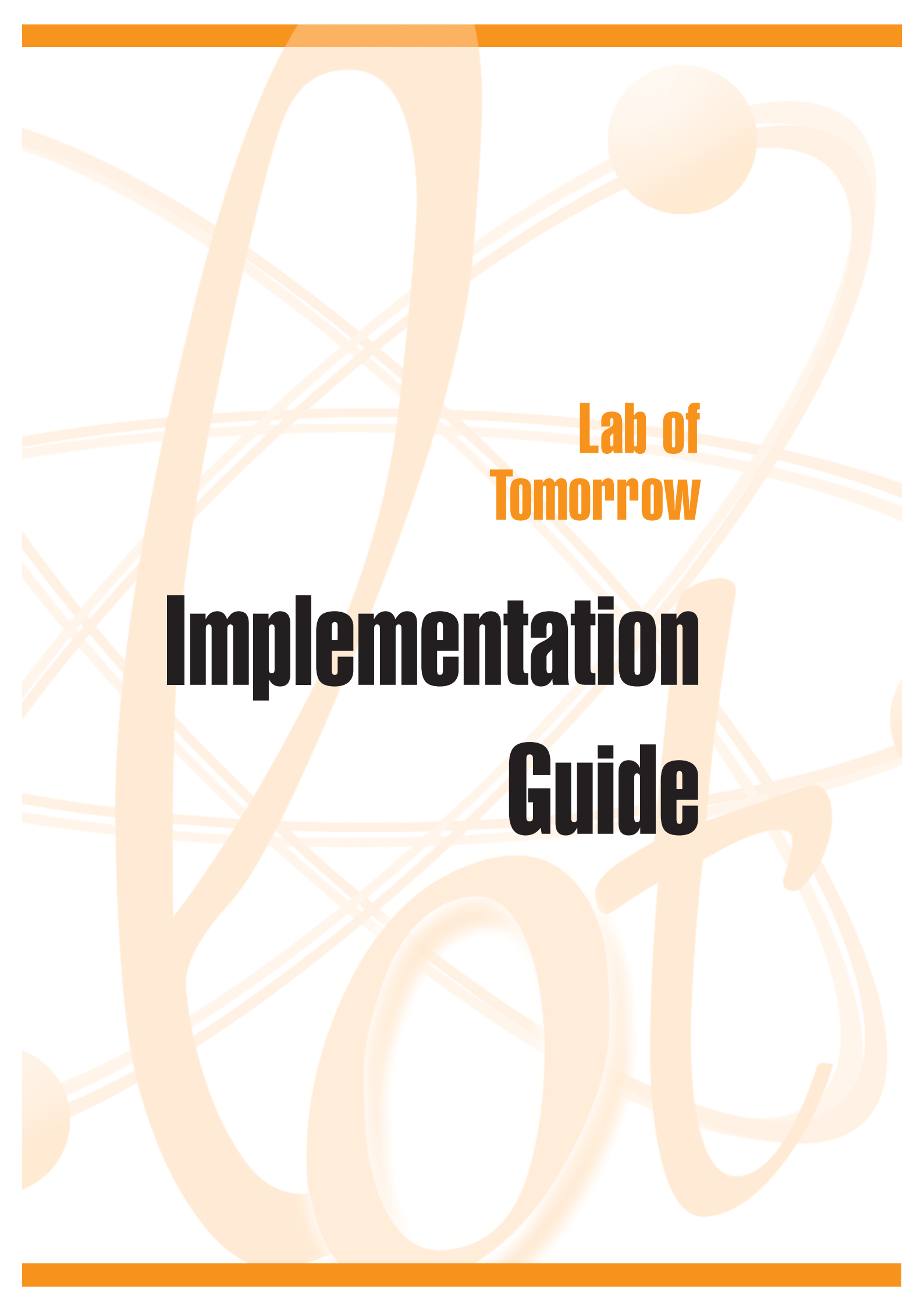


**Lab of
Tomorrow**



IST-2000-25075

Implementation Guide

The background features a complex network of thin, light-orange lines that intersect and loop across the page. Overlaid on these lines are several thick, smooth, orange-colored shapes, including a large vertical loop on the left, a circular shape at the top right, and a large, rounded shape at the bottom. The overall aesthetic is modern and technical.

**Lab of
Tomorrow**

Implementation Guide

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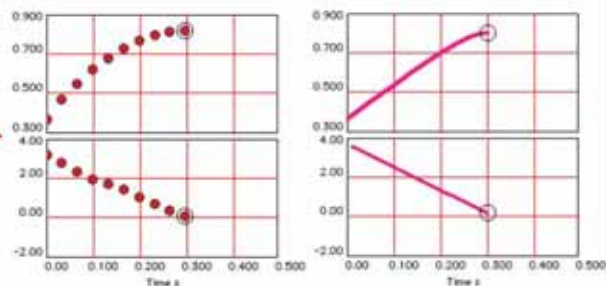
Our vision for the school of tomorrow is that it will not be an island, a self-contained campus, a counterworld. The school of tomorrow will be able to emit and absorb along different wavelengths, be immersed in contemporary culture, be open to the emotions, facts and news of its time. It will be permeated 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

Kick life into the classroom



Data collection with an axion (accelerometer - GPS) embedded in a ball



The graphical user-interface is plotting data on a graph, creating a mathematical model to fit the data and relate the graph with the motions of the axions

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For the teacher

The aim of this implementation guide is to support the teachers involved in the project to implement the proposed activities in the normal school curriculum. The project includes three extended periods of school-centered work. These trials are not only meant for evaluation purposes (technological and pedagogical) but involve **teachers and students** to giving direction to the project and its technological and pedagogical results.

The aim is to help both teachers and students reach beyond "cliches" to the areas in which they can make **the most valuable contributions**, and **potentially increase their role on the world stage afterwards**. 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 project uses a heavily **student-center approach**. This will be achieved by using five real school environments in Austria, Germany, Greece and Italy. Moreover, the trials are used to allow for consideration about ethical and privacy issues, leading to results with respect to implications for the open school communities and for intercultural effects. During the schoolcentered work students will use the axions embedded in objects (toys, clothes) in their everyday activities and measure a series of quantities (temperature, acceleration, etc). The data collected by the axions are transmitted in real time to a main server and stored. Almost all physical phenomena and fundamental laws in disciplines like Mechanics, Chemistry and Biology can be studied using the acquired data. The analysis and the display of the data is done with the use of the specially developed graphical user-interface. During the first cycle of school activities, **the Test Run**, the partnership will initiate the application of the developed axions in the school communities. The Test Run will have duration of three months and students' reactions to the proposed pedagogical approach will be monitored and analyzed in detail. With the experience gained during the Test Run and after the appropriate modifications on both the educational tools and on the didactical approach, the partnership will implement the project in the classroom during a second implementation cycle, the first phase of the **Final Run**. During this phase students and teachers will follow the constructed lesson plans, by using the already developed tools. The main purpose of this phase is to get both students and teachers familiarized with the new approach and the new tools and prepared them for the final and most important cycle of the schoolcentered work, the final **students' projects** cycle. During the last phase students and teachers will be able to study any aspect they consider important by using the tools and the axions. Additionally, at this stage students will have the opportunity to propose new wearable sensors and ergonomic solutions, providing thus their input in the co-design of the toys and wearables. The open architecture of the axions and the user-interface will allow the adoption of the new ideas in short time. The partnership believes that students can come to view their involvement in this procedure as a craft that rewards dedication and precision but simultaneously encourages a spirit of creativity, exuberance, humour, stylishness and personal expression. Students will

learn the scientific method, design and conduct scientific experiments, collect and display data, and write a report of their results. Students will also give examples of how scientific method can be used to solve real-world problems. The idea of the partnership is that in each of these cycles of the school-centered work less and less guidance is needed, and following the echo from IST'99 session "Children shaping the future", Lab of Tomorrow aims at **giving the chance to the students to actively participate to the co-design of the future educational tools.**

During the implementation of the school-centered activities teachers and students will be provided with the needed **pedagogical** and **technical support** through the project's web site, which will also serve as the starting point for discussions on the project's aspects. The synthesis of the Lab of Tomorrow partnership safeguards the needed expertise in order the goals of the project to be achieved and the proposed tasks to be accomplished. 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 will not remain a rhetorical exercise, in the Lab of Tomorrow project **students and teachers will come together with researchers, psychologists, designers and technologists to re-engineer the lab of the school of tomorrow.** This will be achieved **by developing a new learning scheme based on the production of computational tools and project materials** that allow high school students to design their own scientific projects.

The document consists of four main chapters which include all the necessary information for the project's implementation. The **first chapter** is describing the pedagogical approach of the project and the basic concepts govern the design of the proposed lesson plans. The **second chapter** describes the functionalities of the axions that have been developed. It includes specific guidelines for their use during the classroom activities and for the use of the graphical interface for the demonstration of the collected data. The **third chapter** describes the lessons plans which will help teachers during the implementation of the project in the school environments. These lesson plans should act as recommendation to the 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 information and guidelines for the teachers on how they have to work during the project's implementation in order their findings to be used as input for both the technological and the pedagogical development of the project.

In addition this document includes a series of specific forms that teacher should use during his/her lessons, in order to help the partnership to evaluate the proposed approach and the project's outcomes. **Such forms are the Lab of Tomorrow System Interface Heuristic Evaluation Form**, included in Chapter 2 (session 2.8), the **Worksheets**, included in Chapter 3 after each of the proposed lesson plans and the **Guidelines and Checklists for the video taping of the activities**. All these documents are necessary not only for the smooth implementation of the project but also for evaluation purposes in order the comparison between the proposed approach and the traditional approach to be realised.

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.gr) aims to provide help and support to the teachers of the Lab of Tomorrow.

Introduction

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 axions 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

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.

(*Baber 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 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.

A series of **lesson-plans (scenarios)** have been developed. These series of lessons will be implemented in the science curriculum of the participating schools during the first two cycles of the school-centered work. At the final cycle of the school-centered work students and teachers (having been familiarized with the idea that scientific investigation is a process in which they can take part, day-to-day, creatively and pleasurably) will have the opportunity to design their own scenarios for exploring phenomena in their everyday lives. These new ideas will provide input for the development of new artefacts.



Chapter 1

The Pedagogical Approach of the 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 recognition 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, 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
Meditation	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.

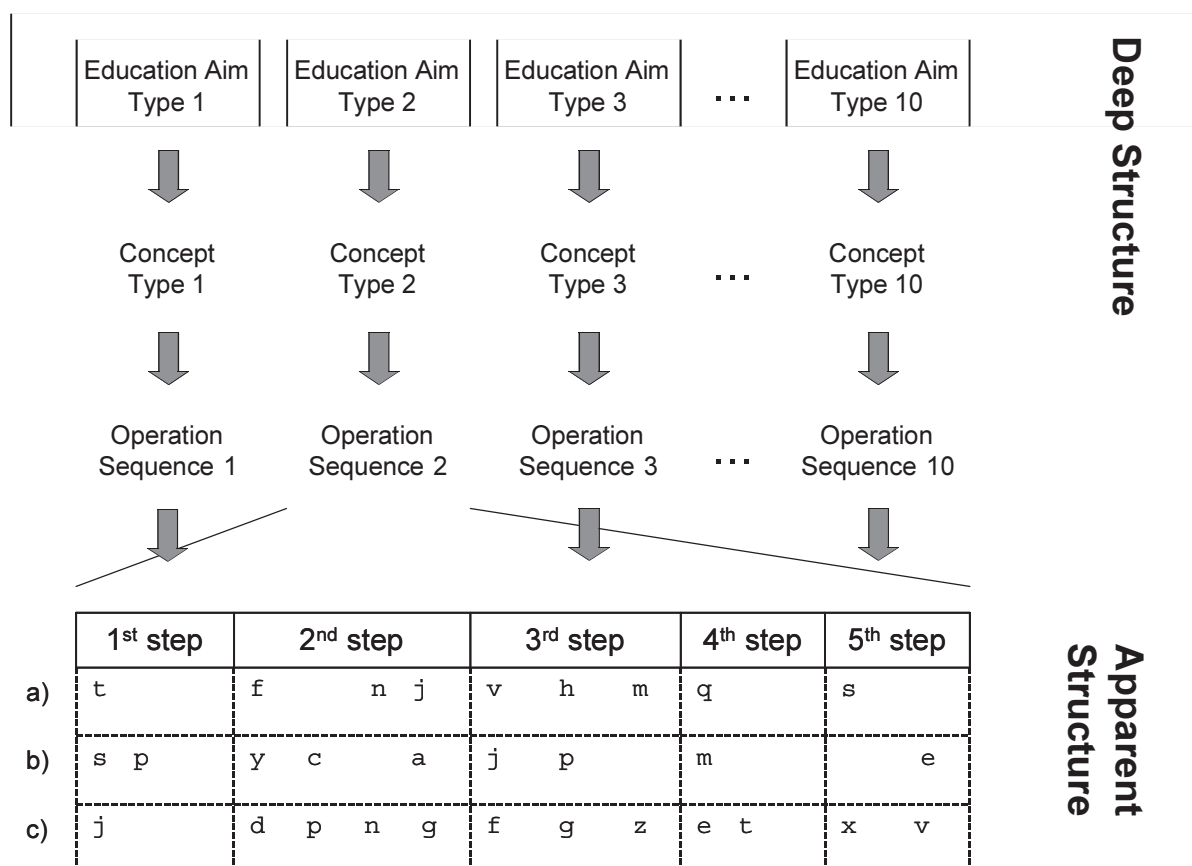


Figure 1: Deep Structure and Apparent Structure, linked by Operation sequences.

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 education-

al 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 objective of learning by own experiences 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 emphasises a discrepancy between expectation 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. Fixing of a satisfying strategy for solving the problem (retention).
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 accumulate 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 1: 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 students 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 a 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 radio-network.:
 - 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

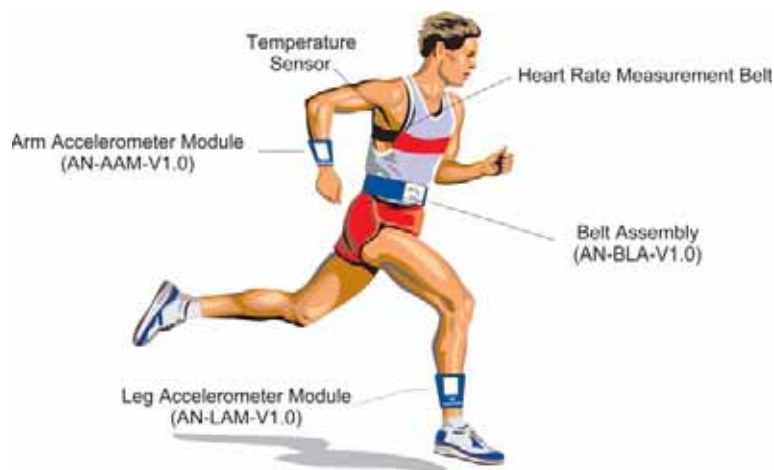


Figure 2.1b: *The components of the Lab of Tomorrow system*

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.

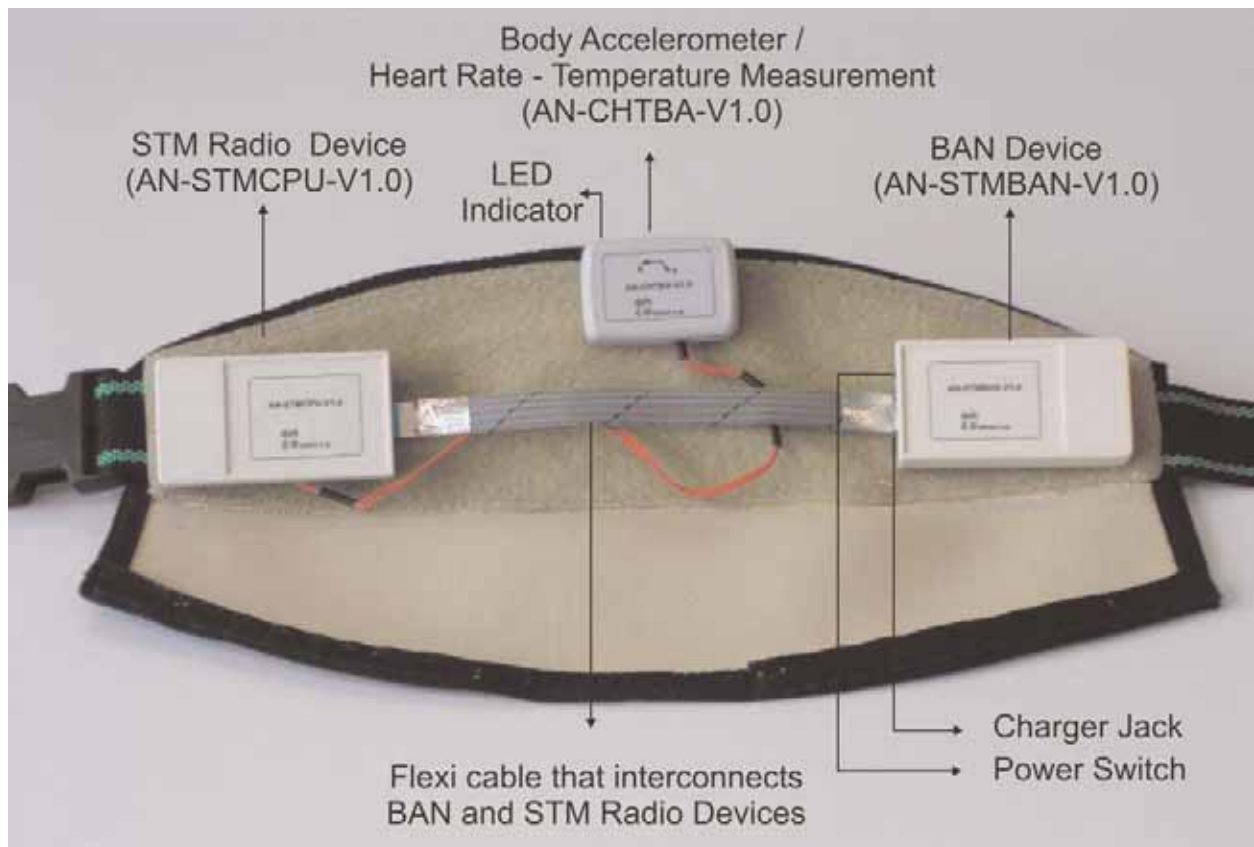


Figure 2.3: Belt Assembly

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.

- b. The Body Area Network radio module (□□-STMBAN-V1.0), which collects wirelessly via the BAN all data from the Arm and Leg Accelerometer modules.
- 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.

Temperature Measurements

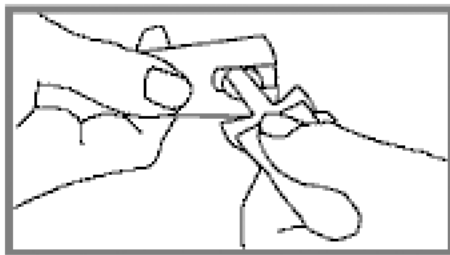
To conduct temperature measurements, connect the temperature sensor to the available connector at the AN-CHTBA-V1.0 module (See Figure 1.4). The temperature sensor should be placed under the armpit, with the metal surface at the skin contact side.



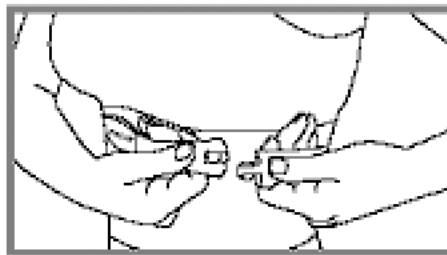
Figure 1.4: AN-CHTBA-V1.0 module

Heart-Rate Measurements

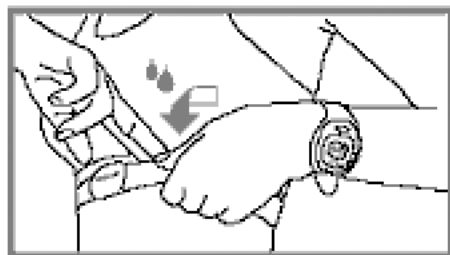
To conduct heart-rate measurements, the student should wear the Polar belt, following the instructions in 2.5.



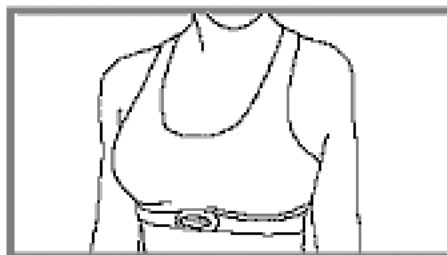
1. Attach the transmitter to the elastic strap.



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 2.5: 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 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.

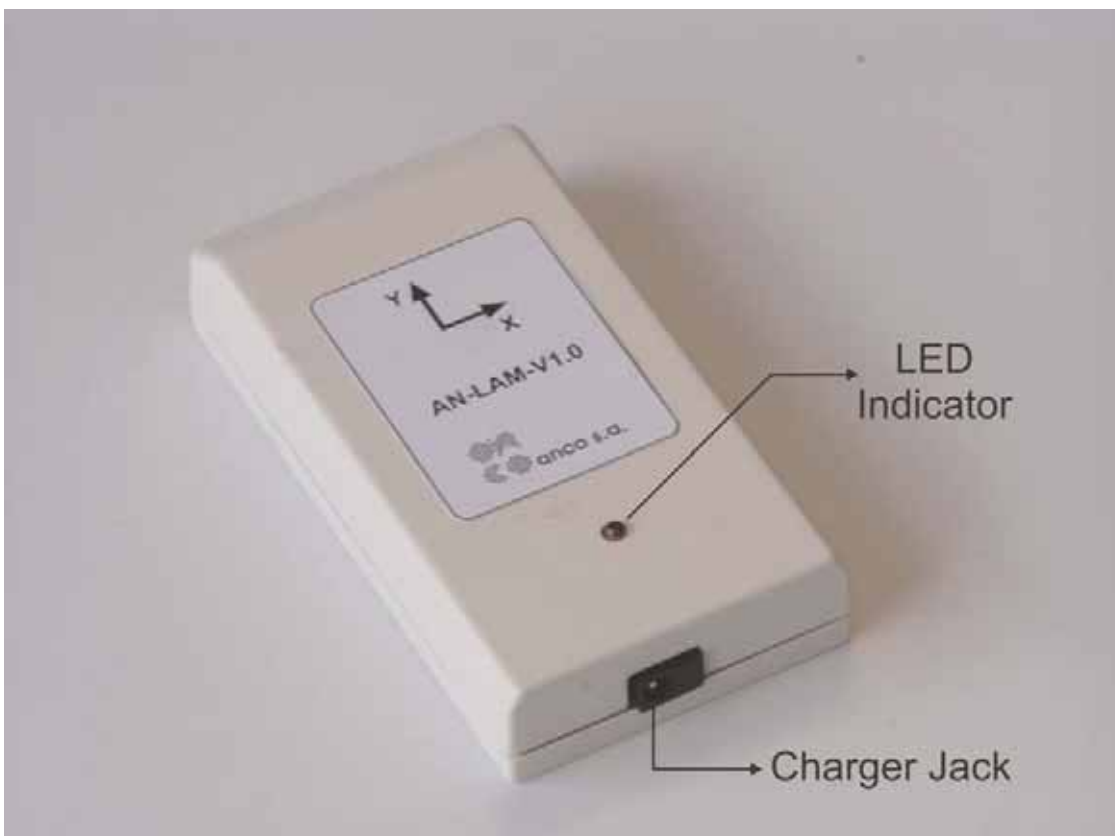


Figure 2.6: Leg Accelerometer

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, 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.

