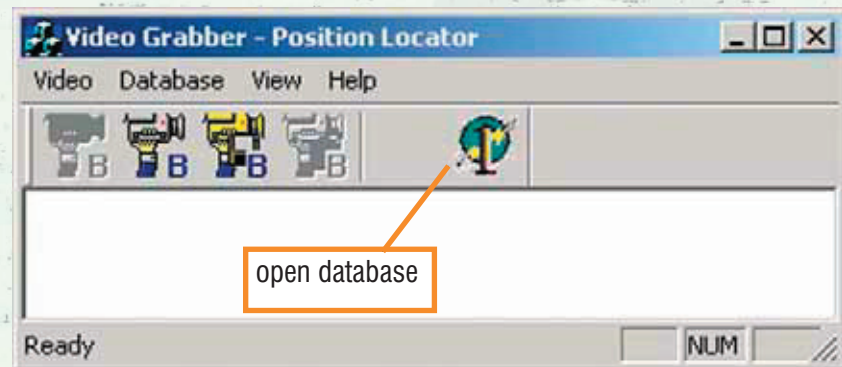
4.5. "Stop recording"

Press the button, when the movement you want to record has finished

5. Analysing the videos

5.1. Press the button

"open database"

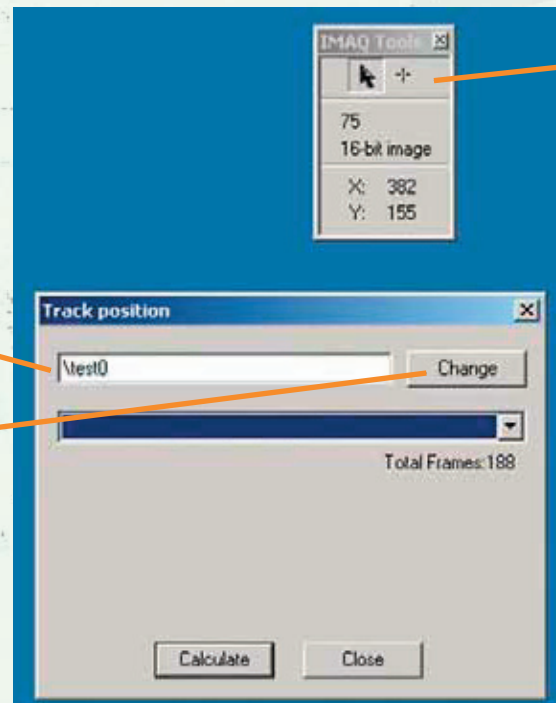


5.2. Choose the experiment and the tool

enter the name of the experiment

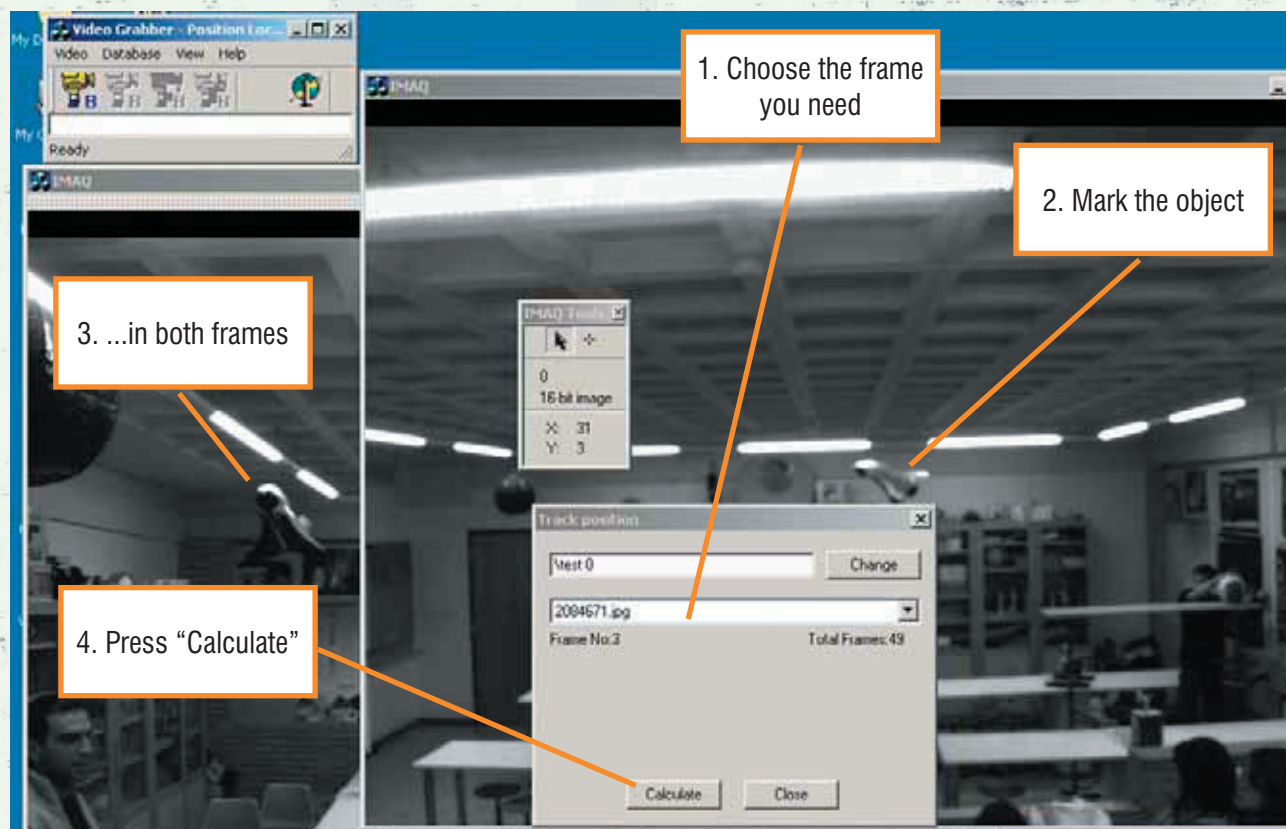
press the button "Change"

choose the tool for marking





5.3. Mark the object in each video frame



Repeat steps 1 - 4 until the whole movement has been analysed, then press "Close"

6. Transferring the data

- 6.1. An MS-Access™ - file ("grab.mdb") has been created automatically, where the x-, y- and z-component of the positions and the assigned time ("tick") is stored:
- 6.2. This file can be transferred to the LOT-computer using the batch-file "Transfer.bat".
- 6.3. There it can be merged into the LOT-software.



Appendices

Appendix A:

Leg / Arm Accelerometer Migration Procedure

In case an Arm or Leg Accelerometer of a Student Set stops functioning, ANCO Axion System hardware has the capability to allow for a replacement of the damaged device with an Arm / Leg Accelerometer from another student set.

Before describing the replacement procedure, it is important to clarify the following: The two Student Sets function at different frequencies, namely channel 1 for the Student Set 01 and channel 2 for Student Set 02.

Thus, if there is a need to replace an Arm / Leg Accelerometer with a module from another student set, the user then has to change the channel of the new module to the channel of the Belt Assembly used.

In order to tune the new Arm or Leg Accelerometer module to the channel of the Belt Assembly, the following steps should be followed:

1. During the migration procedure one Belt Assembly, one Leg and one Arm Accelerometer are required, even if only one Leg / Arm Accelerometer module has to be tuned.
2. Make sure, that the Belt Assembly is switched off and that both Accelerometer modules are in a vertical to ground position. Also, make sure that no other Leg or Arm Accelerometer in the vicinity is active (in a vertical position).
3. Press the Belt Assembly button steadily for 15 seconds. After this period, the Belt Assembly LED will illuminate constantly.
4. Once the tuning process has concluded successfully, the LED indicator of the Belt Assembly will switch off. In case that, for some reason the process has failed, the LED indicator will flash twice just before switching-off.

Troubleshooting

In case the above process fails, then check that none of the following conditions exists:

1. Either the Leg or Arm Accelerometer module is not in a vertical position.
2. There is more than one Leg or Arm Accelerometer modules active in the vicinity.
3. An attempt is made to change channel to either two Leg or two Arm Accelerometers.