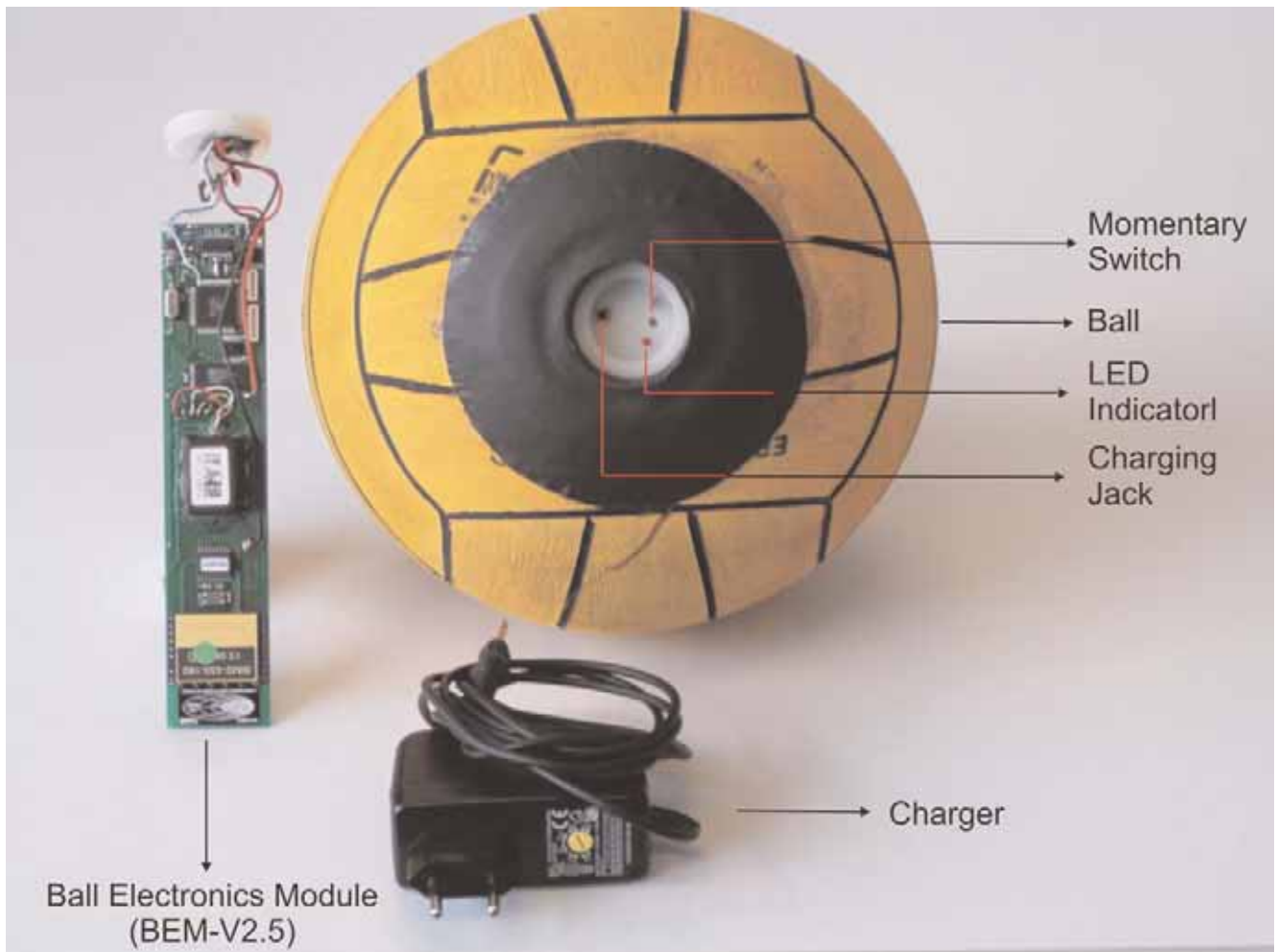


Figure 2.7: Ball Module

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 (see 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.

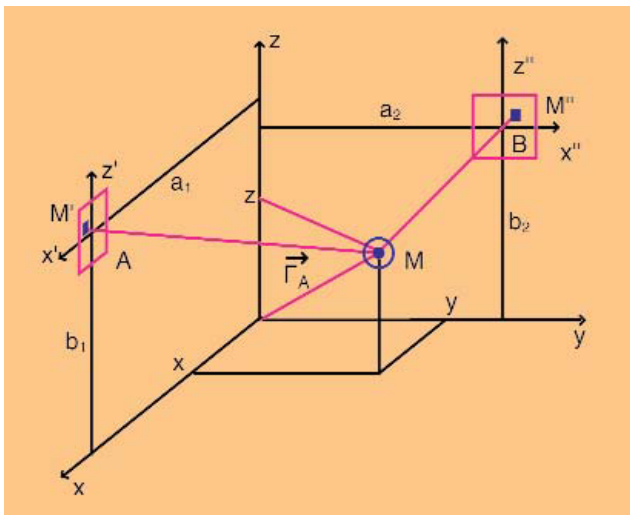


Figure 2.9: The basic principle of the LPS architecture.

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 10-15cm. 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 kinematic 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

2.5.1 Quick Launch Form

2.5.2.1. 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 (See Screenshot 1)

- 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.

2.5.2.2. 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.

2.5.2 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.



2.5.2.3. Menu Bar

2.3.1. "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)

2.3.2. "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)

2.3.3. "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)

2.5.2.4. 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 (Help File-Not Implemented)
17. Courses (Course files-Not Implemented)
18. Settings (Program Settings-Not implemented)
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)

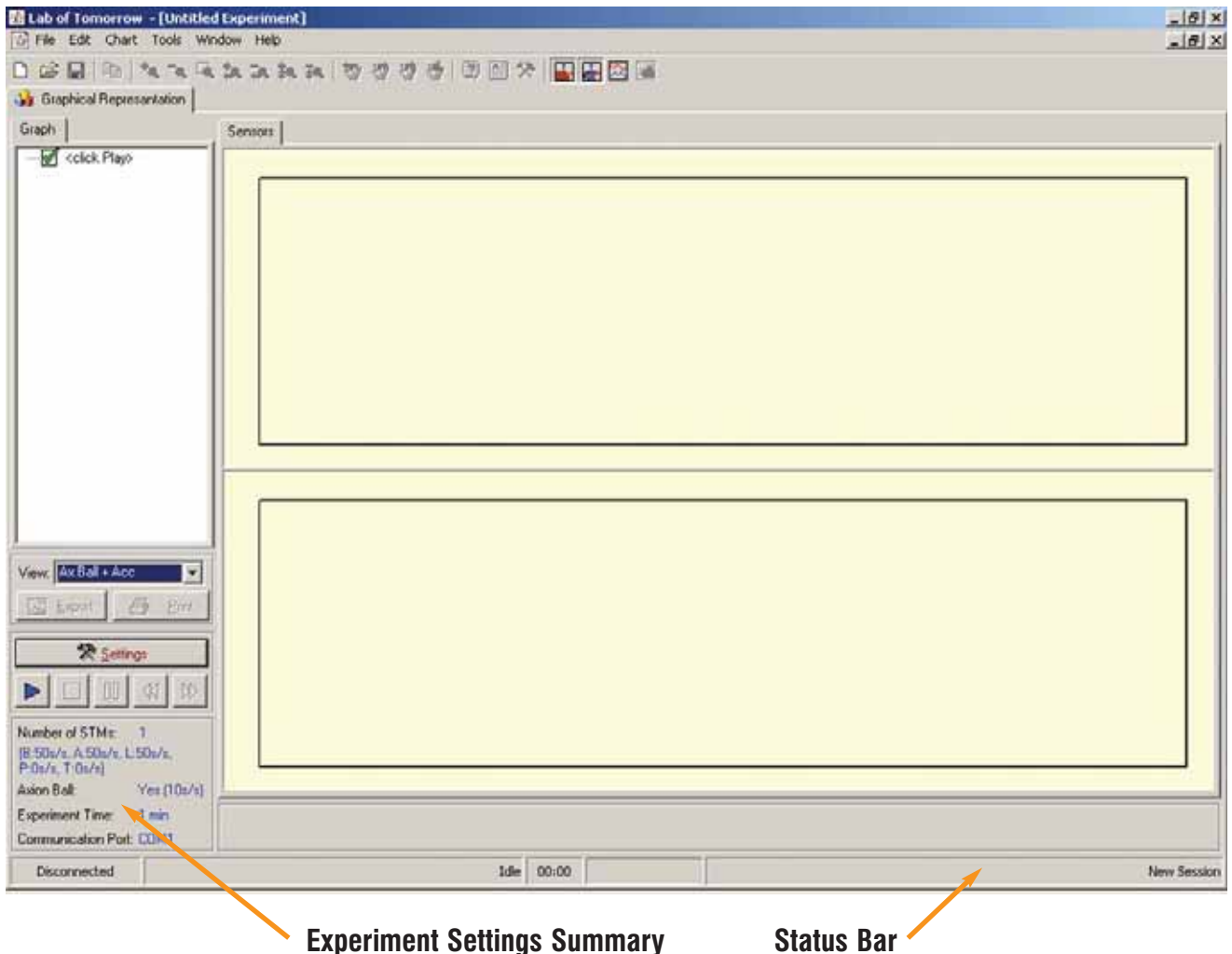
2.6 Using the LOT User Interface

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:



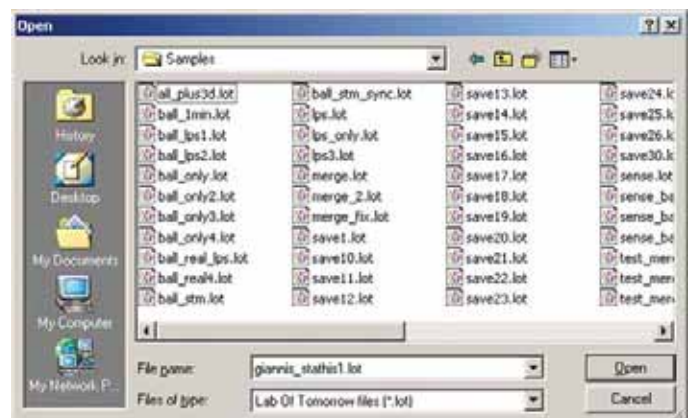
Clicking on the settings, button will show the Experiment Settings form where all experiment settings are configured. When done, the Play button, will start sampling data from the base station. At the time the sampling is over, all chart and data manipulation functions are enabled, and the experiment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

Opening An Experiment

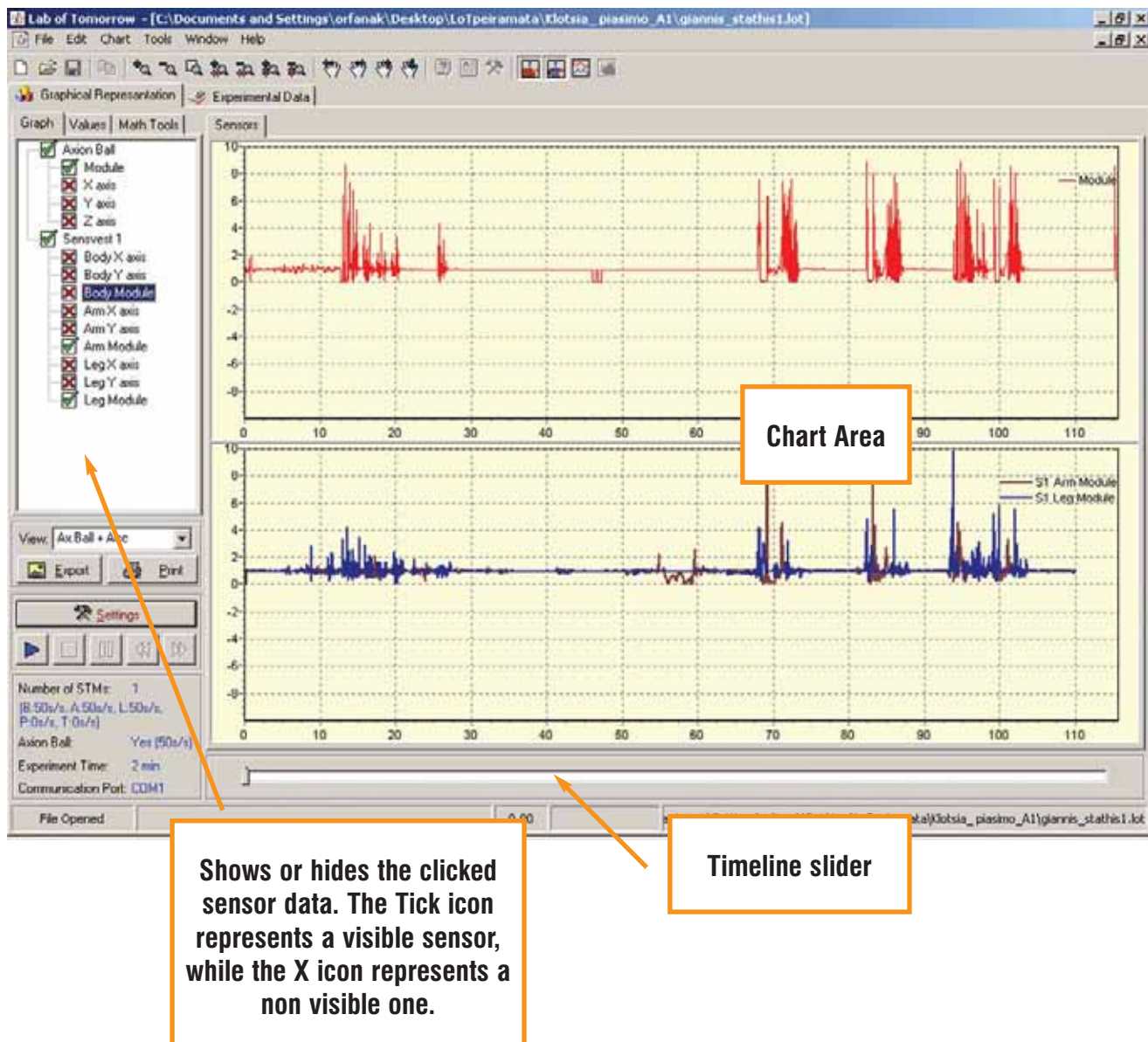
This is very simply done, by just selecting the file you wish to open. The Open Experiment dialog, can be enabled by clicking the Open button in the toolbar or by selecting

[File->Open](#)

(See ScreenShot)



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.



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:

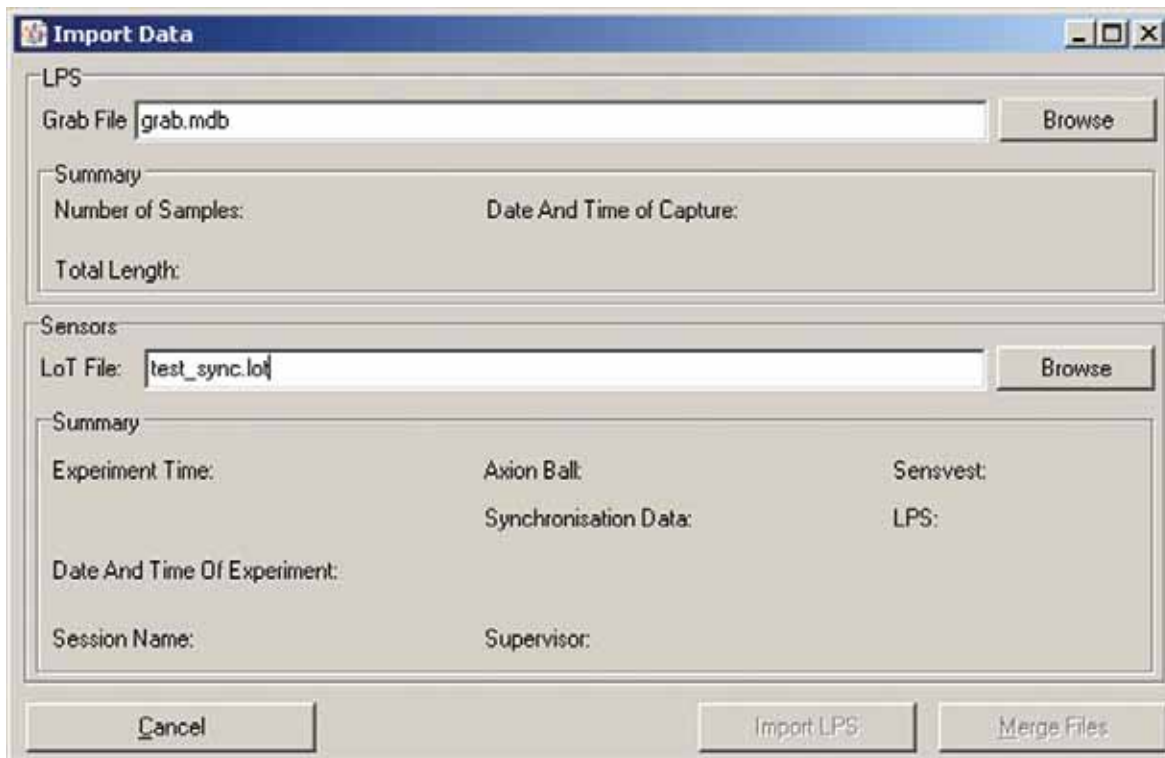
The screenshot shows the 'Import Data' dialog box. It is divided into two main sections: 'LPS' and 'Sensors'. The 'LPS' section contains a 'Grab File' text box and a 'Browse' button. Below it is a 'Summary' frame with fields for 'Number of Samples:', 'Date And Time of Capture:', and 'Total Length:'. The 'Sensors' section contains a 'LoT File' text box and a 'Browse' button. Below it is a 'Summary' frame with fields for 'Experiment Time:', 'Axion Ball:', 'Sensvest:', 'Synchronisation Data:', 'LPS:', 'Date And Time Of Experiment:', 'Session Name:', and 'Supervisor:'. At the bottom of the dialog are three buttons: 'Cancel', 'Import LPS', and 'Merge Files'.

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:

This screenshot shows the 'Import Data' dialog box after a file has been selected. The 'Grab File' text box in the 'LPS' section now contains the text 'grab.mdb'. The 'Import LPS' button at the bottom is now enabled (no longer disabled). The 'Sensors' section remains unchanged. The 'Summary' frames for both sections are still present with their respective fields.

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. (See picture below)



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 (See Diagram Above).

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)

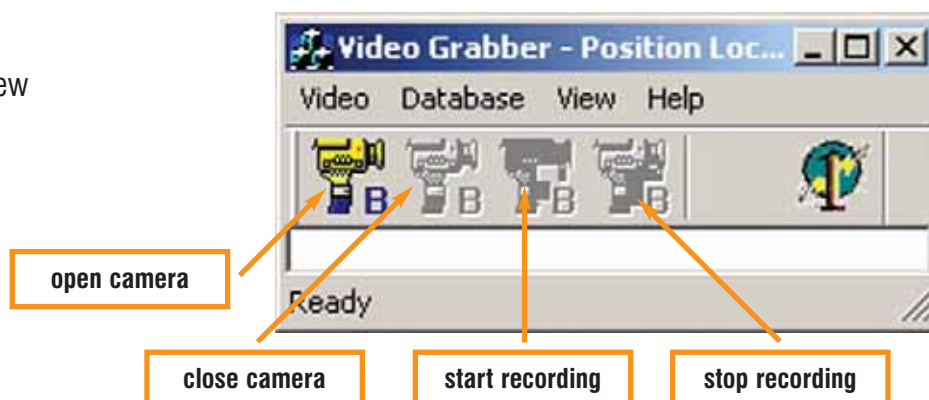
3. Initialize database

(erase previous data)



4. Creating videos

4.1. Button overview



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"

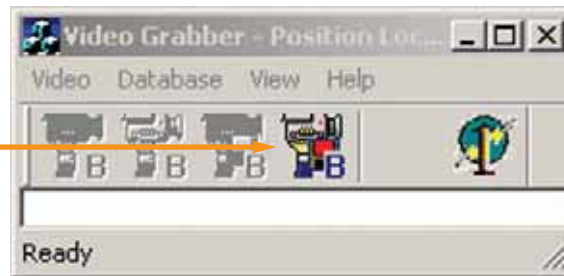
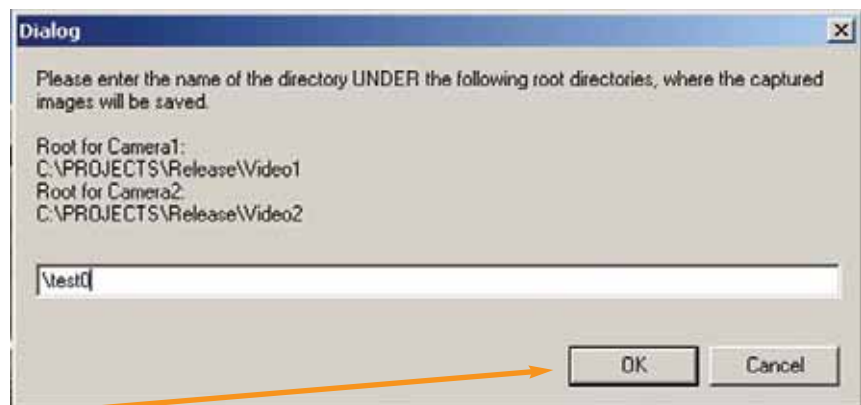
The two video windows disappear

4.3. "Start recording"
press the button

enter a name for
the experiment

then start recording
by pressing "OK"

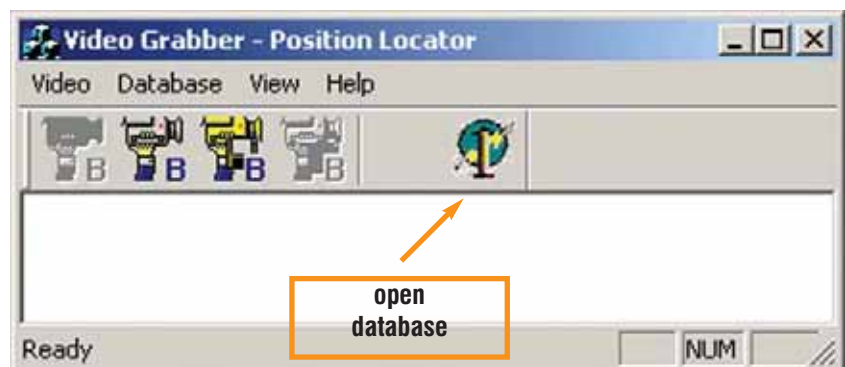
only the "stop
recording" - button
is enabled now



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"

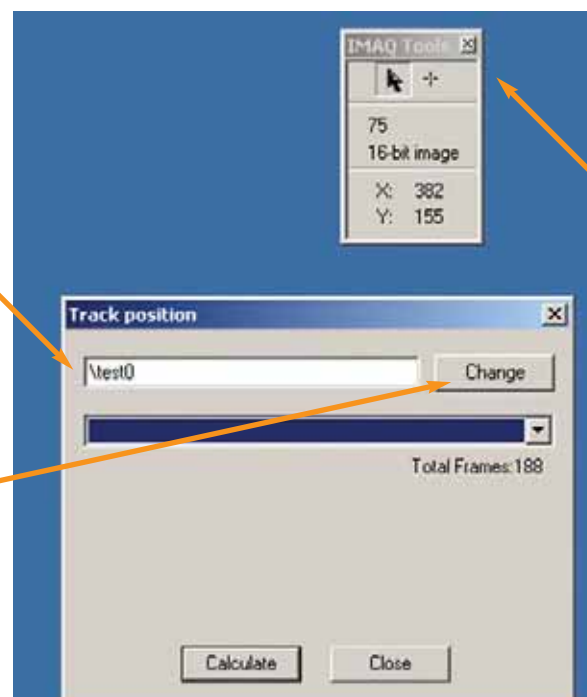


5.2. Choose the experiment
and the tool

enter the name of
the experiment

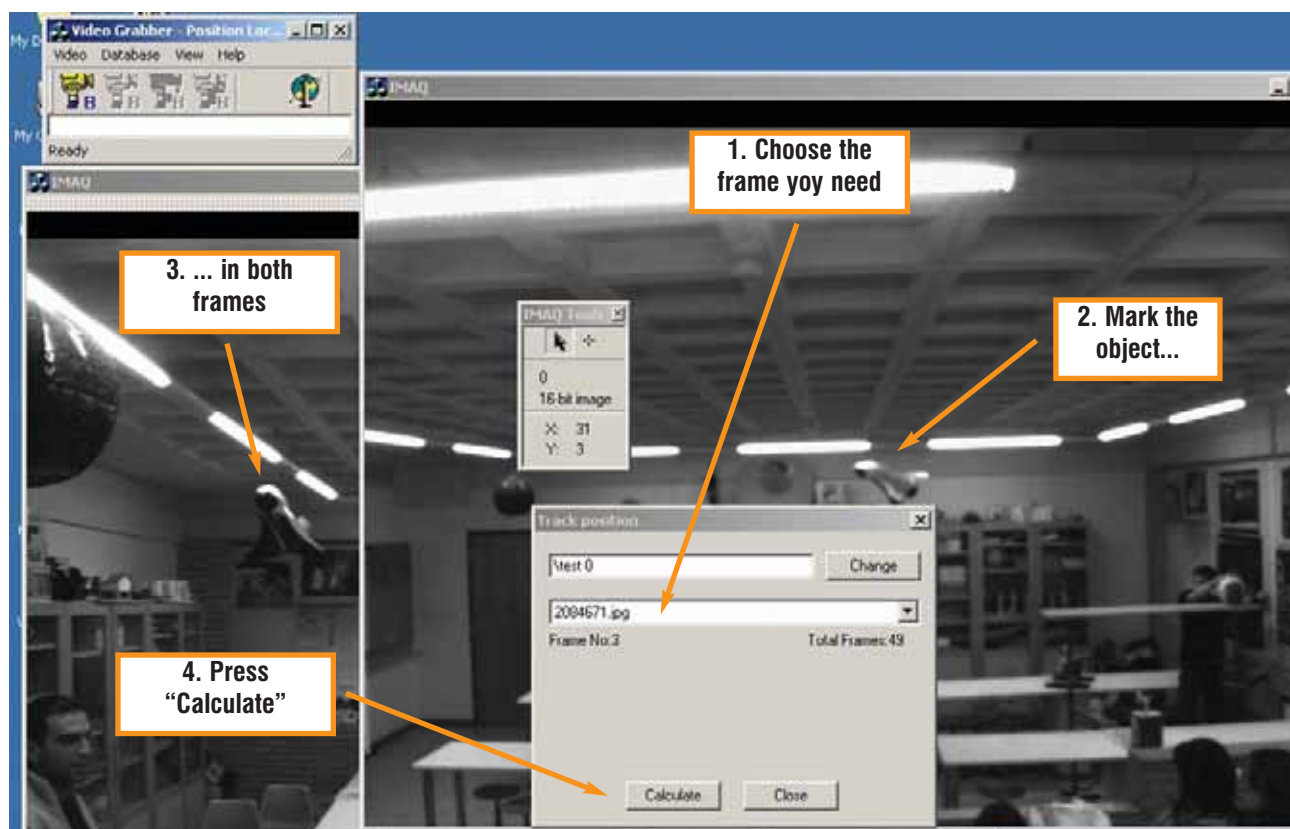
choose the tool
for marking

press the button
"Change"



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 z-component of the positions and the assigned time ("tick") is stored:

Microsoft Access - [Points : Table]					
	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. 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.

2.8 Lab of Tomorrow System Interface Heuristic Evaluation

Heuristics are simple rules that can be used to define a well-designed system for user interaction. In this respect, a system interface refers to not simply what is displayed on a screen, but also to the objects that a person can interact with, e.g., ball, Sensvest, cameras etc. In order to conduct an evaluation, the analyst will consider each question and indicate positive and negative answers. We have produced a table that the teachers can complete - the expectation is that this process should take no more than 20-30 minutes.

	Heuristic	Positive	Negative
1	Users are kept informed of what is happening		
2	Users can understand the system feedback		
3	Mounting of the overall system is easy		
4	Actions can be performed quickly		
5	Actions do not involve too many steps		
6	The Users know the meaning of the terms commonly used within the project: • User Interface • Base Station • STMs • SensVest • Ball • Positioning Cameras		
7a	It is easy to interact with the project object: • User Interface		
7b	It is easy to interact with the project object: • Base Station		
7c	It is easy to interact with the project object: • STMs		
7d	It is easy to interact with the project object: • SensVest		
7e	It is easy to interact with the project object: • Ball		
7f	It is easy to interact with the project object: • Positioning Cameras		
8	It is easy to know what to do		

	Heuristic	Positive	Negative
8	It is easy to know what to do		
9	The User knows which measurements are performed within the project		
10	The User knows the precision of the measurements which are performed within the project		
11	The measurements precision is acceptable for the Users didactical tasks		
12	The language used in the interface is easy to understand		
13	The concepts used in the interface are familiar to the user		
14	User actions are simple and easy to learn		
15	Similar actions are performed in similar ways		
16	Error messages are helpful		
17	The displayed information is easy to interpret		

Chapter 3

Lesson Plans

3.1 The design of learning processes

As described analytically in chapter 1 the science 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, 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 pre-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 pre-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. It is one of the main objectives to acquire the ability of self-organised and self-regulated learning. Schools should generate the conditions for a development of the competence to learn and, as a perspective, an autonomous learning in the future biography. 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 are 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 students 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 pos-

sible to realize a sequence of topics that equally guarantee a systematic learning (vertical knowledge transfer) and a 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.

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 take the structure of the pedagogical framework as well as the advantages of the technical devices into account. 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 five 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:
 $s = v_0 t$, $\langle v \rangle = v(t)$, $dv/dt = 0$
- 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 $F=k \cdot s$, work and energy $E=1/2 \cdot k \cdot s^2$) and potential energy ($E=m \cdot g \cdot h$)
- 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: $s=1/2 \cdot a \cdot t^2$, $v=ds/dt=a \cdot t$
 - c) $a=dv/dt$ as the new physical quantity acceleration
 - d) description of the motion as "uniformly accelerated" ($a=\text{constant}$)
 - 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 $F_{\text{(gravitation)}} = k \cdot m_1 \cdot m_2 / r^2$)

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 throw 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 single
- 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

Introduction

Students have different background in Physics and Science subjects respective to their age and the curriculum of the country they come from. Lab of Tomorrow project is referring to students 15-16 years old. 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 velocity is defined and
- how velocity can be measured
- be able to draw correct s-t- and a v-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 $\leftrightarrow$ 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 to be familiarized with the way of "thinking" and "acting" within the framework of Lab of Tomorrow. The first three categories of preparatory lessons cover learning issues that can be easily covered with educational material that is already available to every science and physics teacher. The last category of preparatory learning activities is presented more analytically here since it refers to basic experiments with the Lab of Tomorrow equipment. Based on the above the preparatory lessons of the lab of tomorrow should include:

- **Worksheets "Mechanics: Introduction into Kinematics" (1 - 2 lessons)**
Choose one of the three different worksheets depending on the time available.
- **Worksheets "Interpretation of diagrams" (1 - 2 lessons / homework)**
- **Worksheets "Getting practice in measuring" (2 - 4 lessons)**
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.
- **Basic experiments with the "Lab of Tomorrow" equipment**
Some basic experiments are suggested so as to familiarise students with the "lab of Tomorrow" equipment and reveal its potential for experimentation in physics and science studies.

Examples of basic experiments with the "Lab of Tomorrow" equipment - Worksheet 1

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 s⁻¹

1. Ball

1.1. Let the ball lying on the Table

1.1.1. 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?

1.1.2. Hit the table with your fist.

Watch the result in the graph.

1.1.3. Hit the ball so that it begins rolling on the table and stop it abruptly (count the number of rotations). If possible, it should be orientated in such a way, that the x-acceleration is "0".

Describe the graphs (y-, z-, module).

Can you see the number of rotations?

How can you see that this motion is a uniform one (except starting and stopping)?

Make one end of the table higher than the other so that you have an inclined plane.

1.1.4. Let the ball roll down the table and stop it abruptly (count the number of rotations). If possible, it should be orientated in such a way, that the x-acceleration is "0".

Describe the graphs (y-, z-, module).

Can you see the number of rotations?
How can you see that this motion is an accelerated one?

1.1.5. Let the ball move down the table on a little wagon, so that it doesn't rotate but moves down accelerated.

1.2. ... is held in the hand

1.2.1. Move the ball upwards and downwards several times with alternating speed.
Explain the different heights of the peaks.
What does "module" mean?

1.2.2. Throw the ball vertically upwards several times and catch it in an alternating manner (very soft - very abrupt)
How long does the free flight last?
Explain the different heights of the peaks when catching the ball.

2. Sens vest (3 accelerometers, temperature and pulse sensor)

2.1. Sit down and stand up.

2.2. Walk around.

2.3. Jump.

2.4. Jog over a distance of 20m on the schoolyard, the other students count the number of steps and take the time needed for this distance.

Try to interpret the graph and compare with the observations above:
leg acc.: count the number of steps, measure the time needed
body acc.: why show x- and y-axis different curves?

2.5. Throw a ball upwards and catch it again.

Do the arm acc. and the ball acc. show the same values while accelerating the ball and while catching it?

2.6. Use a bicycle and drive straight ahead resp. drive in a circle

Explain the graphs of the body and the leg accelerometer.

Basic experiments with the "Lab of Tomorrow" equipment - Worksheet 2

Familiarization with the LOT software and accelerometer sensors

Experiment

Max is rolling down an inclined Plane on in-line skates, the axion ball measuring acceleration in x-, y- and z-direction.

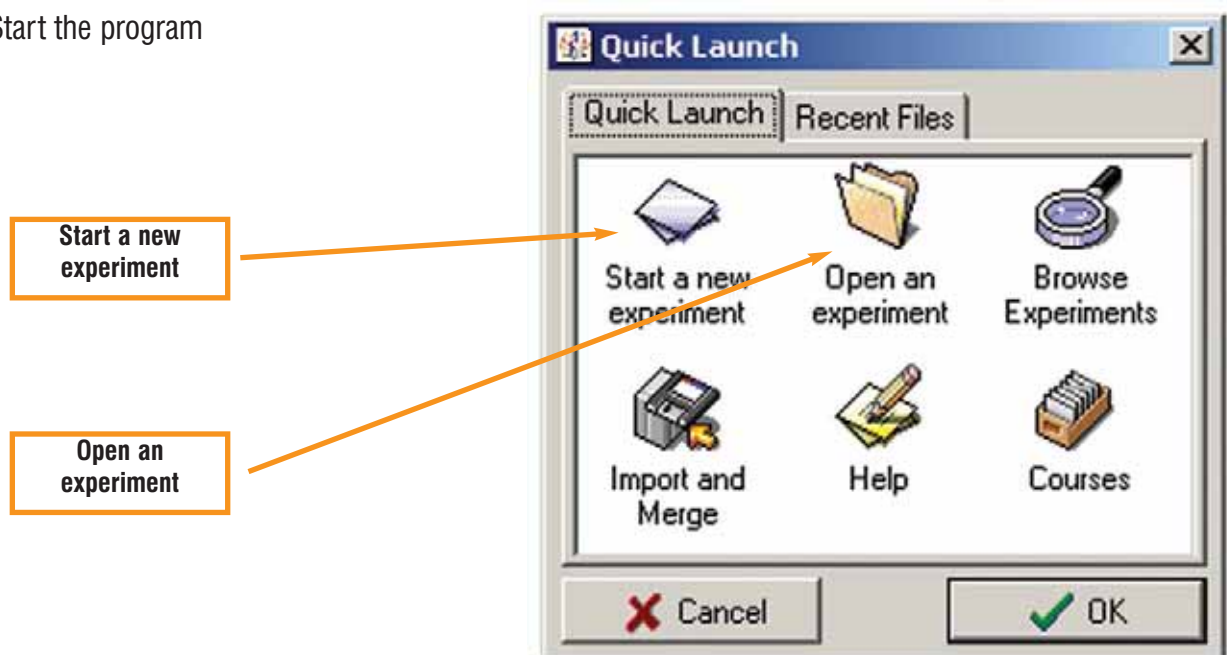
Preparations:

1. Max is holding the ball
2. The sensor's axis are orientated
3. The ball's transmitter is activated

Work with the LoT-Computer:

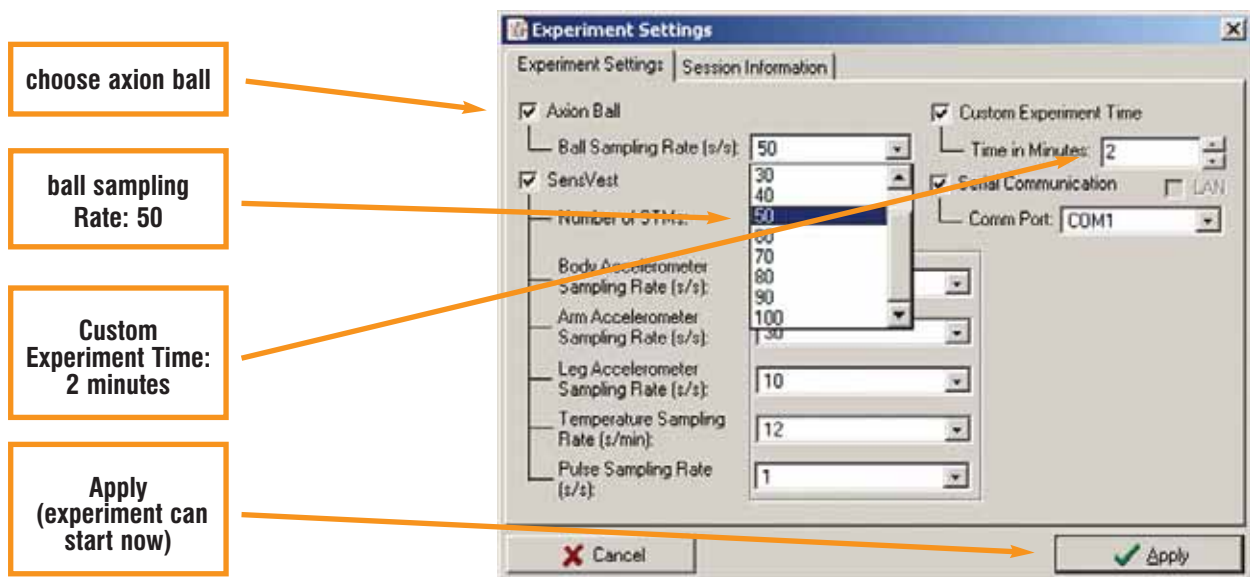
1. Start the program

or



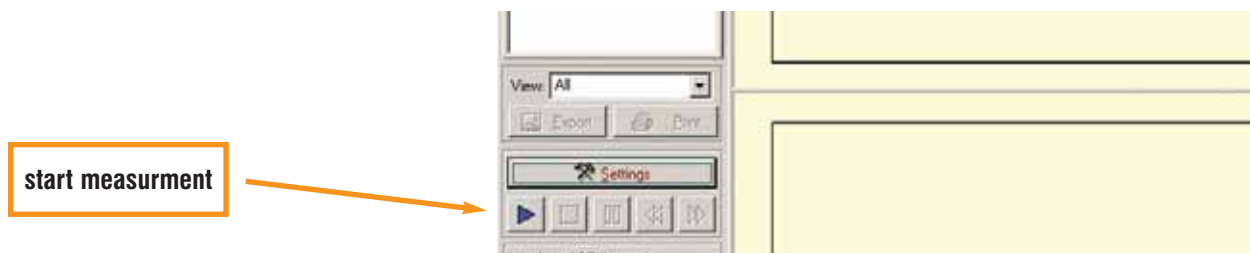
2. Choose experimental parameters:

Example: the **ball** is supposed to deliver **2 minutes** of measurements with **50 measurements each second**



The ball will start sending 50 measurements per second to the LoT computer for 2 minutes.

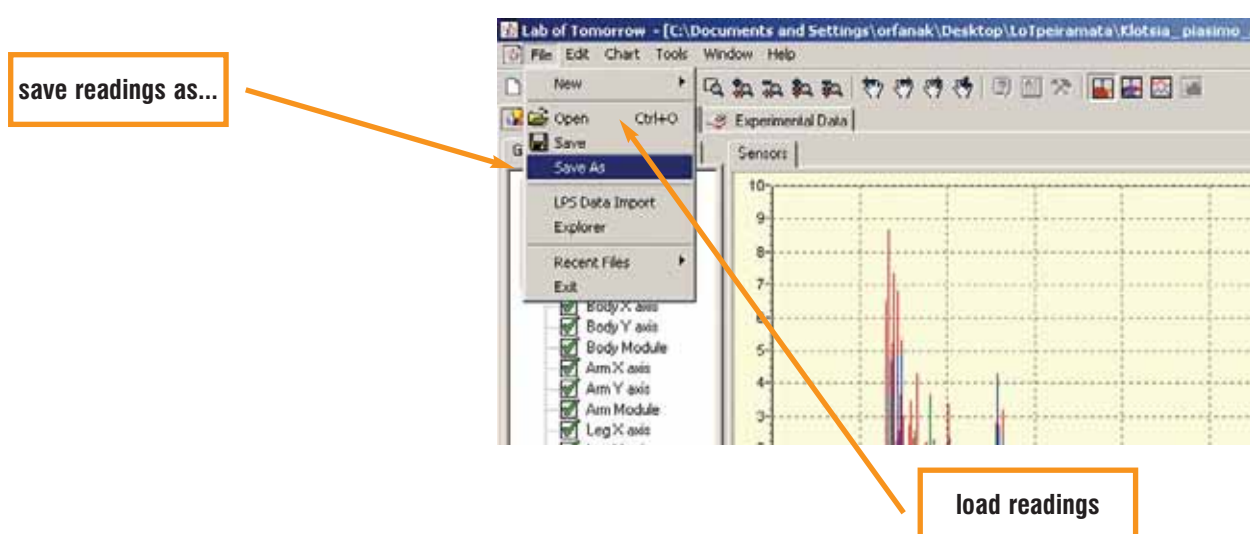
3. Start the measurement => data is transferred from the base station to the computer



4. Carrying out the experiment: Max rides down the plane

5. Stop measurement

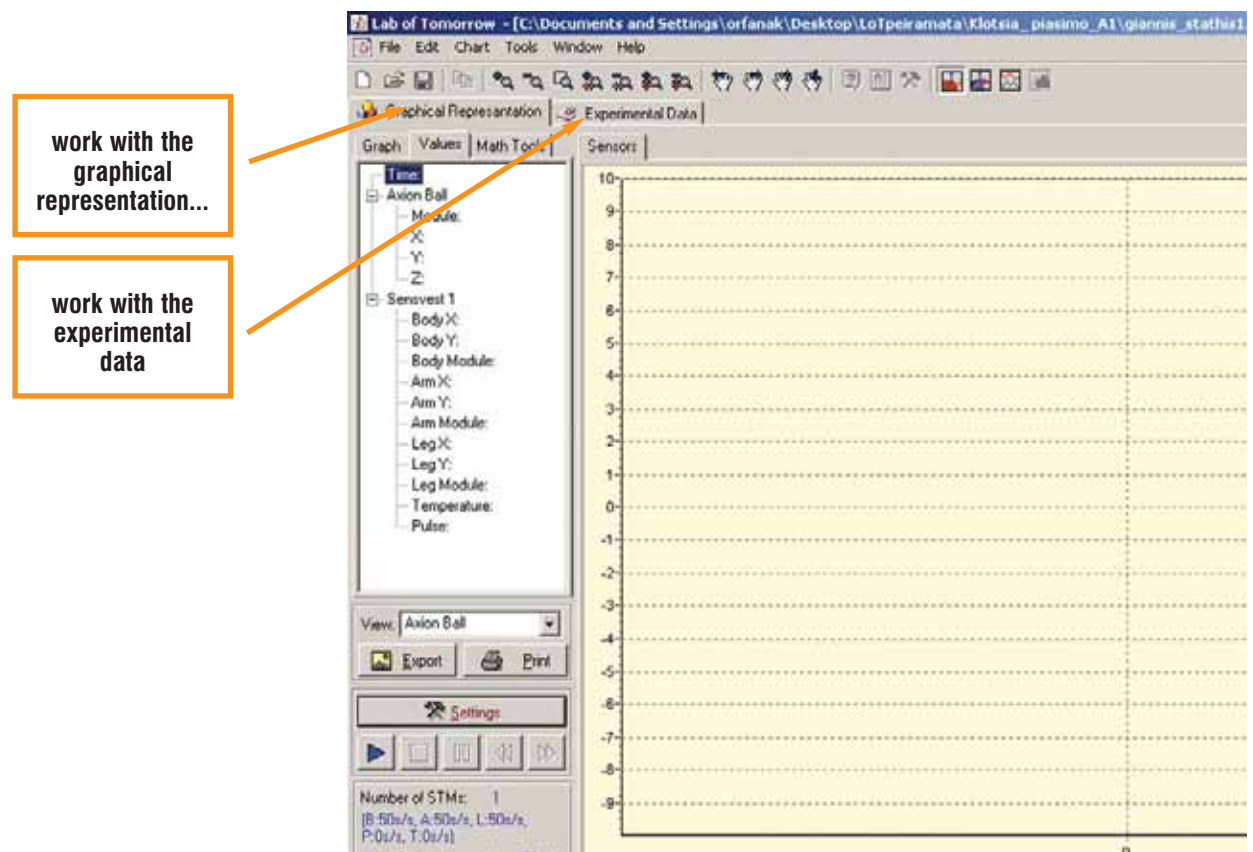
6. Save readings (as "Max_Ball_1")