Appendix B: Repair Instructions in case of Flexi Cable Disconnection or Misplacement

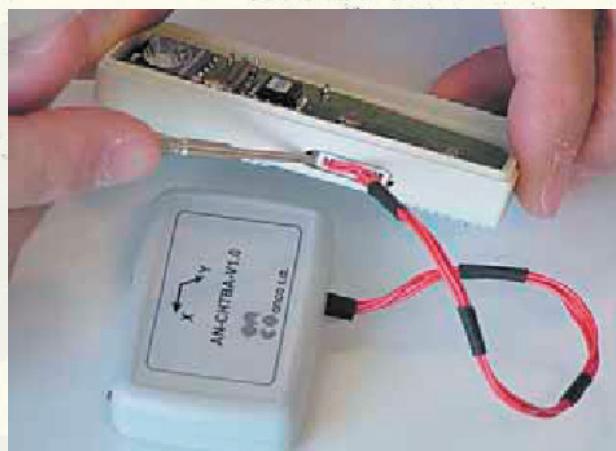
In case that for any reason the flexi cable linking the Student Set radio module with the BAN radio module is disconnected or misplaced from its connector at either side during an experiment (Figure A1), the following instructions should be closely followed in order to reinstall it and establish Belt Assembly proper operation again:

Figure A1 Flexi cable misplacement



- Open the casing of the disconnected module by removing its holding tape. Attention should be paid not to break or damage the locking nails of the cover.
- In case the problem has occurred at the Student Set radio module (AN-STMCPU-V1.0), please disconnect the AN-CHTBA-V1.0 module using a small flat - shaped screw driver. Do not unplug the connector by applying force to the cables (Figure A2).

Figure A2 AN-CHTBA-V1.0 connector unplugging.



- In case the problem has occurred at the BAN radio module (AN-STMBAN-V1.0), please remove first the battery (Figure A3) and reinstall it only after fixing the problem.

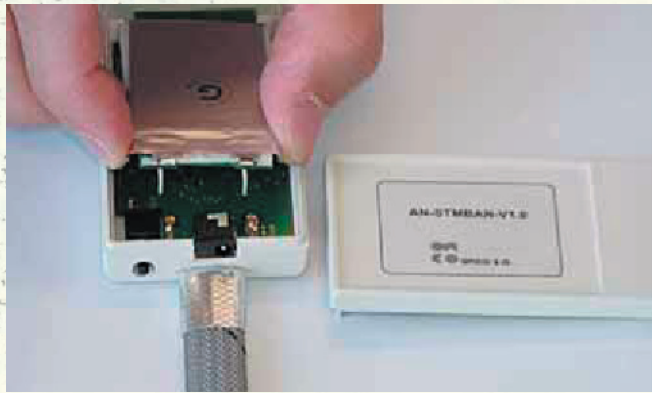


Figure A3 Battery removal

The following steps apply to either case of radio module (STM or BAN):

- Remove the PCB from the casing and lift the lever of the flexi cable connector (Figure A4, step 1).
- Hold the edge of the flexi cable with one hand, the protective sleeve of the cable with the other. Draw backwards the protective sleeve in order to reveal the flexi cable for about 2 - 5 cm (Figure A4, step 2).
- Pass the flexi cable through the cutting of the casing for at least 4 cm (Figure A4, step 3).
- Flip over the flexi cable and push it carefully into the flexi cable connector (make sure that the lever is lifted up). Make sure that the flexi cable has been fully inserted into the connector and then close the lever (push it down) with your finger (Figure A4, step 4).
- Make sure, that the flexi cable has been secured straight and firmly (Figure A4, step 5).
- Place the PCB back in its casing (Figure A4, step 6).
- Put the cover and apply a piece of tape to close the casing.