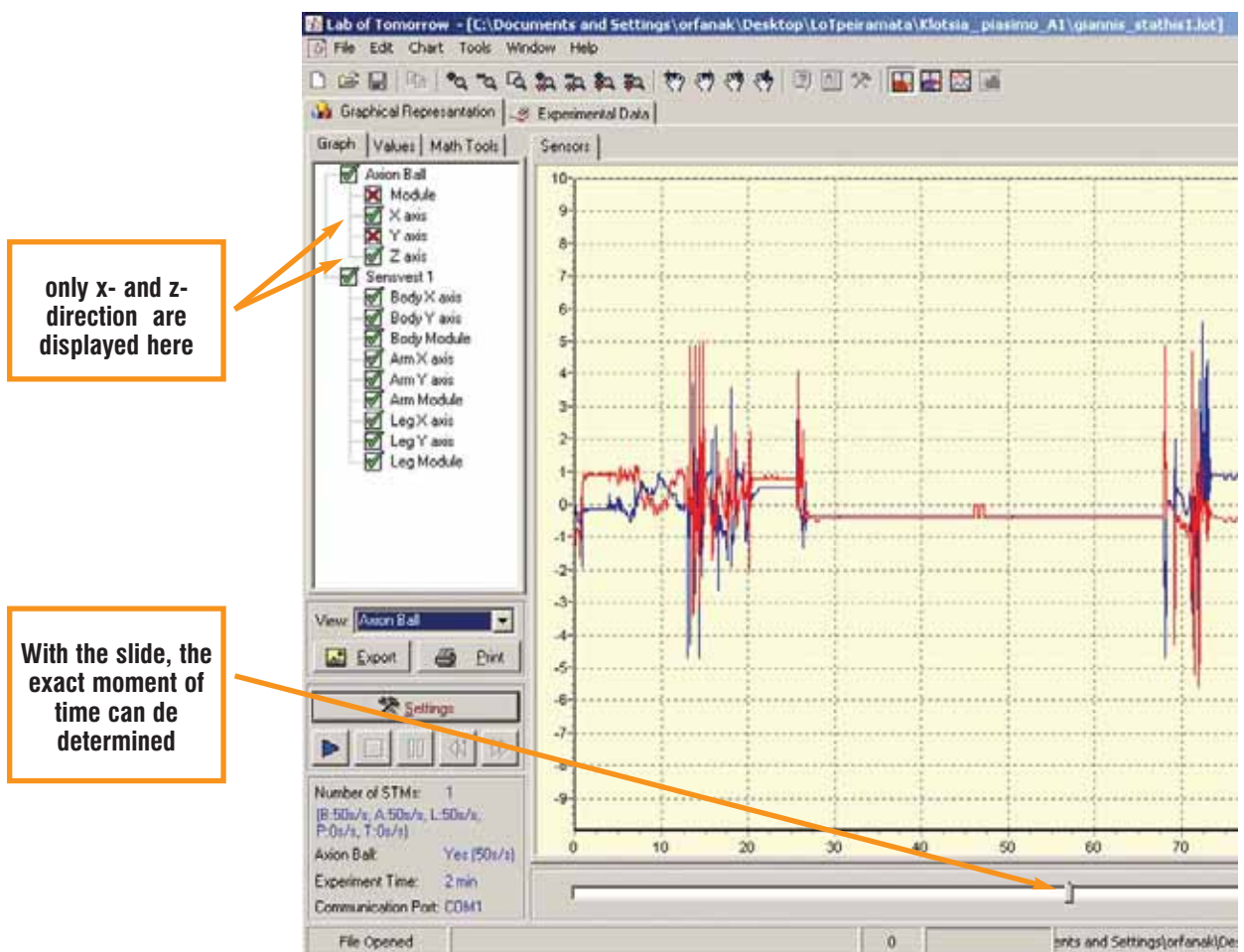
7. Reload Max_Ball_1

8. Analysis of the graphical representation (=> "Graphical Representation")

9. Analysis of the data (=> "Experimental Data")



10. First, you have to look for the interesting data in the graphical representation. With the slide, the corresponding period of time can be exactly captured.



11. Mark the interesting data in the spreadsheet "experimental data" and copy it to the clipboard.

mark data (with shift and cursor keys) ...

...and copy it to the clipboard

Time [s]	Module [g]	X axis [g]	Y axis [g]	Z axis [g]
38.06	0.94339811320566	-0.3	-0.8	-0.4
38.08	0.94339811320566	-0.3	-0.8	-0.4
38.1	0.94339811320566	-0.3	-0.8	-0.4
38.12	0.94339811320566	-0.3	-0.8	-0.4
38.14	0.94339811320566	-0.3	-0.8	-0.4
38.16	0.94339811320566	-0.3	-0.8	-0.4
38.18	0.94339811320566	-0.3	-0.8	-0.4
38.2	0.94339811320566	-0.3	-0.8	-0.4
38.22	0.94339811320566	-0.3	-0.8	-0.4
38.24	0.94339811320566	-0.3	-0.8	-0.4
38.26	0.94339811320566	-0.3	-0.8	-0.4
38.28	0.94339811320566	-0.3	-0.8	-0.4
38.3	0.94339811320566	-0.3	-0.8	-0.4
38.32	0.94339811320566	-0.3	-0.8	-0.4
38.34	0.94339811320566	-0.3	-0.8	-0.4
38.36	0.94339811320566	-0.3	-0.8	-0.4
38.38	0.94339811320566	-0.3	-0.8	-0.4
38.4	0.94339811320566	-0.3	-0.8	-0.4
38.42	0.94339811320566	-0.3	-0.8	-0.4
38.44	0.94339811320566	-0.3	-0.8	-0.4
38.46	0.94339811320566	-0.3	-0.8	-0.4
38.48	0.94339811320566	-0.3	-0.8	-0.4
38.5	0.94339811320566	-0.3	-0.8	-0.4
38.52	0.94339811320566	-0.3	-0.8	-0.4
38.54	0.94339811320566	-0.3	-0.8	-0.4
38.56	0.94339811320566	-0.3	-0.8	-0.4
38.58	0.94339811320566	-0.3	-0.8	-0.4
38.6	0.94339811320566	-0.3	-0.8	-0.4
38.62	0.94339811320566	-0.3	-0.8	-0.4
38.64	0.94339811320566	-0.3	-0.8	-0.4
38.66	0.94339811320566	-0.3	-0.8	-0.4

12. Open Excel and insert the data from the clipboard.

...use the paste function to insert the data in Excel.

Basic experiments with the "Lab of Tomorrow" equipment - Worksheet 3

Familiarization with the LOT software and LPS

Experiment

Max is rolling down an inclined Plane on in-line skates, the LPS measures the position of one point (e.g. Max' nose) in x-, y- and z-direction.

Preparations:

1. prepare the video-computer : (file-name : Max_LPS_1)
2. Start / stop recording
3. Initialize database
4. Mark Max' nose (in the left and in the right picture)
5. "Calculate"
6. Repeat steps 4 und 5 until the complete movement has been captured
7. Close
8. Export data to the LoT computer for further examination

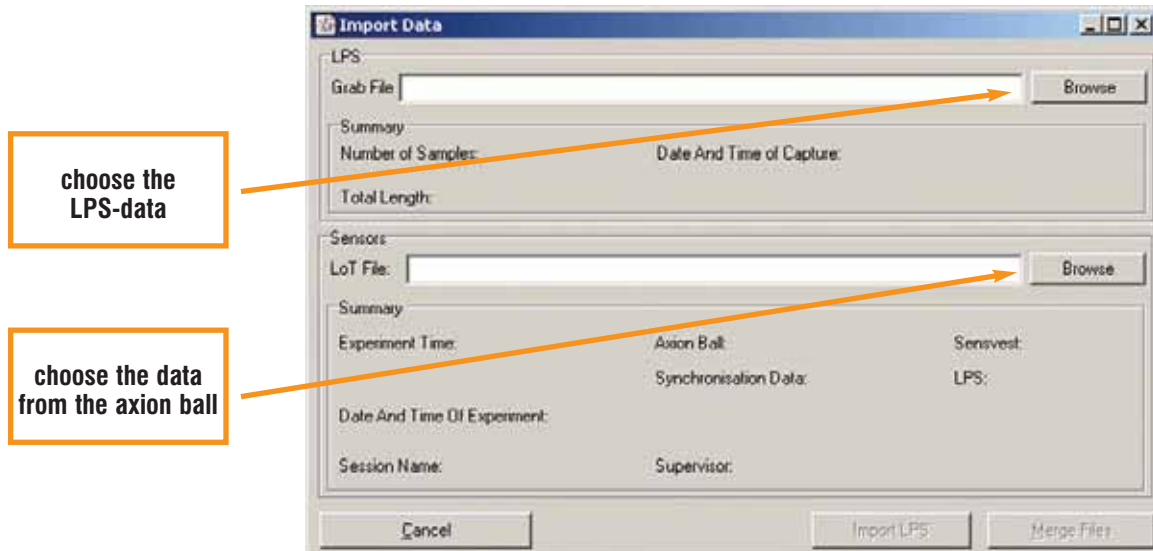
Work with the LoT-Computer:

1. Start the program

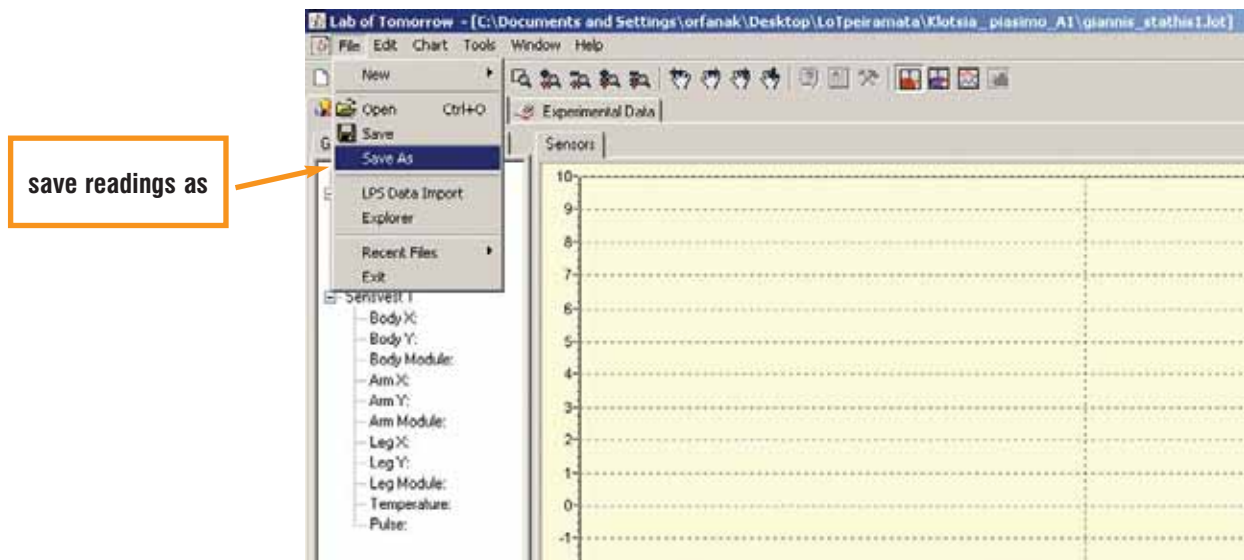
Import and Merge



2. Merge the LPS-data with the data of the axion ball



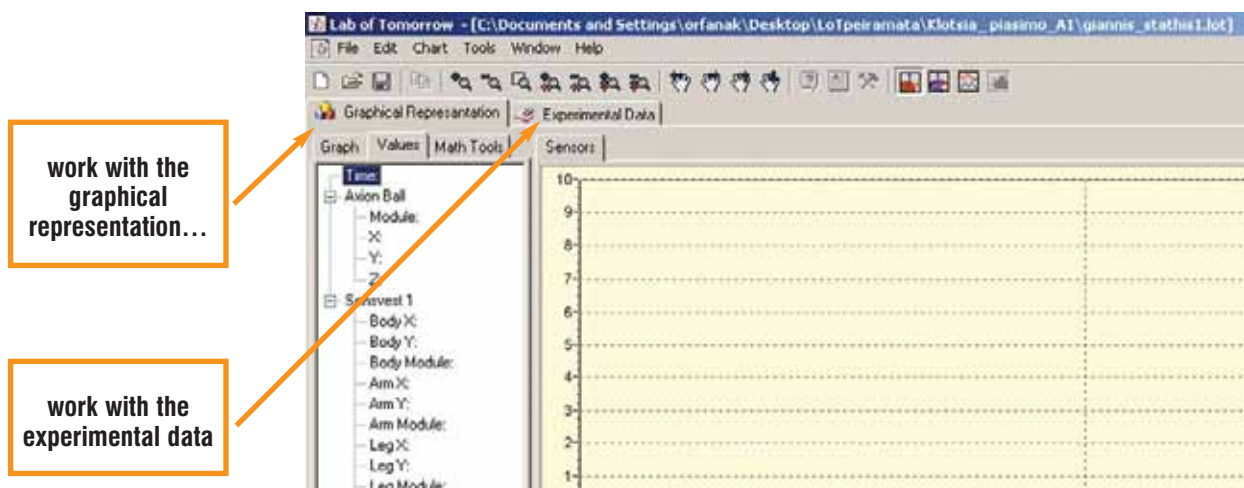
3. Save readings (as Max_LPS_1)



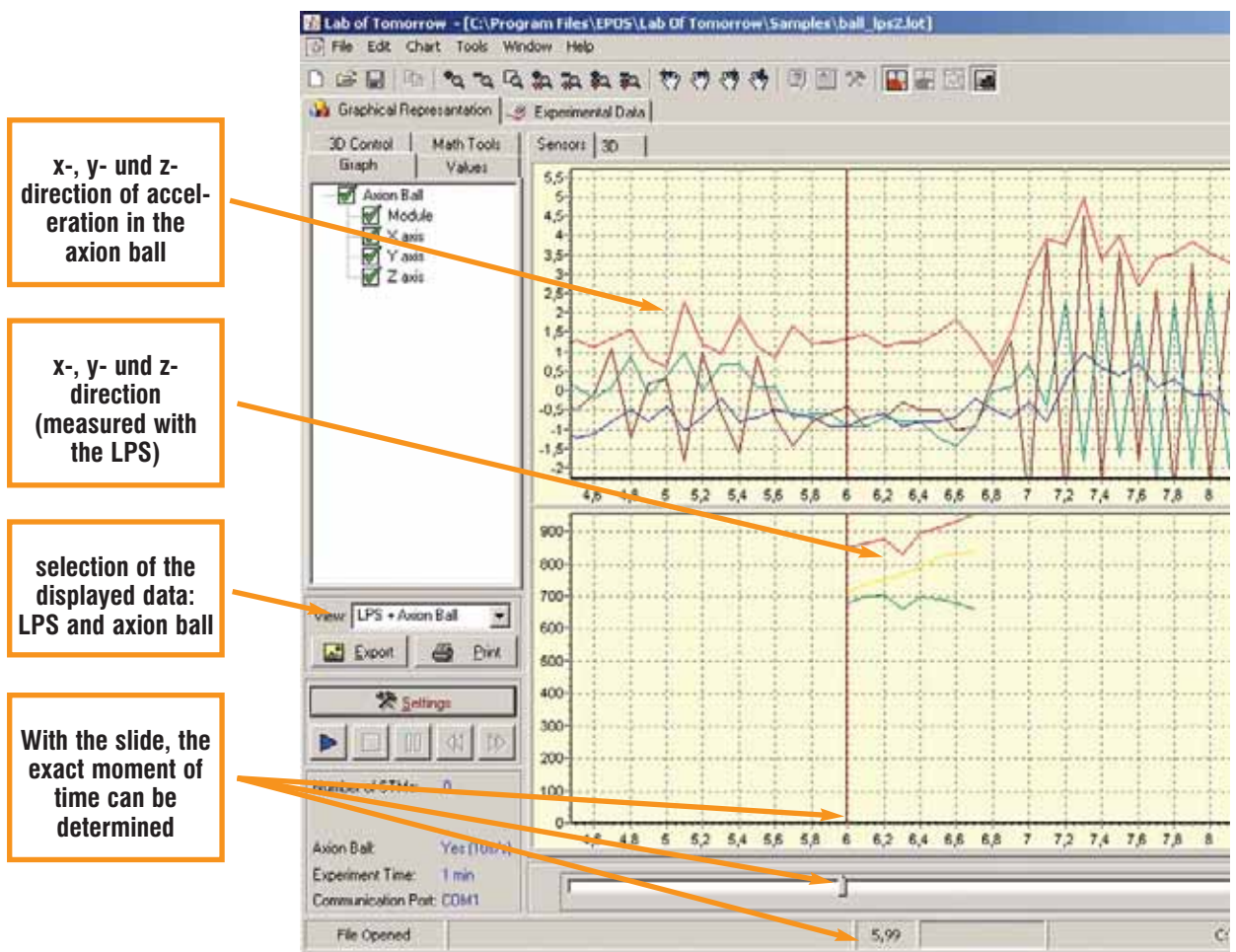
4. Reload Max_LPS_1

5. Analysis of the graphical representation (=> "Graphical Representation")

6. Analysis of the data (=> "Experimental Data")



7. First, you have to look for the interesting data in the graphical representation. With the slide, the corresponding period of time can be exactly captured.



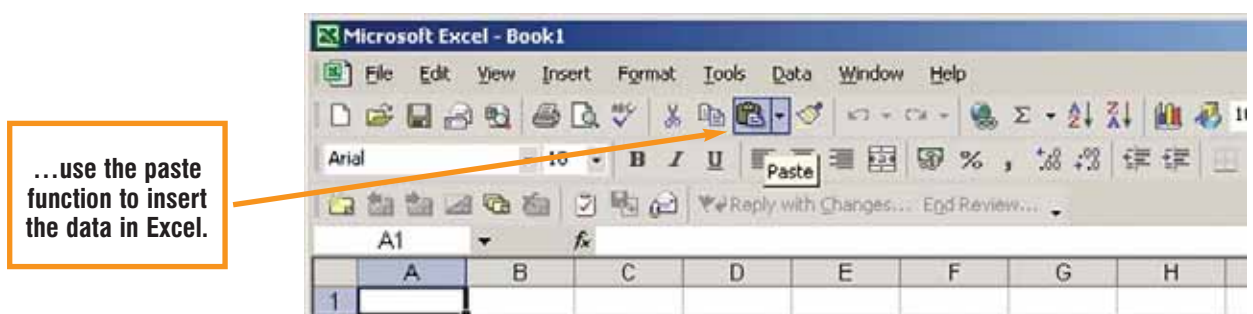
8. Mark the interesting data in the spreadsheet "experimental data" and copy it to the clipboard.

mark data (with shift and cursor keys) ...

...and copy it to the clipboard

Time (s)	X coordinate	Y coordinate	Z coordinate
6	850.33	678.99	717.33
6.1	866.7	700.32	739.4
6.2	877.7	705.32	750
6.3	830.5	680	770.8
6.4	895.33	700.99	780.33
6.5	912.7	693.32	821.4
6.6	932.7	678.32	832
6.7	955.5	680	847.8

9. Open Excel and insert the data from the clipboard.



Basic experiments with the "Lab of Tomorrow" equipment - Worksheet 3

Familiarization with the LOT software and Senvest

Experiment

Max is rolling down an inclined Plane on in-line skates, the LPS measures the position of one point (e.g. Max' nose) in x-, y- and z-direction.

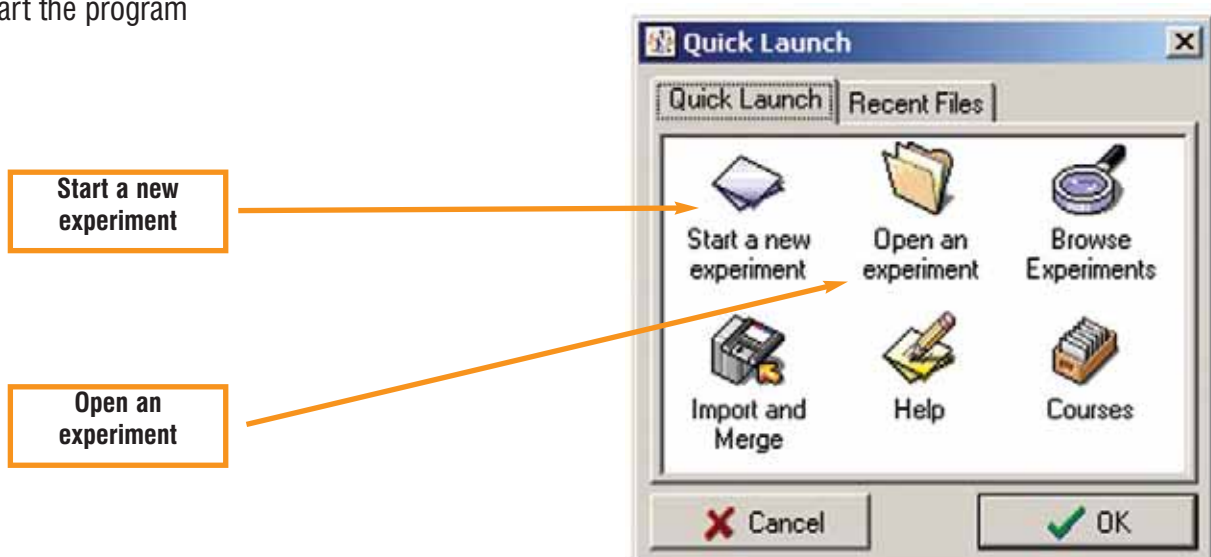
Preparations:

1. Max has to put on the SensVest
2. The sensors have to be positioned
3. Engage sensor-module
4. Initialize sensors => data is transmitted to the base station via radio

Work with the LoT-Computer:

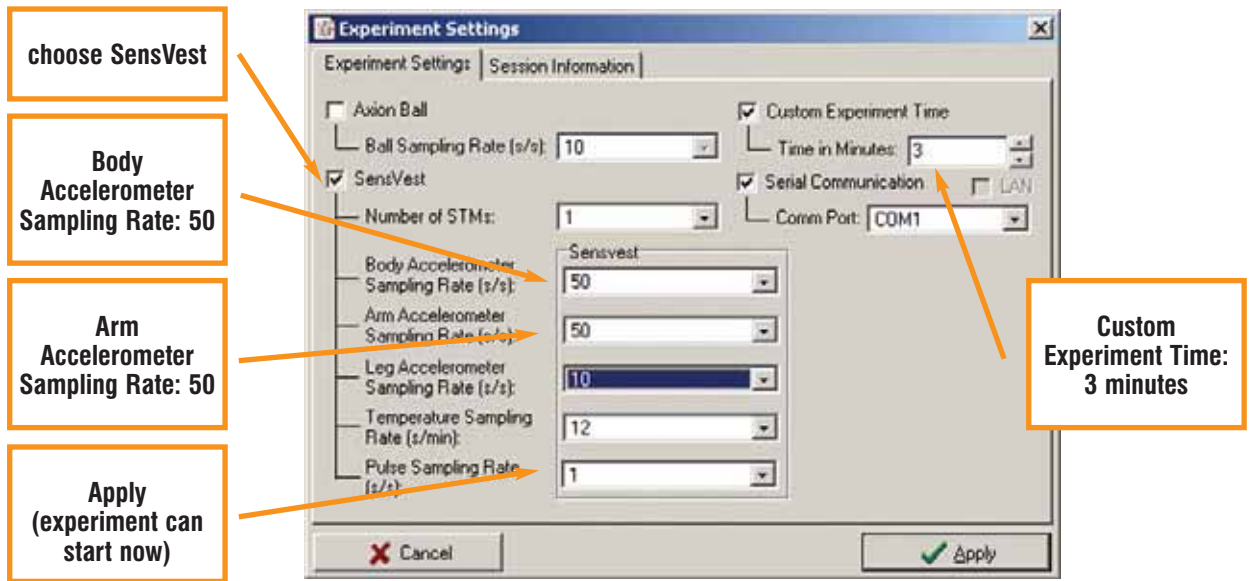
1. Start the program

or



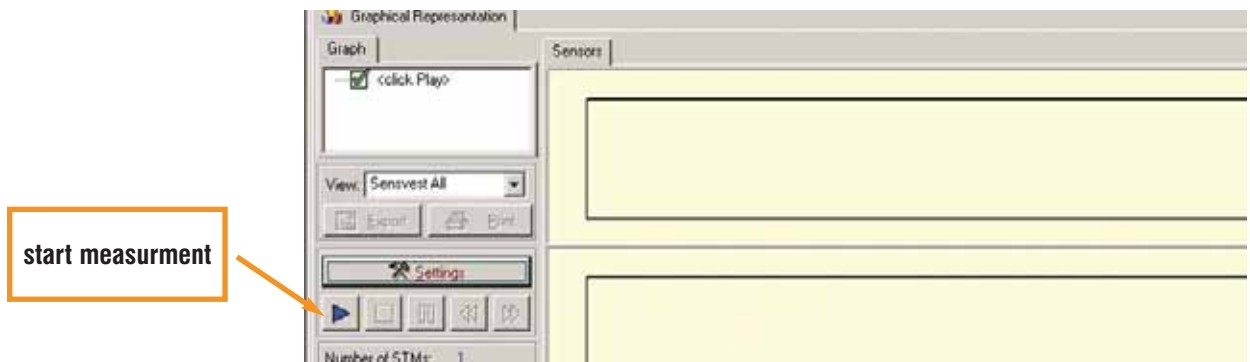
2. Choose experimental parameters:

Example : The **SensVest** is supposed to deliver **50 measurements each second**, both from the **arm-** and the **body-sensor** for the duration of **3 minutes**.



The SensVest will start sending 50 measurements per second to the LoT computer for 3 minutes.

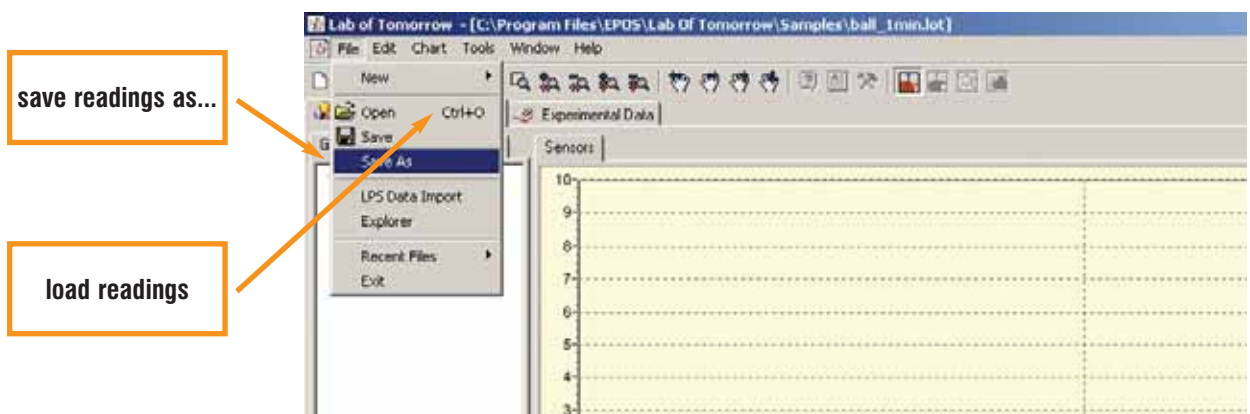
3. Start the measurement => data is transferred from the base station to the computer



4. Carrying out the experiment: Max rides down the plane

5. Stop measurement

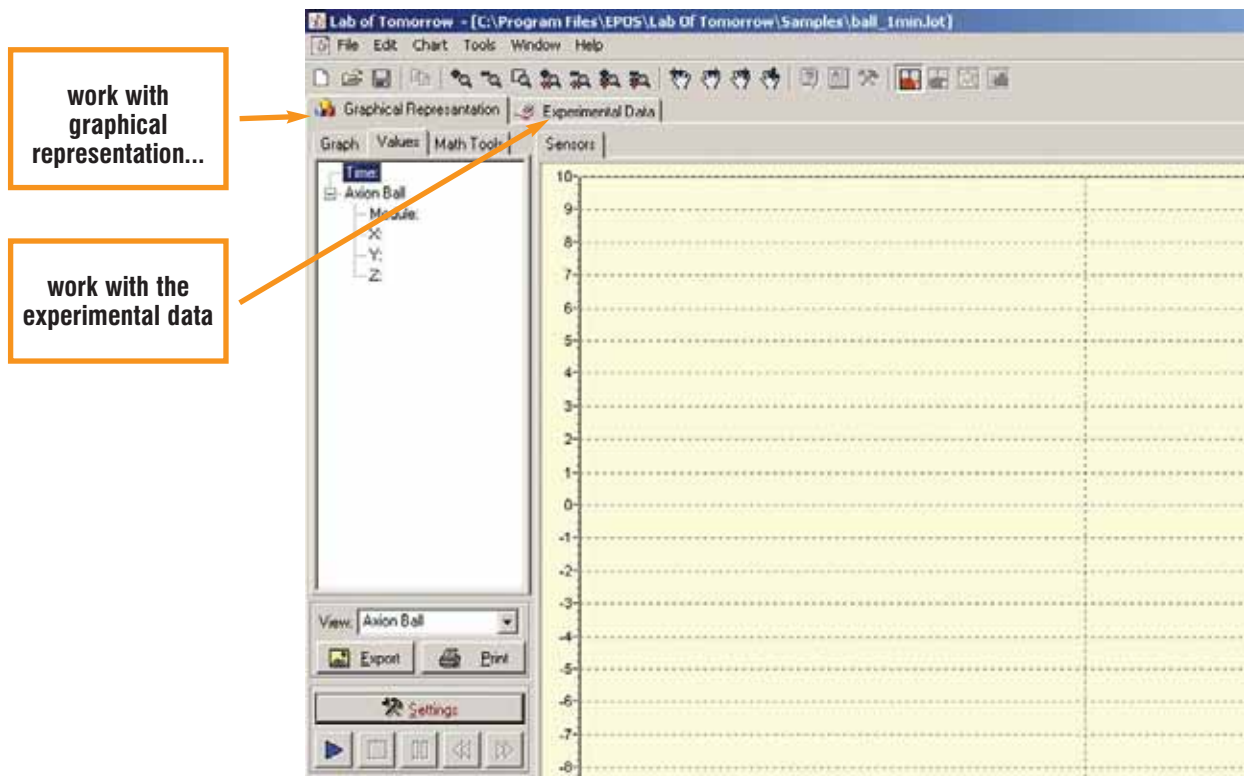
6. Save readings (as Max_SensVest_1)



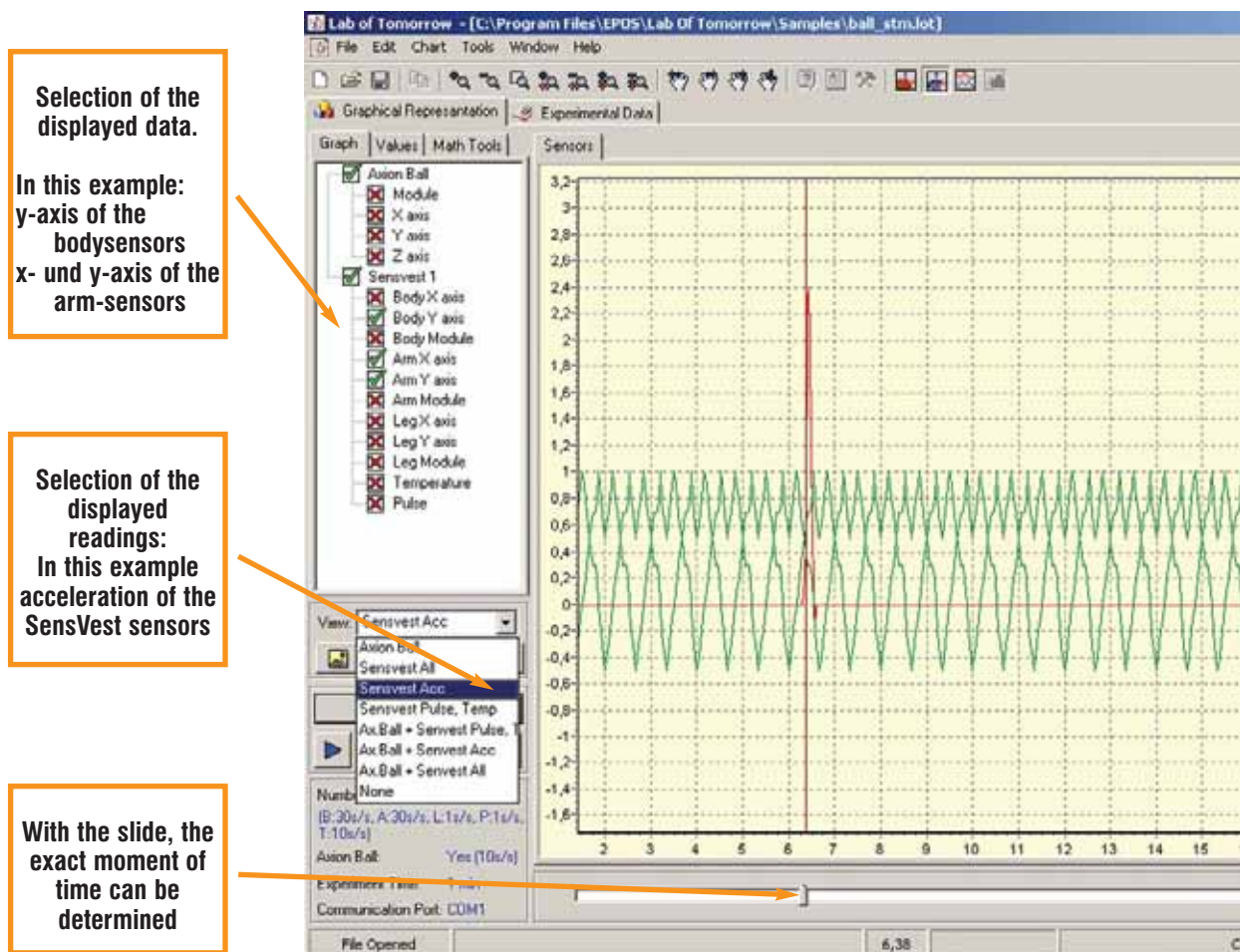
7. Reload Max_SensVest_1

8. Analysis of the graphical representation (=> "Graphical Representation")

9. Analysis of the data (= > "Experimental Data")



10. First, you have to look for the interesting data in the graphical representation. With the slide, the corresponding period of time can be exactly captured.



11. Mark the interesting data in the spreadsheet "experimental data" and copy it to the clipboard.

mark data (with shift and cursor keys) ...

...and copy it to the clipboard

Time [s]	Sens/Vest 1 Body X	Sens/Vest 1 Body Y	Sens/Vest 1 Body Module	Sens/Vest 1 Arm X	Sens/Vest 1 Arm Y
5,333333333333333	-0,1	0	0,1	0,3	0,7
5,866666666666667	-0,1	0	0,1	0,2	0,8
5,9	-0,1	0		0	1
5,933333333333333	0	0		-0,2	0,8
5,966666666666667	0	0		-0,3	0,7
6	0,1	0		-0,4	0,6
6,033333333333333	0	0		-0,5	0,5
6,066666666666667	-0,1	0	0,1	-0,4	0,6
6,1	-0,2	0	0,2	-0,3	0,7
6,133333333333333	0	0	0	-0,2	0,8
6,166666666666667	-0,1	0	0,1	-0,1	0,9
6,2	-0,1	0	0,1	0	1
6,233333333333333	-0,1	0	0,1	0,1	0,9
6,266666666666667	0	0	0	0,2	0,8
6,3	0	0	0	0,3	0,7
6,333333333333333	-0,1	0	0,1	0,4	0,6
6,366666666666667	0	0,2	0,2	0,5	0,5
6,4	-0,1	0,5	0,509901951359279	0,4	0,6
6,433333333333333	-0,2	2,3	2,30867927612304	0,3	0,7
6,466666666666667	0	2,4	2,4	0,3	0,7
6,5	-0,1	2	2,00249843945008	0,3	0,7
6,533333333333333	-0,1	0,5	0,509901951359279	0,2	0,8
6,566666666666667	-0,1	0,2	0,22360737749979	0	1
6,6	0	-0,2	0,2	-0,2	0,8
6,633333333333333	0	0	0	-0,3	0,7
6,666666666666667	-0,1	0	0,1	-0,4	0,6
6,7	0	0	0	-0,5	0,5
6,733333333333333	-0,1	0	0,1	-0,4	0,6
6,766666666666667	-0,2	0	0,2	-0,3	0,7
6,8	0	0	0	-0,2	0,8

11. Mark the interesting data in the spreadsheet "experimental data" and copy it to the clipboard.

...use the paste function to insert the data in Excel.

	A	B	C	D	E	F	G	H
1		6,3	0	0	0	0,3	0,7	0,761577
2		6,333333	-0,1	0	0,1	0,4	0,6	0,72111
3		6,366667	0	0,2	0,2	0,5	0,5	0,707107
4		6,4	-0,1	0,5	0,509902	0,4	0,6	0,72111
5		6,433333	-0,2	2,3	2,308679	0,3	0,7	0,761577
6		6,466667	0	2,4	2,4	0,3	0,7	0,761577
7		6,5	-0,1	2	2,002498	0,3	0,7	0,761577
8		6,533333	-0,1	0,5	0,509902	0,2	0,8	0,824621
9		6,566667	-0,1	0,2	0,223607	0	1	1

3.5 Lesson Plans

The above experimental and preparatory teaching and learning activities and exercises provide the necessary framework for the successful implementation of the Lab of Tomorrow project in usual classroom conditions. The teacher that plans to utilise the systems in his class is free to choose any subject from the Lab of Tomorrow table of contents that considers appropriate and believes that could contribute to useful learning outcomes. In order to assist teachers in this procedure, six lesson plan have been developed and are presented in the following paragraphs. The lesson plans have been designed in a way that reveals the potential of the Lab of Tomorrow approach in pedagogy. In parallel an effort has been made to develop material in accordance with national educational curricula of the countries participating in the project. The lesson plans follow the general structure that it is presented below and most of them are accompanied with a sample of a worksheet for the students.

General Structure of the Lesson Plans

I. General Info

1. Duration:
 - i) Conventional Lesson
 - ii) Experimental Activities
2. Vocabulary
3. Tools and Materials
4. Aims and Objectives
5. Student's usual Misconceptions

II. Lesson Plan

1. Stimulation
2. Experimental Activities
3. Observation - Discussion
4. Conclusion Drawing
5. Consolidation
6. Questions
7. Exercises
8. Integration with other subjects
9. Appendix
(attached Questions, Exercises, Integration with other subjects as appendix)

Linear Motion

Rectilinear Motion of the Axion Ball

Mechanics

Force and Motion



I. General Info

This lesson plan provides information and material concerning the experimental study of rectilinear motion using the axion ball developed in the lab of tomorrow framework. 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

position, time, linear motion, velocity, average velocity, acceleration, deceleration, force, friction

Tools and Materials

Axion Ball, LPS, rope, plane surface, dynamometer, weights

Aims and Objectives

General Aims

The students should:

- be able to distinguish the general characteristics of motion
- be able to classify motions in steady and not steady
- be able to define acceleration as the rate of velocity
- be able to report the kind of motion regarding an applied force and vice versa
- be able to give the definition of the concept of force

Specific Aims

The students should:

- be able to describe the initial conditions of the motion and report how these conditions affect motion itself
- be able to report daily life examples concerning the same force with different initial conditions
- be able to define Newton's 1st law and explain that motion can exist even if no force is exerted on the object
- be able to find out that steady applied force results in steadily accelerative motion
- be able to recognize friction as a force
- be able to describe the laws of the basic physical quantities involved in linear motion verbally, mathematically, graphically

Student's usual Misconceptions

- Whenever there is a motion there is a force acting too
- Motion with constant velocity is a result of constant force
- Immobility means the lack of an applied force
- Friction not recognized as a force

II. Educational Phase

a. Stimulation

Duration ~20min

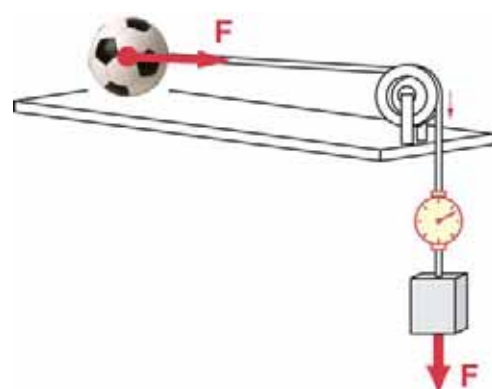
- Presentation of selected video of a football game
- Short discussion about football and physics
- Track student's misconceptions as far as objects' motion is concerned
- Draw up a list on the blackboard with these misconceptions without any comments.

b. Experimental Activities



I) Ball drifting on a surface with relevant low initial velocity.

The axion ball is allowed to drift on a surface with low initial velocity after being slightly pushed. The ball continues its motion throughout the LPS inspection area. Data are recorded.



II) Ball drifting by an applied force on the surface starting with zero initial velocity.

The ball is drifted by an applied constant force with the assistance of a rope. The LPS is used to record the successive positions of the ball. The former allows the study of rectilinear motion with constant acceleration. If the applied force is the weight of an object, then the acceleration is equal to

$$a = \frac{M}{M + m} g$$

where **m** is the mass of the ball and **M** the mass of the falling object.



III) Alternative-Additional Experiments

As alternative experiments the following can be proposed:

- Introducing friction with the use of different kind of surfaces
- Motion of the ball on an inclined plane

c. Observation - Discussion

Discussion of theoretical issues arising from the experimental activities. This is facilitated with the assistance of the Website's Theory Tutorial and Links.

- 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
- Introduction to the concept of friction
- Acceleration as the rate of velocity
- Average velocity

d. Conclusion Drawing

- Derivation of Newton's 1st law, $F=0 \Rightarrow$ immobility or constant velocity
- Physical Quantities, mathematical laws, graphical representations

e. Consolidation

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

Worksheet

Axion Ball - Linear Motion

Experiments

- 1) Ball drifting on a surface with relevant low initial velocity
- 2) Ball drifting by an applied force on a surface starting with zero initial velocity

Duration:

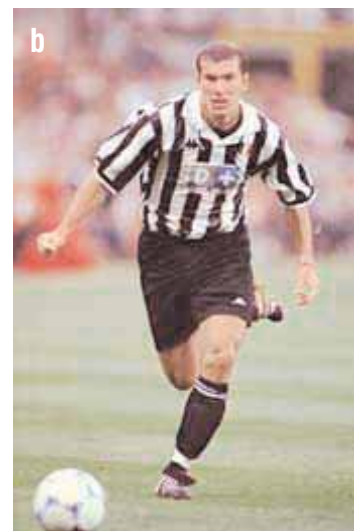
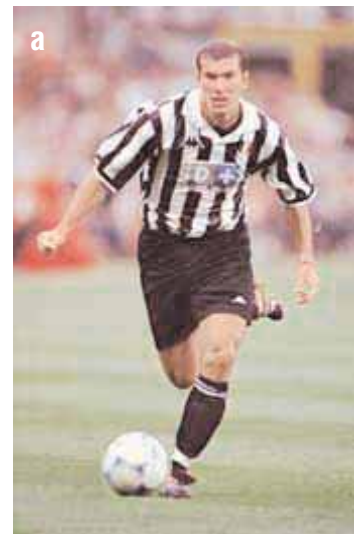
1. Choose an appropriate dataset of the experiment 1), you carried out before. On the pc
 - i) Download the video of the experimental activity
 - ii) Create a table of your dataset with columns time, position,, velocity, acceleration respectively
 - iii) Plot diagrams $x-t$, $u-t$, $a-t$ of your experimental data
 - iv) Create the same diagrams as iii) for the ideal case of rectilinear motion with constant velocity.
What do you observe?
2. The pictures aside illustrate the famous soccer player Zinedine Zidane in two successive snapshots, at the moment he kicks the ball during game and a moment slightly afterwards.

Write down:

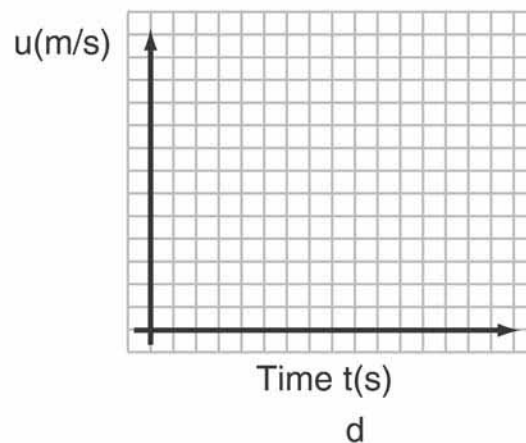
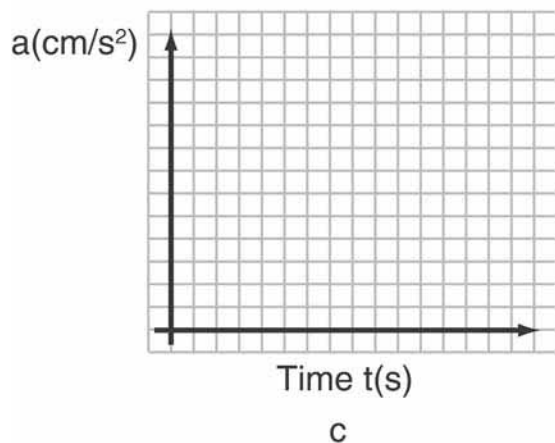
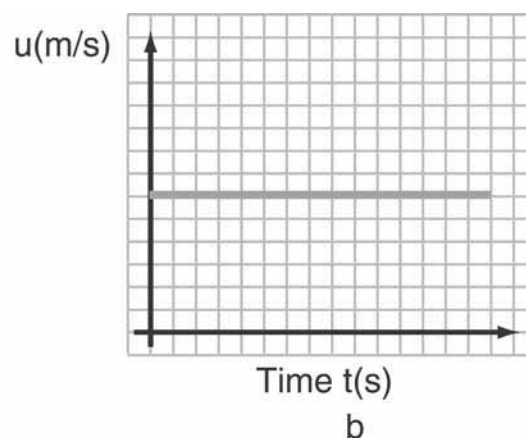
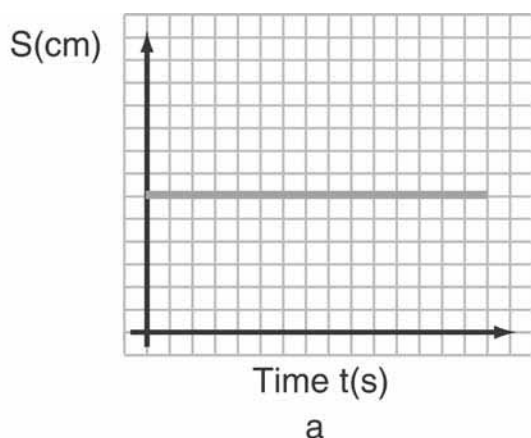
- a) What makes the ball in picture a to move forward?