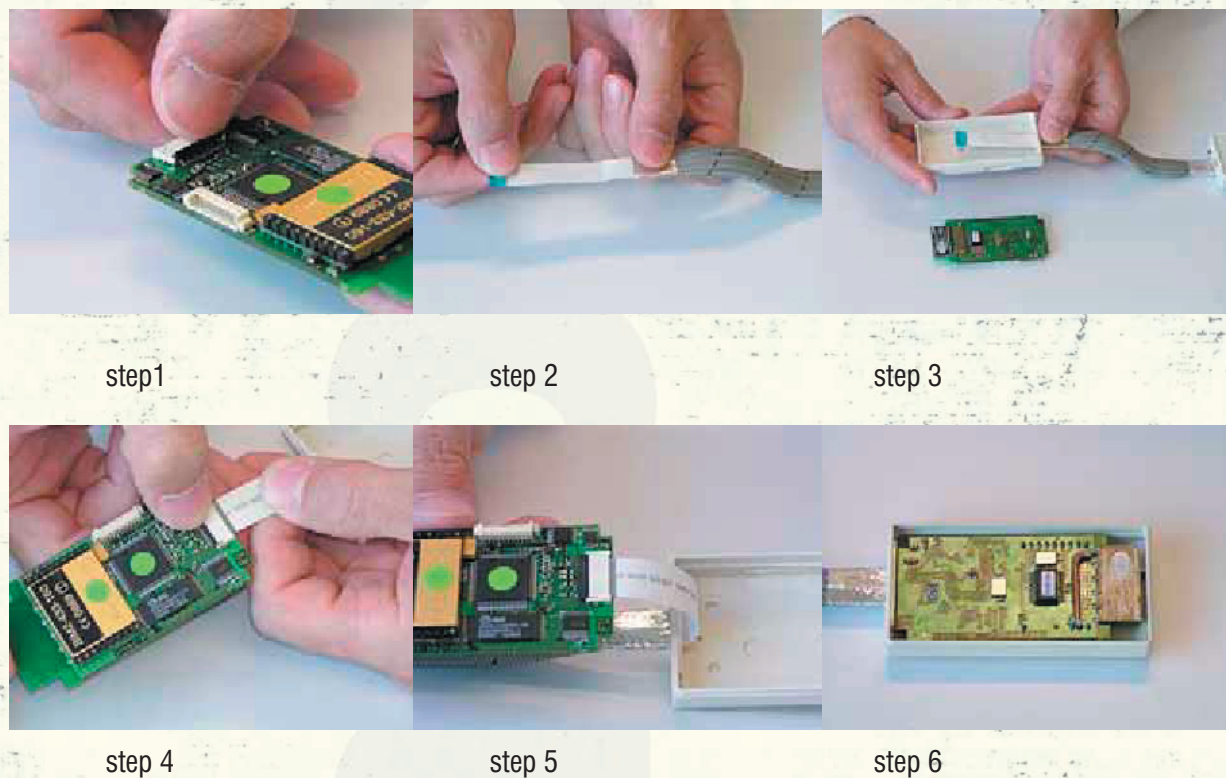


Figure A4 Steps for reconnecting the Flexi cable at the STM or BAN radio module.

Appendix C

Set-up and calibration of the LPS system

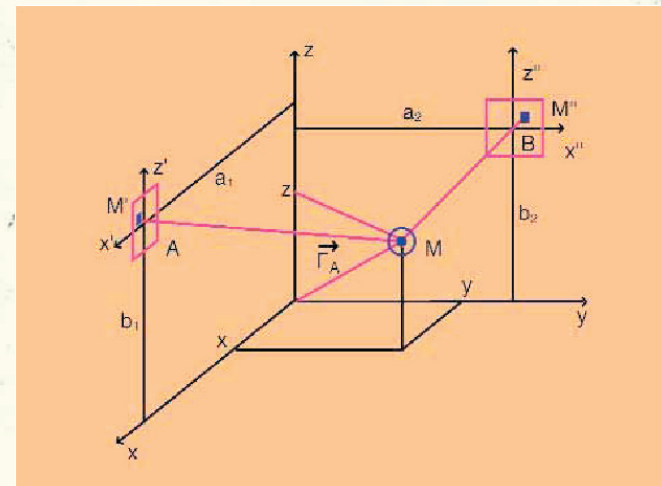
The LPS system consists of the following items

1. The LPS PC with the two video grabber cards, which have a BNC cable output each.
2. Two Sony cameras.
3. Two cables 25 meters long and two cables 5 meters long connecting the Sony cameras with the camera adaptor boxes.
4. 2 BNC cables.
5. 2 camera adaptor boxes (DC-700 Sony).

The installation procedure consists of the following steps

1. First the area where the cameras will be installed permanently is chosen. There are two sets of cables, one of which is 25 m long something that gives enough freedom for the selection of the area. It is preferable that cameras are permanently mounted on a wall and their bodies should be horizontal to the ground.
2. Special attention should be given to the common field of view of both cameras to cover the area that must be monitored.
3. Once the user has selected and permanently installed the cameras then he must set a three-axis orthogonal system like the one that is presented in the following picture.

3-ORTHOGONAL CAMERA CALIBRATION
SYSTEM





Point A and B are the centres of the camera lenses that are placed on the xz and yz levels respectively. Care should be taken to perform every measurement from the centre of the lenses and not from the point that the camera is mounted on the wall. Lines MA and MB starting from the centres of the lenses and meeting at point M should be vertical to each other. Failure to achieve this vertical placement of the cameras will result in a systematic measurement error.

Following this 3-axis orthogonal system four numbers should be determined: a_1 , b_1 , a_2 , b_2 as they are set on picture 1. Once these measurements have been performed as accurately as possible, then the user must go to the LPS PC desktop and find the file videograbber.ini. After opening this file the user must change the following parameters according to the measurements.

$a1a=a_1$

$b1a=b_1$

$a2a=a_2$

$b2b=b_2$

All numbers should be set in cm. No other parameter within the file should be altered. Then the file should be saved and closed.

4. Then the camera cables must be mounted from the one end to the cameras and from the other end to each camera adaptor box (DC-700 Sony). In the next step, from the video 1 output of each camera adaptor box, a BNC cable must connect this box with each one of the video grabber PC cards outputs. This procedure should be done for both cameras.

5. Finally before starting the measurement procedure, the user should check if all the cable connections of the system are ok and then open first the power in the black camera adaptor boxes (DC-700 Sony). Then it should open the software and the two video icons. Special attention should be given to the following point.

When the two video images are presented on the PC screen, the image that comes from the camera which is in the yz level must appear on the left hand of the PC screen. If this is opposite, the user should just switch the BNC cables of the video cards in the PC and the problem will be fixed. Half size windows should be used in this step because it is easier to determine which window is left and which is right.

6. After this the user should be ready to measure. Some sample measurements from some fixed points of which the exact (x,y,z) position is known should be taken and be compared with the ones calculated from the LPS. If the difference between the LPS measurement and the actual measurement is less than 10 cm the system is properly calibrated and ready to operate. If this difference lays in the region of 10-25 cm then the user should conduct more measurements to verify whether this is a calibration error or a random error caused by the user

itself, during the identification of the object in the PC and its marking. If the error is greater then the user should repeat from the beginning steps 1-6.

NOTE: If the user changes the position of the cameras the whole calibration procedure should be repeated. It is also advisable to check periodically the accuracy of the measurements because it is easy for the cameras to be slightly moved either by the user-students or by the force implied on the camera body by the cable that connects it with the camera adaptor boxes. Consequently it would be advisable to give extra care to the mounting of the cameras in order to avoid all the above problems that may produce systematic errors to the measurements.



Appendix E: Lab of Tomorrow Glossary

Axions. A series of artifacts that consist of three main parts: a sensor interface, a main electronic board and a communication system. Examples of axions in LoT are the SensVest Module and the Axion Ball.

SensVest Module. A wearable system of sensors measuring physical parameters.

Accelerometer Module. A device that measures the magnitude of its acceleration (or the acceleration of the body that is attached to). In LoT the accelerometer module is attached either to the user's leg or to a ball (axion ball).

Axion Ball. A ball with a three dimensional accelerometer module stabilized inside it.

Student Transmitter Module (STM). A radio module that receives data from the SensVest Module and then transmits them to the Base Station Module.

Base Station Module. A radio module that is responsible for the initialization of the systems (axion ball, sens-vest), the collection of transmitted data from them, the proper formatting of these data and its dispatch to the workstation.

Workstation. A PC that collects and processes all system data. Local Positioning System (LPS). A two-digital camera system that is used to determine the position coordinates of an object in real space.

User Interface. A software interface that allows the students to manipulate the data collected by the axions.



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