- b) What makes the ball in picture b to move forward?

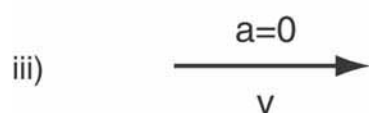
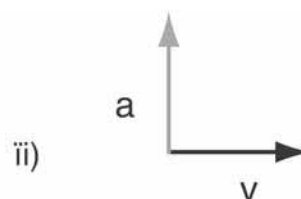
Discuss the answers with your teacher



3. a) Determine the kind of motion that it is illustrated in the diagrams a and b.
 Use the data of experiment 2) to construct diagram c. Use the data of experiment 1) to construct diagram d
 b) Define the motion in each of the diagrams c and d



4. Which of the following diagrams represents the motion of the ball in the experiment 2)?



5. For the experiment 1) you carried out before calculate the average acceleration a . Suppose the ball continues its motion with this acceleration for another 10s.

Calculate :

- the final velocity of the ball in m/s and km/h
- the total distance $S(m)$ travelled by the ball at this time period.

[illegible]

6. For the experiment 2) you carried out before fill in the following table with your experimental data

[illegible]

Represent graphically your dataset and calculate the value of the acceleration of the motion.

- Is the acceleration constant?
- What is the value of the acceleration of gravity?
- Compare these two values. What do you observe? Explain
- How long did it took the ball to travel 2m?

- 7.
- Report activities form the lesson of gymnastic that you find interesting and you think that could be monitored and studied with the LPS system.
 - Report daily activities you think that could be studied with the LPS system.

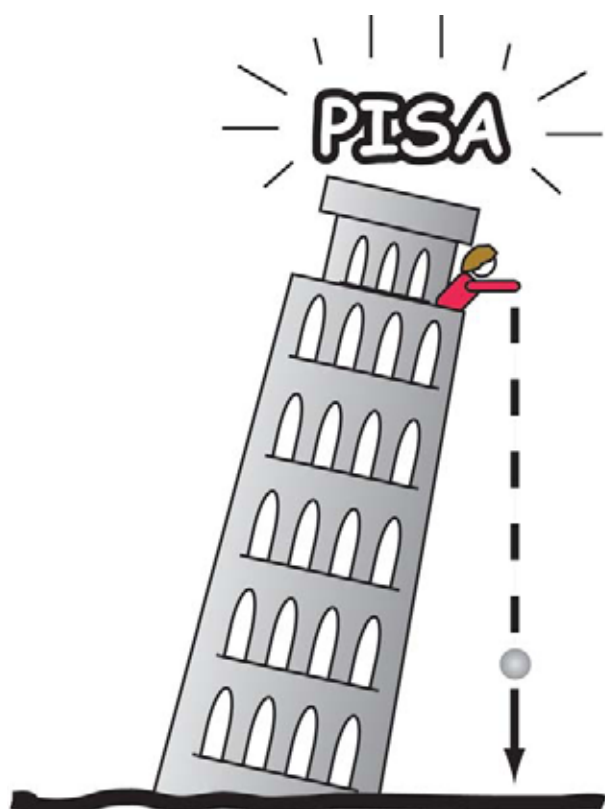
Did you know?
Before being used in time measurement, second were a unit of measurement for the parts of circle's perimeter. Ptolemaios borrowed the Babylonian numerical system, which had as its base the number 60, and applied it to measure spheres with units that later on were named minutes and seconds.
The same system was adapted to measure the minutes on the circular faces of the watch. The seconds as units of time measurement were developed in the end of the 17th century, when the designing and manufacturing of watches had progressed to such an extend that even those small sub-division could be counted.

Free Fall

Axion Ball

Mechanics

Force and Motion



I. General Info

This lesson plan provides information and material concerning the experimental study of free fall motion using the axion ball developed in the lab of tomorrow framework. 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

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

Tools and Materials

Axion Ball, LPS

Aims and Objectives

The students should:

- 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

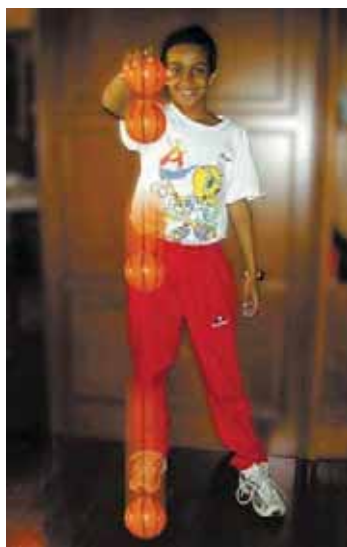
II. Educational Phase

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.

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. The LPS system is used to record frames that represent the motion of the ball

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

c. Observation - Discussion

Discussion of theoretical issues arising from the experimental activities.

This is facilitated with the assistance of the Website's Theory Tutorial and Links.

- 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

e. Consolidation

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



Worksheet

Axion Ball - Free Fall

Experiments

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

1. Instructed by your teacher choose an appropriate dataset of the experiment 1), you carried out before.
On your pc:

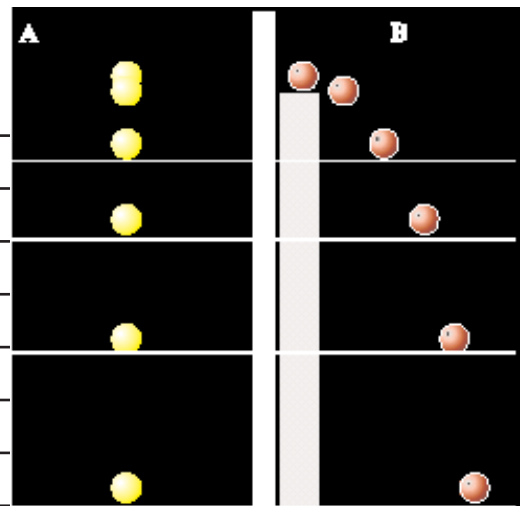
- Download the video of the experimental activity
- Create a table of your dataset with columns time, position, velocity, acceleration respectively
- Plot diagrams $x-t$, $u-t$, $a-t$ of your experimental data
- Create the same diagrams as iii) for the ideal case of rectilinear motion with constant velocity.
What do you observe?

2. Explain why when falling using a parachute is not harmful.

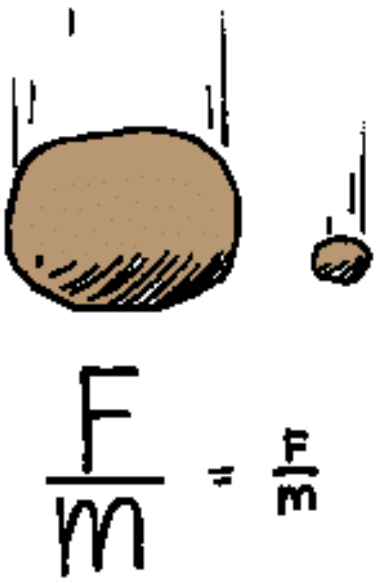
- Is the parachute fall a free fall?
- Could you now give an explanation why in our daily life have the feeling that different objects fall on earth at different time intervals?



3. Which of the spheres, in the picture aside will reach the ground first? Ignore air resistance.



4. Which of the illustrated stones aside will reach the ground first during a free fall?



5. From a certain point in the tower of "Pisa" and 120m height, we drop an object:
a) When will it reach the ground?
b) With what velocity?
Draw a graph with a $u - t$ and $x - t$ diagram.

6. a) Does the gravity acceleration change in different parts of this planet? Justify your answer.
b) Why does the pencil that falls from the hands of a German student "want" to reach the floor sooner than that of a Greek student?

7. During a free fall:

- a) a heavy object falls at the same time as a heavier object.
 - b) The displacement of every object is equivalent to the time it takes to get there.
 - c) The velocity of each object it is given through $u=g \cdot t$
 - d) The acceleration during a free fall depends upon the mass of the object
- With which of the above statements do you agree?

8. The movement of the ball as it is allowed to fall is analyzed in the following table:

Frame	t	x	u	Δu	a
1		7,70	231		
2		8,75	263	32	9,6

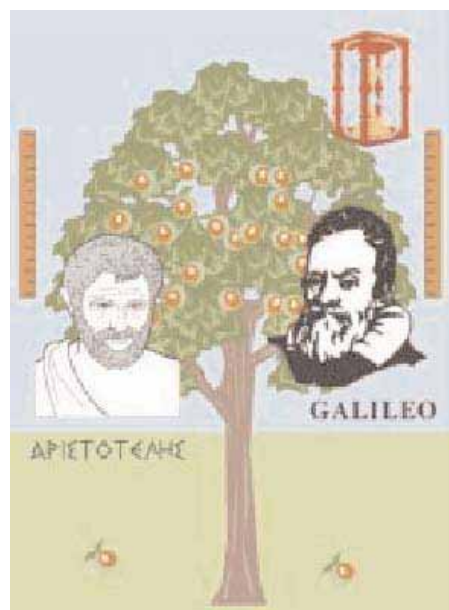
- a) Find the average acceleration from the value as they are in the last column of the table above
- b) What is the conclusion as far as the acceleration is concerned?

NOTE. The experiment provides values to fill in the first two columns of the table.
Use these data to fill in the rest of the columns as it is demonstrated with example above

9. We throw an object upwards in a straight line and we assume that this movement is separated into 3 stages: as it is going up, when it reaches the highest point and when it comes down. Disregarding the air's resistance, draw diagrams of velocity and acceleration of the object versus time, for every stage of its motion.

10. In a science fiction story it is winter and it is snowing and Aristoteles is discussing with Galileo. They observe snowflake as it is falling and they try to answer the question why this snowflake falls down more slowly than a heavy pebble.

Write a small imaginary dialog between them.



Horizontal Throw

Mechanics Force and Motion



I. General Info

This lesson plan provides information and material concerning the experimental study of horizontal throw motion using the axion ball developed in the lab of tomorrow framework. 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

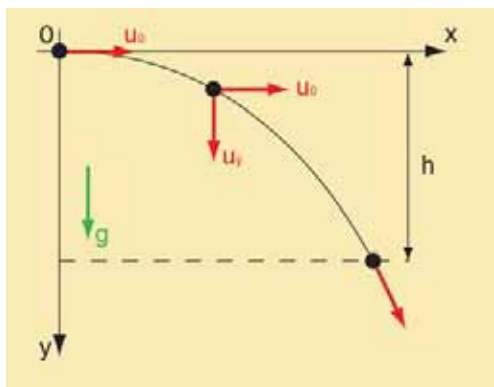
II. Educational Phase

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



I) Horizontal Throw.

The axion ball is thrown horizontally from an exalted surface. Data are recorded and processed and then the exact trajectory of the ball is constructed.

II) Alternative-Additional Experiments

As alternative experiment the following can be proposed:

- to repeat the activity with different initial velocities

c. Observation - Discussion

Discussion of theoretical issues arising from the experimental activities.

This is facilitated with the assistance of the Website's Theory Tutorial and Links.

- 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 (Refer to the relevant Worksheet).

Worksheet

Axion Ball - Horizontal Throw

Experiments

1) Ball thrown horizontally from an exalted surface.

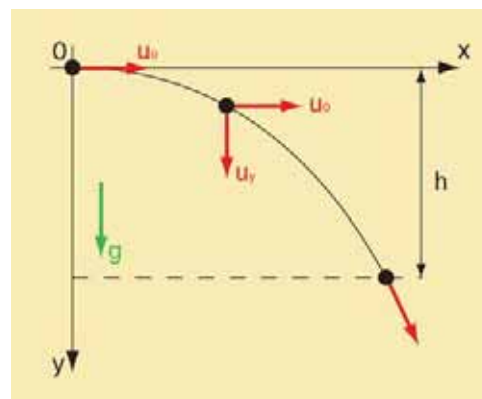
1. Instructed by your teacher choose an appropriate dataset of the experiment 1), you carried out before.

On your pc:

- Download the video of the experimental activity
- Create a table of your dataset with columns time, position, velocity, acceleration respectively
- Plot diagrams $x-t$, $u-t$, $a-t$ of your experimental data
- Create the same diagrams as iii) for the ideal case of rectilinear motion with constant velocity.
What do you observe?

2. Horizontal throw can be analysed in two independent motions in x , y axes as it is shown at the figure aside. Using the recorded data by the LP system fill in the following table.

Frame	x	u_x	a_x	y	u_y	a_y	t



a) Draw the diagrams $x-t$, $y-t$, $y-x$. Could you report the motion presented in each one of the diagrams?

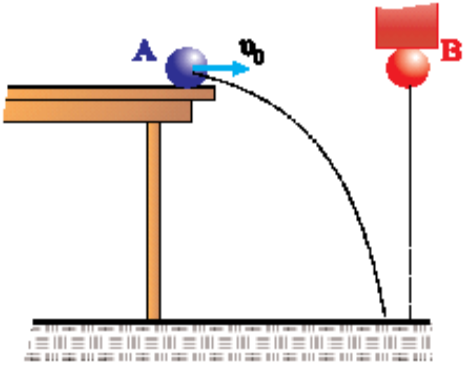
b) Draw the diagram y versus x^2 of the experimental data. Fit this plot with an $y=ax$ expression. The fitting will provide you the value of a .

Using the expression $y = \frac{g}{2u_0^2} x^2$ derived in the course book and the value of a calculate your experimental value for the acceleration of gravity.

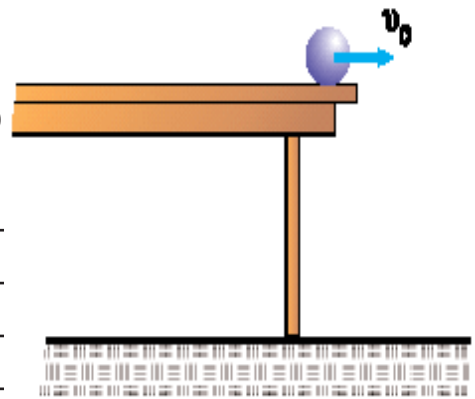
c) Compare this experimental and the known theoretical value of gravitational acceleration. What do you observe? Explain.

NOTE: consider the value of the initial velocity **u** known
Theoretical value for acceleration of gravity is **$g=9,83 \text{ m/s}^2$**

3. In the figure aside two identical spheres are presented. The sphere A leaves the table the same instant with sphere B.
- a) Which sphere will reach the floor first? Explain.
 - b) Answer a) again if the initial velocity of sphere **A** is **$2u_0$**



4. A sphere is lying at the edge of a table as it is shown in the figure aside. Initial velocity $\mathbf{u}_0$ is given to the sphere at the instant $\mathbf{t=0}$. Write down the expressions that represent the motion of the sphere and give an explanation how to calculate the necessary time for the sphere to reach the floor.



5. The sphere of exercise 3 is given an initial velocity 2m/s a while the height of the table is 1m.
 a) Calculate the time needed for the sphere to reach the floor.
 b) Find the velocity magnitude that the sphere has when it touches the floor.

6. In the motion picture "Pearl Harbour" bombs seem to fall from the Japanese airplanes completely vertically. Explain if this could happen in the real world or it is a mistake of the computer animators who produced these scenes.

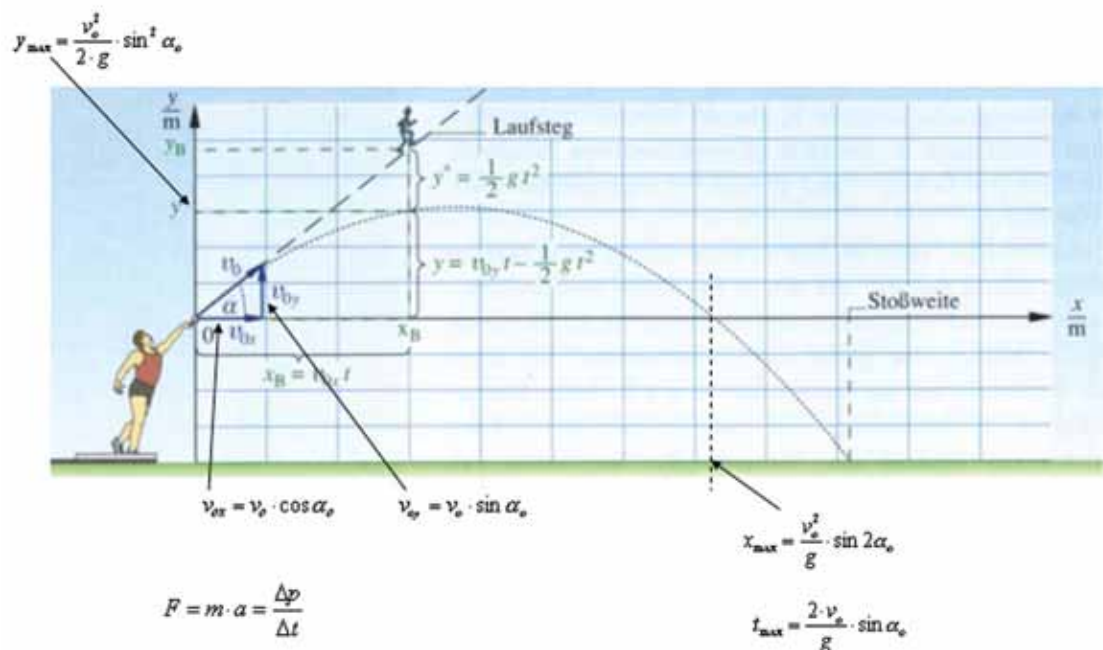


Volleyball game

Projectile motion

Mechanics

Force and Motion



As an example of a more complex situation for the use of the axioms, the following volleyball lesson is given, based on the general presenting structure of LoT lessons.

I. General Info

This Lesson plan is a proposal for a sequence of lessons in which students can apply their physical knowledge. They already know

- physical quantities
- laws of uniform rectilinear motion
- laws of accelerated rectilinear motion
- (superposition of motions)
- evaluation of graphs and measurements (most of those facts have been found out experimentally, some of them by using Lab of Tomorrow equipment)
- so the students know, how the axioms work

a) Duration

i) *Conventional Lesson*

45 min to collect ideas and prepare the experiments

3 x 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

b) Vocabulary

- velocity
- acceleration
- rectilinear motion
- curvilinear motion
- superposition of motions
- trajectory

c) Tools and Materials

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

d) 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
- and thus
- let students apply their physical knowledge
- enable introduction of new principles
- allow students to develop their own experimental ideas

e) 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.

II. Lesson Plan

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

- Measure the initial velocity ...
... and 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.



Physics in Sports

**A qualitative approach
with the use of Sensvest**

Mechanics

Force and Motion



I. General Info

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

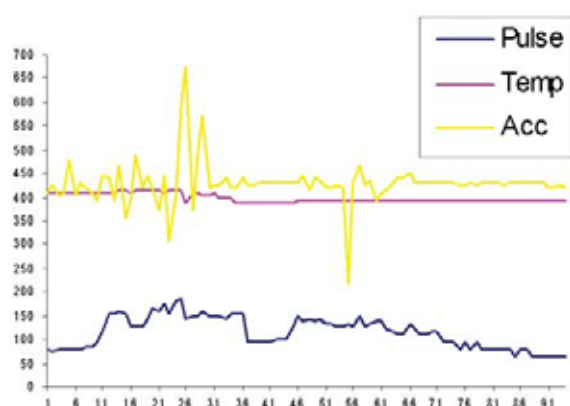
II. Educational Phase

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



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

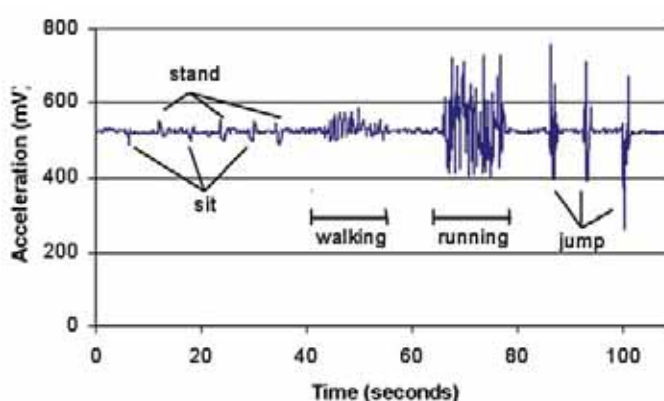
A student wearing the sensvest walks in one direction with approximately constant velocity, after some meters walk, turns around to continue his walk back to his starting point. Data from the sensvest (body acceleration, pulse rate, temperature) are recorded.

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) 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. This is facilitated with the assistance of the Website's Theory Tutorial and Links.

- 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)

SensVest Axion - Physics in Sports

- 1) Walk to one direction, turn around and walk backwards
- 2) Accelerate to one direction, turn around and accelerate backwards
- 3) Jumping repeatedly with different rates

On your pc:

- What do you observe? Discuss with your teacher.

(where a the acceleration, T the body temperature and P the pulse rate

[illegible]

- How many jumps were done after 15s?
- Enrich the above dataset with the relevant data measurements of the pulse rate and body temperature. Represent them graphically versus time. What do you observe?

[illegible]



3. Why long distance runners (1000m, 3000m e.t.c) wear few light clothes and leave uncovered most of their body (T-shirts, shorts)?



4. Why marathon athletes during their run are given repeatedly every several kilometres, bottles of water to drink and wet sponges?

5. Write down in a few lines why you thing the arms swing during running? Discuss with your teacher.

Did you know?

The existence of the heart was well known to the Greeks, who gave it the name Kardia, still surviving in modern words such as cardiac and tachycardia. Aristotle believed that the heart was the seat of the soul and the center of man. Romans modified Kardia to Cor, the latter word still surviving in "cordial greetings". The old Teutonic word herton was also derived from Cor and gives us heart via the medieval heorte.

6. Use your personal data recorded with the sensvest to complete the following:

My Resting Heart Rate

(When I'm calm and relaxed)

_____ beats in 6 seconds x 10 = _____ beats per minute

My Active Heart Rate

(After I've jogged in place for 1 minute)

_____ beats in 6 seconds x 10 My Recovery Time

(From active to resting Heart beat)

_____ minutes

7. After the victorious battle of Greeks against Persians in Marathon at 490 B.C, an Athenian soldier, Thersippos the Erchiephs as it is mentioned by the ancient historian Ploutarxos, run in full armour, about 42km to announce to the city the good news "We won", said this brave man when he arrived in Athens, and then fell down and died by exhaustion. The Marathon run included in the modern Olympic games is dedicated to honor this legendary soldier. Having this little story in mind try to answer the following:

a) Assuming you running the Marathon with an average speed you had during your activities with the sensvest, how long would it take for you to deliver the victory message?

b) In what way do you believe the soldier of our history could had increased his possibilities to survive this exhausting run?



Energy Physics in Sports

Energy consumption in physical activities



I. General Info

This lesson plan is designed for investigating energy transformations and power consumption during physiological activities. Measurement of energy flow and power in the human body is not easy; normally research is done with ergometers, respirometers and biochemical examinations such as measurement of the lactate-content of the blood. Those examinations cannot be done in usual school laboratories. This lesson plan is designed for combining measurements using the sensvest, (e.g. pulse frequency, step frequency, body temperature etc) with respirometer measurements to study energy consumption by human body.

It must be mentioned here that within the framework of the project there is a research effort in collaboration with ergo physiological centers so as the Lab of Tomorrow equipment to be used for such measurements.

Duration:

- i) Classroom lesson 2x45min
- ii) Experimental activities 45min

Vocabulary

Heart rate, step rate, step width, power, force, energy (kinetic / potential), aerobic and anaerobic processes

Tools and Materials

Sensvest, stop watch, respirometer

Aims and Objectives

The students should

- " be able to distinguish the concepts of potential and kinetic energy
- " be able to develop their own experimental ideas and identify which measurements can be taken with the sensvest and how these measurements are related with physical values
- " be able to estimate the quality of physical measurements,
- " be able to give qualitative statements about the precision of a measurement
- " be able to identify errors, caused by unknown influences or unknown physiological processes

Student's usual Misconceptions

- " Everything can be determined exactly by physical methods.
- " There is energy consumption only in intense physical activities.

II. Educational Phase

a. Stimulation

Duration ~30min

- " Video about professional training methods
- " Students report about their own sporting activities and abilities.
Why are they so different?
- " Present physiological facts from biology books or the internet
- " find the context between energy and power in physics and in physiology

b. Experimental Activities

A student jogs over the lane at the sports field with constant velocity. The sensor vest

1. records the pulse frequency in dependence of time
2. records the step rate in dependence of time
3. records the body temperature in dependence of time



Other students at the sports field measure the

1. step width (how many steps on 50 m?)
2. velocity of the jogger every time, the jogger has completed a new round.

Observation - Discussion

Discussion on theoretical issues.

This is facilitated by the interface theory tutorial and links.

- " Theory and experiment comparison
 - " Examples deriving from daily activities to start a discussion on the misconceptions
- Theory and experiment comparison by regarding the graphs of pulse rate, temperature, power, etc.
- i. evaluate the data,
 - ii. draw the graphs

Appendix I

Energy flow

Calculation of energy consumption based on respirometer data

Mass	$m = 70 \text{ kg}$
basal metabolism	$E = 7000 \text{ kJ} \quad \text{each day}$
=>	$P_{bm} = 7000 \text{ kJ} / (24 \cdot 3600) \text{ s} = \mathbf{81 \text{ W}}$

inhaled air gives an estimate for energy flow and power input:

chemical reaction: $\text{C}_6\text{H}_{12}\text{O}_6 + 6 \text{ O}_2 \rightarrow 6 \text{ H}_2\text{O} + 6 \text{ CO}_2 + 2830 \text{ kJ}$

volume of 6 mol O_2 : $6 \cdot 22,4 \text{ l} = 134,4 \text{ l}$

energy release of 1 l O_2 : $(2830 / 134,4) \text{ kJ} = \mathbf{21 \text{ kJ}} \quad (1)$

Estimate of the O_2 -supply of the body by blood:

blood volume per heartbeat: $V_b \sim 70 \text{ ml}$

O_2 -concentration in arterial blood: $c_a \sim 19,8 \%$

O_2 -concentration in venous blood: $c_v \sim 15,2 \%$

O_2 -transport into the body cells $\mathbf{3,2 \text{ ml}} \quad \mathbf{\text{per heartbeat}}$

with (1) **energy release:** $\mathbf{70 \text{ J}} \quad \mathbf{\text{per heartbeat}}$

(these are values for an untrained adult)

(Another (better !!) estimate is given by the measure of the inhaled oxygen, but that cannot be done without respirometer measurements)

Example for power input:

Standing / sitting:

heart rate: $70 \text{ min}^{-1} \Rightarrow P_{in} = 70 \text{ J} \cdot 70/60 \text{ s}^{-1} = \mathbf{81,7 \text{ W}}$

this power input is delivered by aerobic processes in the muscles; it is highly correspondent with the basal metabolism (see above)

Jogging:

Heart rate: $150 \text{ min}^{-1} \Rightarrow P_{in} = 70 \text{ J} \cdot 2,5 \text{ s}^{-1} = \mathbf{175 \text{ W}}$

this power input is delivered by aerobic processes in the muscles

Example for power output:**physics of walking:**

While walking, the center of mass of the body typically lifts and sinks by approx. $h = 2\text{ cm}$. So the potential energy per step is

$$E = m \cdot g \cdot h$$

the power output while walking with the step frequency f is $P_{\text{out}} = m \cdot g \cdot h \cdot f$

example: $m = 70\text{ kg}$; $f = 1\text{ s}^{-1} \Rightarrow P_{\text{out}} = 70 \cdot 9,81 \cdot 0,02 \cdot 1\text{ W} = \mathbf{13,7\text{ W}}$

physics of jogging:

E and P_{out} see above, h might be a bit greater: $h = 3,5\text{ cm}$

example: $m = 70\text{ kg}$; $f = 3\text{ s}^{-1} \Rightarrow P_{\text{out}} = 70 \cdot 9,81 \cdot 0,035 \cdot 3\text{ W} = \mathbf{72,1\text{ W}}$
 stepwidth: $w = 0,8\text{ m}$ $v = f \cdot w = 3\text{ s}^{-1} \cdot 0,8\text{ m} = 2,4\text{ m/s} = \mathbf{8,6\text{ km/h}}$

another model, that regards sprinting as a sequence of jumps, comes to another approximation:

$$P_{\text{out}} = m \cdot v^3 / (16 \cdot w) = 70\text{ kg} \cdot (2,4\text{ m})^3 / (16 \cdot 0,8\text{ m}) = \mathbf{75,6\text{ W}}$$

The real value might be found in the middle between those estimated values and it is actually correlated with the rate of oxygen uptake during physiological activities. These kind of measurements require the use of respirometers in order to provide accurate data. Information concerning the oxygen uptake can be found in diagrams as the one below but one must be careful when using such diagrams because there are many factors (age, weight, basal metabolic rate etc.) that determine the shape of the diagram curves.

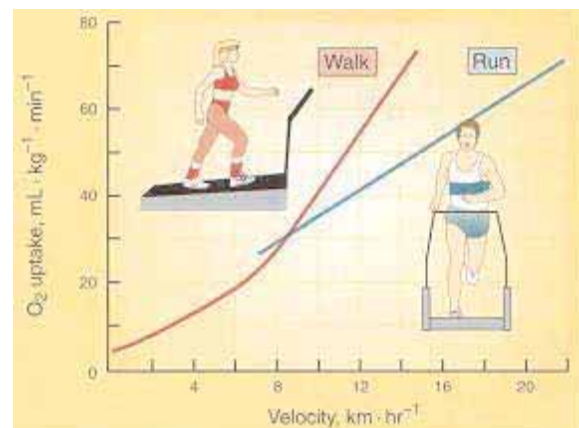


Diagram 1. Oxygen uptake vs velocity in walking and running

Efficiency (η) = $P_{\text{out}} / (P_{\text{in}} - P_{\text{bm}})$
 where
 P_{out} : power output during sporting activity
 P_{bm} : basal metabolism
 P_{in} : power input (food, oxygen, etc.)

Example: Jogging: $P_{\text{out}} = 75\text{ W}$; $P_{\text{in}} = 175\text{ W}$
 $\Rightarrow = 75\text{ W} / (175\text{ W} - 80\text{ W}) \sim 0,8 \Rightarrow 80\%$

This value is much too high !!! A realistic value is about 25 %

So there are a lot of things to discuss!!

(Tipp: P_{out} is quite ok., P_{in} has to be much higher)



Chapter 4

Evaluation of the Lab of Tomorrow project

4.1 Framework of the Evaluation

General requirements

A very important issue concerning the evaluation tool is the availability in three languages. Furthermore, the curricula of four countries have to be taken into account for the validity of the tests and assessment tools.

Information-Communication-Technology (ICT)

Working with computer, new technology and multimedia products is mainly determinate by two variables: students' attitude towards new technologies, computers and software tools as well as the prior knowledge of new technologies, computers and specific software tools.

Video documentation

One method for the empirical analysis of teaching and learning activities in classrooms is the video-documentation. Using this tool requires a high quality standard and for the Lab of Tomorrow project the possibility of an international comparison. As a consequence, strict video guidelines have to be developed.

Evaluation schedule and "To do`s"

The evaluation design for the Lab of Tomorrow project's implementation is organized as a semi-experimental design (see Figure 32). The experimental group consists of the classes in the participating schools. The control group is build up by classes that are taught in traditional way, but on the same topics as the experimental group. For that reason the adoption of the project's activities to the normal school curriculum based on the lesson plans presented in Chapter 3 is of major importance for the effectiveness of the project's evaluation. The following table summarizes the evaluation activities and the corresponding responsibilities:

"To do"	Responsibility
School background	Questionnaire prepared by the evaluation team, carried out by the head-master of the schools
TIMSS	Prepared and carried out by an authorized member of the evaluation team
Additional Tests	Optional tests, depending on the results of the pre-test; prepared by the evaluation team, carried out by the teachers
Video	School video groups prepare and capture videotapes, code selected tapes on the apparent structure and send all on CD to the evaluation team. The analysis of selected (and translated) tapes on the deep structure will be carried out by the evaluation team.
ICT	The assessment tool for ICT will be prepared by the evaluation team and carried out by the teachers.

4.2 Assessment Tools

TIMSS (Third International Mathematics and Science Study)

The general idea and the structure of the "Third International Mathematics and Science Study" (TIMSS) is described below in great detail in the fifth pedagogical report (*Tiemann et al., 2002*). For the Lab of Tomorrow project's evaluation performance and background tests in several grades are used. The first ones are from the 7th and 8th grade, so called **"TIMSS population II"**. It is designed for students at the age of 15. At the final year of secondary school the **"TIMSS population III"** is used. It is designed for students at the age of 18. Both tests are suitable for the Lab of Tomorrow project's implementation, because their contents match with the content of the curricular of the participating countries and the content of the project.

Secondly, Mathematics and Science items and test booklets are used for evaluation. They have approved scales describing students' performance and they are available in different languages.

ICT Assessment Tool

This assessment tool consists of the "Computer Attitude Scale" (CAS), which examines the computer anxiety, computer confidence, computer liking and computer usefulness, and the Level of Computer Familiarity as far as TOEFL examinees are concerned.

School background test

The school background is an important factor that should be taken into account when evaluating the school data. The questionnaire consists for examples of items related to

- Size of the city
- Educational profiles, activities
- Social backgrounds, motivations
- Number and distribution of teachers
- Co-operations

Video documentation

For the video documentation at each school video groups must be established. These groups have to document the lessons of the Lab of Tomorrow project, so that their videos match with the general requirements of video documentation. The evaluation team has prepared two documents to act as guidelines for the work of the video groups, the **"Video-Checklists"** and the **"Video-Rules"**. Both are presented in the following sections of this chapter.

Before the evaluation of Lab of Tomorrow project's implementation, manipulation checks ensure the high standard of the video material. These are "home works" for the video groups that are controlled by experts on video-analysis of the evaluation team. Because the schools have to code the videos on the surface structure, the evaluation team carries out a coding training seminar as online teacher training seminar, to inform the teachers about lesson features and their coding on the apparent structure.

4.3 Guidelines and Checklists for the teachers

Goal of video-taping classroom work

The investigations building the framework for the taping of the classroom work examine teacher and student actions simultaneously. The objective is to show how teachers plan, structure and methodologically realize lessons, and how students adjust their actions to this. We are going to use - unlike the TIMSS video project - two cameras, arranged perpendicularly to each other: the **action camera** and the **student camera**, showing classroom work from two different perspectives.

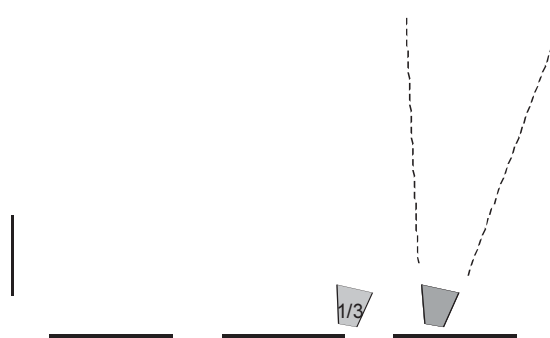
Camera positions

The arrangement of the cameras is similar to the one used by [Seidel \(2000\)](#). Both cameras have fixed positions, i.e. in general, they are not moved through the room; they are fixed at a tripod height of about 175cm (approx. 5 ft. 9 in.), so the students won't cover each other in the picture.

Action camera

The action camera is operated; angle and zoom are changeable. It is supposed to record the essential actions in classroom work. This does not only mean specific events, but rather interpersonal interactions, interactions between persons and objects, or more in general: between picture elements.

The action camera shouldn't be moved through the room. Nevertheless, the position of the action camera should enable us to record all events. A good position for that is the area between the "student side" and the "teacher side" (see picture), with the back to the windows; blackboard, projection screen, and experiment setup have to be observable. If there is not enough room in the classroom, the "1/3-position" ([Seidel 2000](#)) is preferable: the camera is positioned next to the first row of students, with a distance to the blackboard of about one third of the room length.



Position and

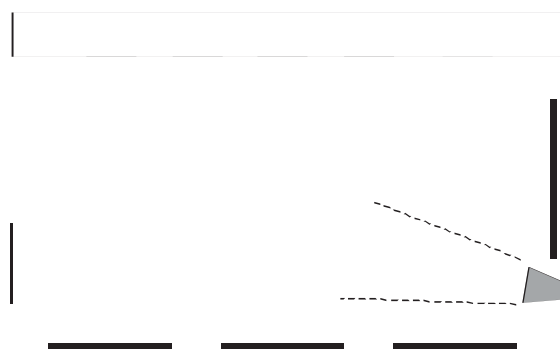
angle of the action camera.

The rules developed for the TIMSS video project ([Stigler 1995](#)) are applicable for the action camera (see section "Camerawork"). Unlike in [Seidel \(2000\)](#), we don't strictly recommend wide-angle as the standard setting.

Before class starts, it has to be coordinated with the teacher whether there will be any structure that might block the view (one also should be careful with calling students up to the front, etc.). If experiments are conducted by students, one has to determine which students should be taped as exemplary group and if they are observable from the current position. The camera can be taken off the tripod, if e.g. students gather around an experiment or computer screen, or if the view is blocked in any other way. Since this happens while the tape is running, the camera has to be moved extremely carefully - and be put back onto the tripod with the same care.

Student camera

The student camera should not be moved. It is supposed to give a complementary picture, namely the students' reaction to the teacher's actions. Thus the communication processes and work strategies of the students observed can be analyzed continuously and thoroughly. The respective coding procedure can be done independently from the taping of the action camera. The selected students should face the camera when recorded; the first row is not suitable for that. The camera shouldn't be positioned too close to the students, so that the students won't be permanently reminded of the taping. The camera can be put near the teacher's desk; it should be about the level of the heads of the seated students, so that the table in front of them is also well visible. Students standing or sitting at, in front of, or besides the desk should be visible, so adjust the camera view accordingly. In difficult lighting or room circumstances, one may want to change the seating plan.



Position and angle of the student camera.

Light and Shade

Generally speaking, brightness or exceptional darkness are no problem for the cameras used. Nevertheless, significant differences of brightness can make the picture unclear or indiscernible. Therefore an even lighting of the class room is important. Backlighting should be avoided, hence the cameras should be always placed with the back to the windows facing the class. If necessary, it should be estimated if changes of lighting are to be expected, e.g. because of experiments making very dark or very bright conditions necessary. For controlling the lighting, the lights already installed in the classroom should be used. Electric light is artificial light, hence it's more "red" than daylight; the white balance should be set accordingly. The outcome of mixing artificial light and daylight will look pretty "colourful", which seems unnatural. This should be avoided. Nevertheless the classroom should - if possible - be kept like the students are used to. If the brightness changes during the recording or if it seems unsuitable, the brightness has to be carefully readjusted by changing the aperture manually. Most of the time, automatic aperture works fine; exceptions may be: projections or computer/TV-screens

Microphone

Class work with a directional microphone

According to [Stigler \(1995\)](#), the use of directional microphones is the best way to record the sound of the whole class. If it's moved with the camera, it will get less interfering noise from the directions perpendicular to the view axis than the Lavalier microphones. The microphone is to be attached to the camera by using a microphone clamp to fasten it to the hot shoe (the socket for the flash). Its signal is put into the right channel.



Attention:

This "safety notice" doesn't relate to the people participating in recording or in the classroom work. It relates to the technical equipment. Major defects are not only expensive, but they also endanger the efficient completion of the whole study! Heed the following advice at all costs:

- The whole video equipment should be handled with care.
- Lay cables in a way that won't make people stumble!
- Secure camera tripods by blocking them with other objects if necessary - otherwise they might be knocked over by accident!
- Always securely close the case lid, because equipment might fall out when some one tries to lift the case they thought to be securely shut!
- Never expose video tapes to magnetic fields!
- Never short-circuit batteries!
- The setup- and disassemble-sequence has to be heeded!

Cameras work

Basic rules

I. Perspective of the perfect student

The camera is supposed to reproduce the perspective of the ideal student. The perfect student always follows classroom work, paying maximum attention. He/she works on tasks etc. with the same concentration. The perspective may change between teacher, experiment, blackboard, fellow students, and so on, though.

II. The focus of interest: the teacher

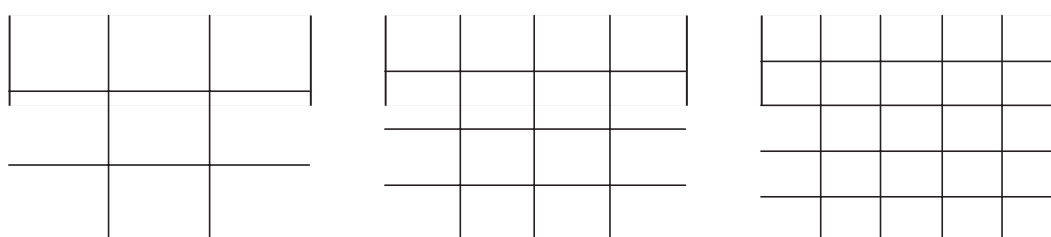
No matter what the students do - everything the teachers does or says influences the course of the class. That's why his/her actions have to be documented as comprehensive as possible.

Detail

To choose the detail (the view), there are only two possibilities while filming: panning (moving the camera horizontally) and zooming (change magnification). These actions must not be done too fast, especially if done simultaneously. Zooming should be used sparingly, because it seems "not nice" and "too much like filmed"; it's unlike natural vision. According to [Stigler \(1999\)](#), the best view for the action camera is "Master of Scene" (MOS). The MOS-view covers everything relevant to the current actions, i.e. every person and object is visible completely, every hand demonstrating, every person speaking or spoken to. If anything important can be discerned with the current view, it will be zoomed starting from the MOS (see below: "Special Classroom Situations"). Before performing a significant pan, the zoom should be taken back.

The following rules-of-thumb for views should be understood as mere suggestions. For an overview, individually speaking persons, and especially interpersonal interaction, the long shot is preferable, i.e. the maximum wide-angle setting of the lens. For demonstrations with smaller objects, a medium focal distance may suit fine. The same is true for details of group work; otherwise one should show four cooperating students in the detail. Close-ups, e.g. details of the blackboard writing or experiment setup, should be used sparingly in order to prevent losing other things out of view.

The picture should seem well-balanced and natural despite the demands concerning picture content and picture settings. This can be strongly affected by picking an unpleasant or unusual view. One can hardly explain within a few pages the meaning of a "good shot", but there are a few hints that may be worthwhile trying. First of all, the camera has to be set up so that the picture elements are in a well-proportioned arrangement. To achieve this, one can shoot the video picture divided into thirds, quarters and fifths; the important picture elements are put along this grid.



Thirds-, quarter-, and fifth-proportions grid.

This "lines of reference" can be vertical or horizontal lines like e.g. the edges of the blackboard, desks, but also standing or seated persons. The eye of the beholder normally "rests" on the eyes of the speaker, on the object that is used in that moment, or also on different subjects if these are outstanding in regards to brightness, shape, color, or movement. In a well-composed picture, these points are near the grid intersections. The eye level should be preferably set and kept on the top (thirds-) grid line.

Putting the motif right into the center of the picture will seem extremely "undynamic", it will even seem "wrong", if the motif is pointing to a direction, e.g. if the person in the picture speaks towards something out of the picture. In this case, the picture has to be open in the direction intended, e.g. the motif has to be moved towards the picture edge it's not talking to. If, for example, the teacher (while we use the thirds-grid) is talking to the right in a medium long shot, he should cover the first vertical line (starting from the left).

Agreeable zooming will keep these proportions mostly. If a different division seems better when closing in onto the object, it should be realized very slowly. It may be helpful to pick the point of interest before zooming and keeping it at the same point of the grid while changing the view. This means in many cases: zooming in means lowering the view, zooming out means raising the view.

Three additional hints may help to avoid awkward camerawork: many people tend to zoom too close and for too long. Before doing a significant pan, one should zoom out - otherwise the shot may become confusing. Before panning, one has to know exactly whereto and what kind of picture is supposed to become. Otherwise the perspective may seem like searching, which also makes the viewer lose orientation - since he/she thinks that the camera "knows" what it wants to show.

During the entire length of taping the class, brightness and focus have to be kept in an acceptable range. While taping, it has to be checked constantly and the aperture or focus have to be adjusted manually if necessary; most of the time, the automatic will work fine, though.

Timing

Both cameras simultaneously tape the entire class from beginning to end. Basic rule for panning and zooming: **the picture should be moved as calmly and unobtrusively as the situation allows**. Especially when taping dialogues, one shouldn't move the view from one speaker to another too fast; on the other hand, nothing essential should be invisible. In case of doubt, the decision has to be made in favor of the presumably more important contribution. **If texts, pictures, objects used in class are vital for understanding the class, they should be recorded in a "still frame"**. This means zooming onto the material until it takes up the whole picture.

Objects, experiments or demonstrations have to remain in the picture until the essentials are understood; if possible, they should be shown just before the teacher or students refer to it, or their statements may become hard to comprehend. **During writing up on blackboard or on overhead projections, one doesn't have to follow the whole procedure, except if its development is intended and crucial for understanding the class**. If that's not the case, it should be taped as a still frame when completed. It should be taped until all the essential points can be recognized and understood. By rule of thumb, this would be about 5 to 10 seconds. Pages containing only text have the rule of thumb that it should be entirely in the picture for the time one needs to read it four times completely.

If work sheets or other text sources are used (and if they are important), they should be taped just shortly so it can be identified during the analysis. Creating a still frame of these papers can be done either afterwards or replaced by getting photocopies of them.

Special classroom situations

During pre-tests for the TIMSS video project, [Stigler et al. \(1999\)](#) found three typical classroom situations where the basic rules mentioned above can't be put into effect without problems. In these cases, the following guidelines apply.

1. Student attention not directed to the teacher

The teacher can't be recorded at the same time when students work alone or in groups. In this case it has to be decided, which part of the class is the essential one. The view should be changed accordingly if necessary. It is important to tape everything new, to document changes in behavior or work strategy immediately. One essential action for this is looking over the view-finder frequently to see the whole picture!

The student group performing an experiment, for example, can be shown up to the point when it is clear what they do, how and what they are talking about. If the teacher becomes active after this moment, walking through the classroom in order to pose questions or give hints here or there, he/she should be followed. When this situation is sufficiently established for the viewer, the camera may pan back to the student group - definitely when a new situation arises there, like when the students finished measuring and start the evaluation. In other cases or when in doubt, the camera should rather follow the teacher than the students.

2. Dialogue too fast

If it's impossible to fit all participants of a discussion in the picture, the essential part of the class has to be documented by recording the person speaking at that time. If the statements are very short, the camera remains directed on the speaker who contributes the most; fast panning is not acceptable.

3. Speaker and object far apart

If the speaker and the object in question don't fit into the picture together, the object should be documented first until it's recognized and understood. After that, the camera remains directed at the speaker. The sequence object-speaker is advantageous, as otherwise the viewer wouldn't be able to make too much sense of the speaker referring to the object. For individual remarks or demonstrations, it is enough to pan to the object shortly; if there are many referrals to the object, the camera should remain directed at the object.

Schedule

Preparation

Day before the video-taping:

- Check batteries and tapes

40 minutes before taping:

- Arrival at the scene;

Meeting place is the room in the school where the cameras are locked inside.

20 minutes before taping:

- Setting up the entire equipment;

fix the cables, so nobody will trip over them!

If there may be disturbances, put a note outside the door saying something like "Do not disturb, recording in progress". The whole set up is described in the checklist (see "Disposition and checklists"); every step that is completed is to be checked.

After setting up:

1. Insert batteries
2. Turn on microphones
3. Turn on cameras (setting "lock")
4. Check picture and sound
5. Check whether camera settings are okay (' default values)
6. Check whether automatic aperture, focus and sound control is sufficient; readjust if necessary
7. Unprotect tapes, rewind
(if not sure: check if tape is really blank)
Start tapes at 0:00:00
8. Fill out clapper boards
9. Record pan through the classroom for orientation, i.e. pan slowly from the front to the back and back to the front
10. Set cameras to "Standby"

Warning:

After five minutes of idle "Standby", most cameras turn off automatically!

Taping the class

For the whole course of taping the class, the following order is to be kept:

1. Record clapper boards (7 seconds or "Photo")
2. Notify that recording starts
3. Turn on both cameras simultaneously, using the remote control for the long shot camera
4. Tape the class... (see camerawork)
readjust focus, brightness or sound manually if necessary;
if something goes wrong that can't be worked out from the camera: get the attention of the class observer and instruct him/her
5. Follow helpful signs (waving, pointing) of the class observer, if applicable
6. Don't shut off the camera too soon, but rather tape more than necessary
7. When finished: record the clapper boards again, this time upside down

Going it over

1. Write-protect and label the tapes!
2. Put the (rechargeable) batteries back into the charger!
3. Go over checklists!

Documentation

Recording technique

Setup in the classroom

Room, time, topic, class, teacher, observer, camera operator, technician

Checklists

Checklist I: Preparation (completeness, function, disposition, material)

Setup: completeness, order of events

Checklist II: Recording

Course of events, problems?

Checklist III: Going it over

Completeness, problem identification

Camera training

Getting acquainted

The whole technical setup should be learned in the following order:

- camera: automatics, tapes, zoom, focus & aperture (also manually!)
- tripods
- microphones
- transport
- setting up and disassembly
- documentation

Camera work

The basics of camerawork were already discussed in the section of the same name. They should be practiced in the following order:

- Focus:
Good practice is to record several objects and papers (with text) distributed throughout the room at different distances.
- Zoom:
Try it as slow as possible.
Beware of the tendency to make a close-up!
- Panning:
Coordinated panning can be practised by recording small objects that are distributed throughout the room; after this try following movements as calm as possible.
- Picture composition:
Tape discussion groups or other social situations inconspicuously.
- Hand-held camera:
Just try to detach and re-attach the camera from the tripod without shaking.

Checklists for video-taping

Checklist I: Completeness and Setup

Rechargeable batteries fully charged?

Fresh batteries?

Fixing material available?

☐ (Duck-)Tape

☐ material to bundle up cables (cable clips, wires, etc.)

Stowed the tapes (rewound, if necessary)?

Case with video equipment complete?

☐ according to the check lists (stored within the cases)

Do these steps one after another, in the order suggested here!

Check off each step only after completing it!

☐ Checked and completed checklist 1 up to here?

☐ Put cases where they are needed

☐ Set up receiver and ☐ Turn on receiver

☐ Set up room microphones and ☐ Turn on room microphones

☐ Lay cables and immediately fix them

☐ Set up tripods

☐ Set up the camera's power supply

☐ Set up and connect the camera

☐ Insert camera batteries and ☐ Turn on the camera's power supply

☐ Set up directional microphones and ☐ Turn on directional microphones

☐ Hand out wireless microphone and ☐ Turn on wireless microphone

☐ Turn on cameras

☐ Connect headphones

☐ Check whether cameras are set to standard settings (refer to lists in the equipment cases)

☐ Check or perform white equalizing

☐ Check if autofocus and autoexposure is turned on

☐ Check whether or not programmed to "autolock" (if needed)

☐ Check sound and picture quality; improve if necessary

☐ Check if auto settings for exposure, focus and sound are okay; if not: set manually

☐ Stow audio and video equipment cases

☐ Remove write-protection from tapes and insert them

☐ Rewind tapes, reset counter to 0:00:00

☐ Fill out clapper boards and ☐ Record clapper boards (7 seconds or "Photo")

☐ Record pan through the classroom for orientation (approx. 20 seconds)

☐ Keep cameras on "Standby"

(Note: automatic shutdown after a few minutes of inactivity)

☐ Start recording shortly before class starts:

Start all cameras simultaneously;

don't shut off camera too soon;

record lesson material (if needed);

don't forget the last, reverse clapping boards;

If recording the second part of a double lesson, continue as follows:

☐ Rewind, take out and label tape of the action camera

☐ Insert new tape, rewind it and reset counter to 0:00:00

☐ Fill out clapper boards and ☐ Record clapper boards (7 seconds or "Photo")

☐ Record pan through the classroom for orientation (approx. 20 seconds)

☐ Keep cameras on "Standby"

(Note: automatic shutdown after a few minutes of inactivity)

☐ Record as before

Checklist II: Documentation of the recordings

Please fill out for every recording!

The checkboxes are to be read as follows:

"○" multiple choice, i.e. at least one of the circles has to be checked;

"□" obligatory choice, i.e. box must be checked.

General

▶ Date:

____ - ____ - ____

▶ Lesson:

○ Single lesson ○ Part 1 or ○ Part 2 of a double lesson

▶ Camera:

▶ Observer: _____

▶ Teacher: _____

▶ School: _____

Recording

Short description:

Technical Summary

▶ The recording worked out well.

○ yes ○ no, because of the following:

▶ Camerawork:

▶ Video recording: _____

▶ Sound recording: _____

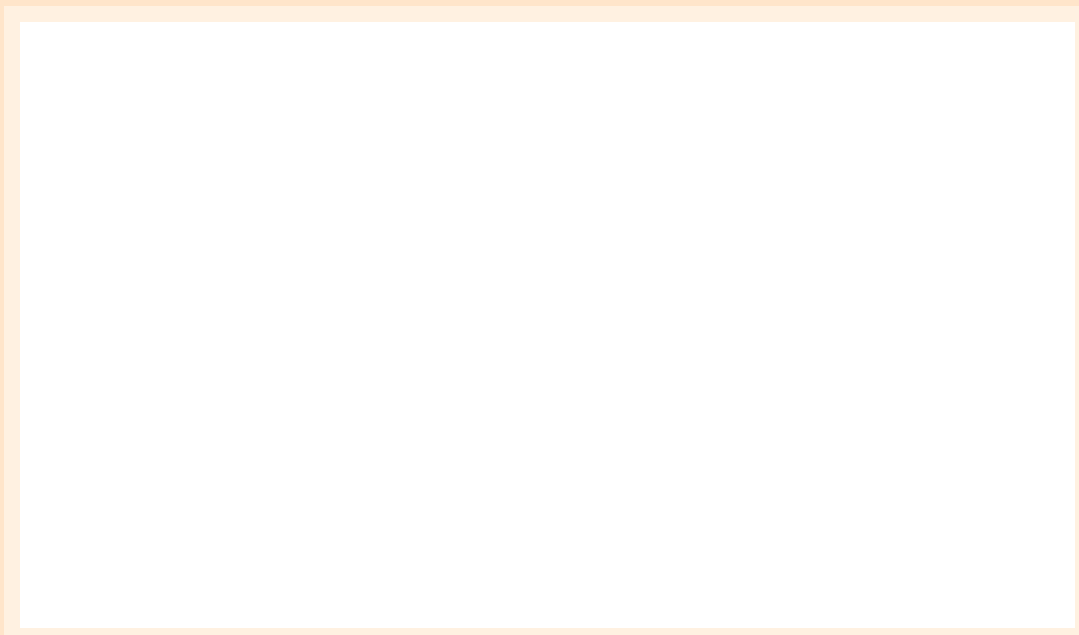
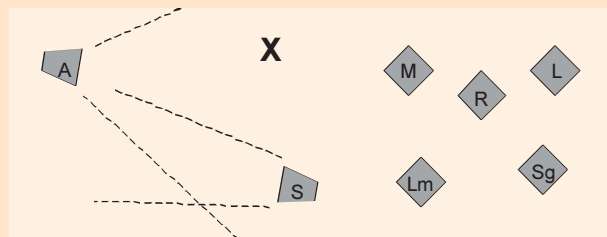
▶ Other: _____

Setup

Please outline the positions and directions with accuracy!

- ▶ Action camera (A)
- ▶ Student camera (S)
- ▶ Long shot camera (T)
- ▶ Teacher's position (X)
- ▶ Teacher microphone (if not wireless) (Lm)
- ▶ Student group microphone(s) (Sg)
- ▶ Class room microphone(s) (L, R, M)
- ▶ Furthermore:

Blackboard, desks, windows, door, experiment setup (if needed), projector



Clapper board Action camera

Date / Lesson

School

Class

Teacher

A

Camera

Observer

Clapper board Student Camera

Date / Lesson

School

Class

Teacher

S

Camera

Observer

Chapter 5

How to use the LoT Equipment - a short manual

5.1 Base Station.

5.1.1 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.

5.1.2 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 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.

5.2.1 Belt Assembly.

5.2.1.1 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 (see Figure 5) 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.

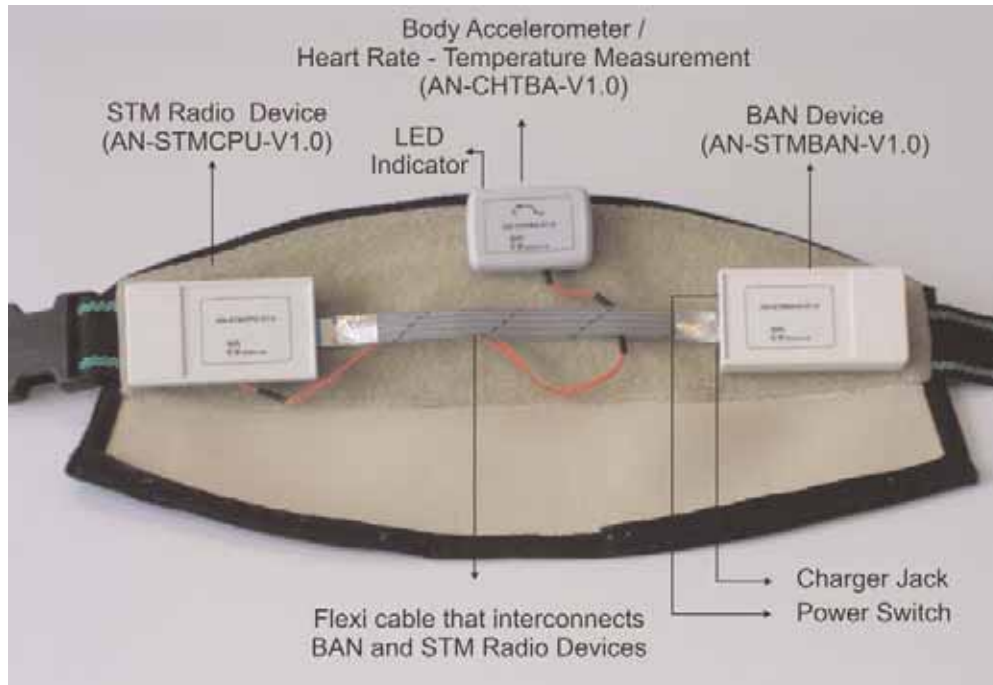


Figure 2: Belt Assembly.

5.2.1.2 Operation.

The Belt Assembly consists of three main modules:

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

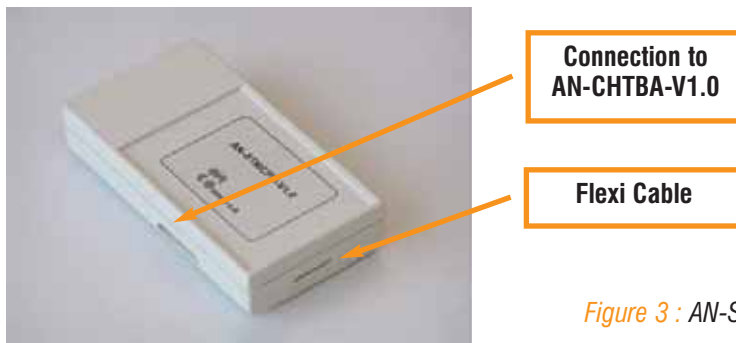


Figure 3 : AN-STMCPU-V1.0

- b. 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.

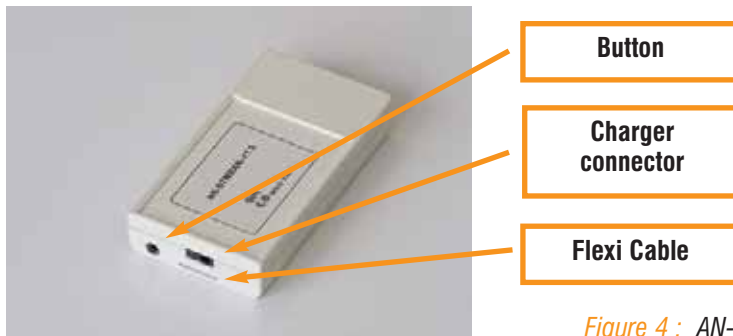


Figure 4 : AN-STMBAN-V1.0

- 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.

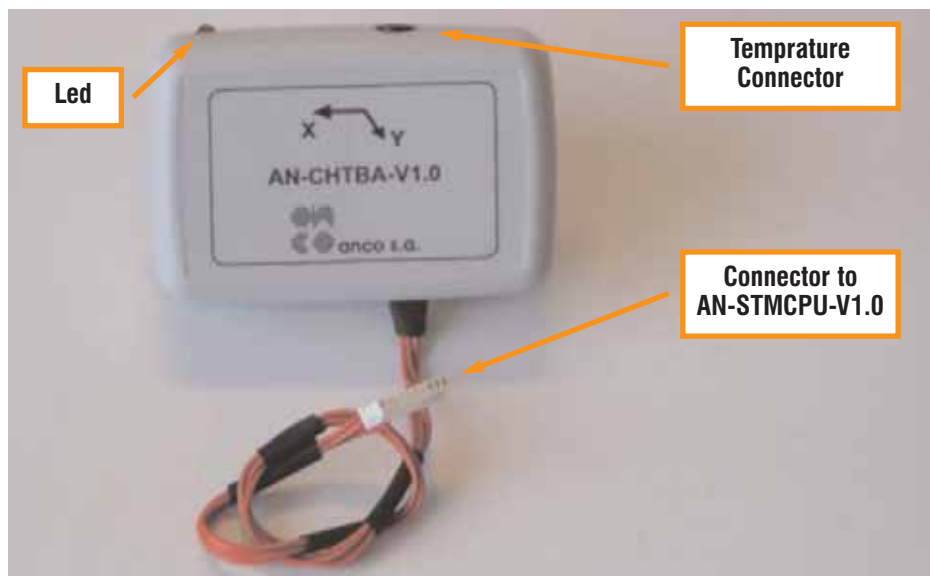


Figure 5: AN-CHTBA-V1.0 module.

5.2.1.2.1 Temperature Measurements.

To conduct temperature measurements, connect the temperature sensor to the available connector at the AN-CHTBA-V1.0 module (See Figure 6). The temperature sensor should be placed under the armpit, with the metal surface at the skin contact side.

5.2.1.2.2 Heart-Rate Measurements.

To conduct heart-rate measurements, the student should wear the Polar belt, following the instructions in Figure 6.

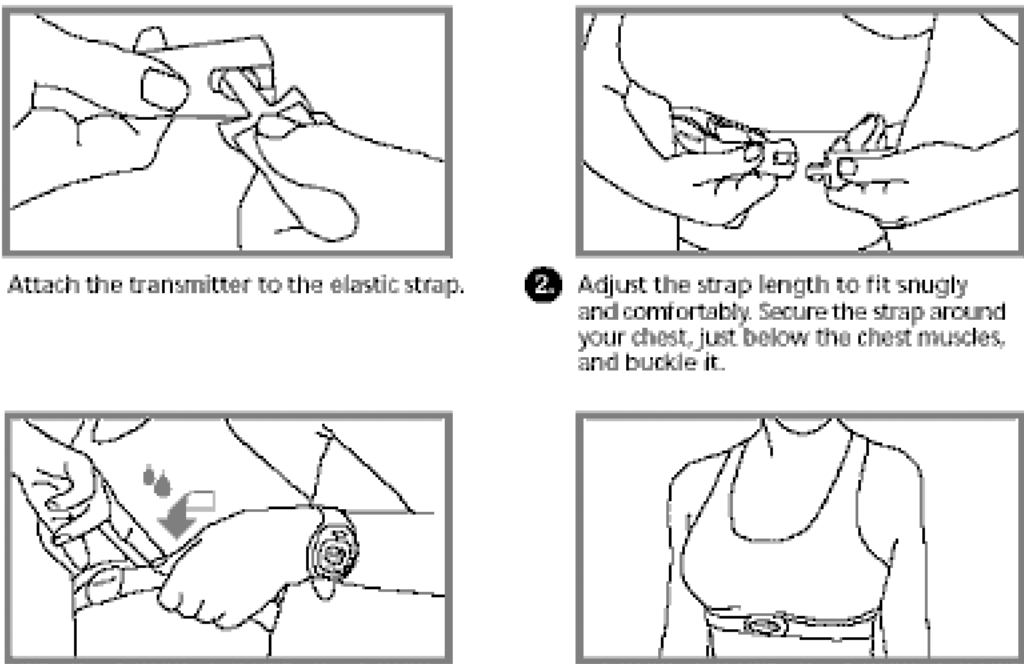
- 
1. Attach the transmitter to the elastic strap.
 2. Adjust the strap length to fit snugly and comfortably. Secure the strap around your chest, just below the chest muscles, and buckle it.
 3. Lift the transmitter off your chest and moisten the two grooved electrode areas on the back.
 4. Check that the wet electrode areas are firmly against your skin and the Polar logo is in a central, upright position.

Figure 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.

5.2.1.3 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 (see charger connector in Figure 5) 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.

5.2.2 Leg and Arm Accelerometers.

5.2.2.1 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 7 : Leg and Arm Accelerometer.

1.2.2.2 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.

5.2.2.3 Battery Charging.

The accelerometer modules have the same battery type as the Belt Assembly. The same charger is used to re-charge 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.

5.3.1 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 8: Ball Module

5.3.2 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:
 $x=0$, $y=0$, $z=+1$.

5.3.3 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.

Appendixes

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 Tips.

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 (see Figure 9), the following instructions should be closely followed in order to reinstall it and establish Belt Assembly proper operation again :



Figure 9 : 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 (see Figure 10).

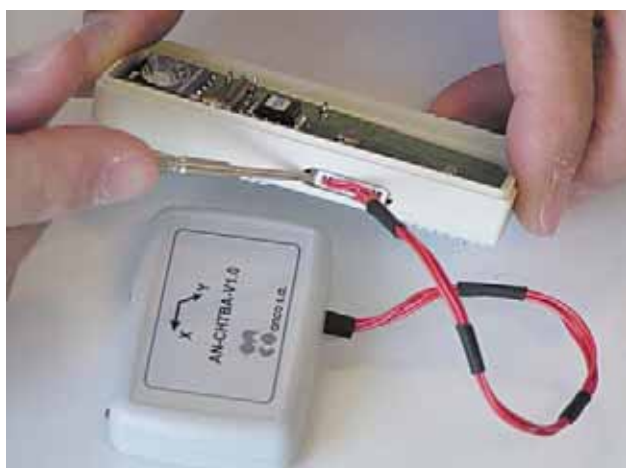


Figure 10 : AN-CHTBA-V1.0 connector unplugging.

- In case the problem has occurred at the BAN radio module (AN-STMBAN-V1.0), please remove first the battery (see figure 11) and reinstall it only after fixing the problem.



Figure 11 : Battery removal.

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

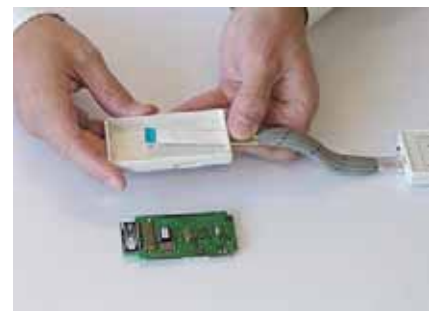
- Remove the PCB from the casing and lift the lever of the flexi cable connector (see Figure 12, step 1).
- Hold the edge of the flexi cable with one hand, the protective sleeve of the cable with the other. Draw backwards the protective sleeve in order to reveal the flexi cable for about 2 - 5 cm (see figure 12, step 2).
- Pass the flexi cable through the cutting of the casing for at least 4cm (see Figure 12, 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 (see Figure 12, step 4).
- Make sure, that the flexi cable has been secured straight and firmly (see Figure 12, step 5).
- Place the PCB back in its casing (see Figure 12, step 6).
- Put the cover and apply a piece of tape to close the casing.



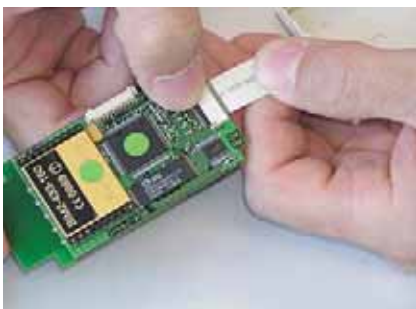
step 1



step 2



step 3



step 4



step 5



step 6

Figure 12 : Steps for reconnecting the Flexi cable at the STM or BAN radio module.

Appendix C: Using the Video Grabber Software

Student's User Manual (by U. Wlotzka)

1. Start the software "Video Grabber"



2. Choose the video scale (recommended: half size)

3. Initialize database (erase previous data)



4. Creating videos

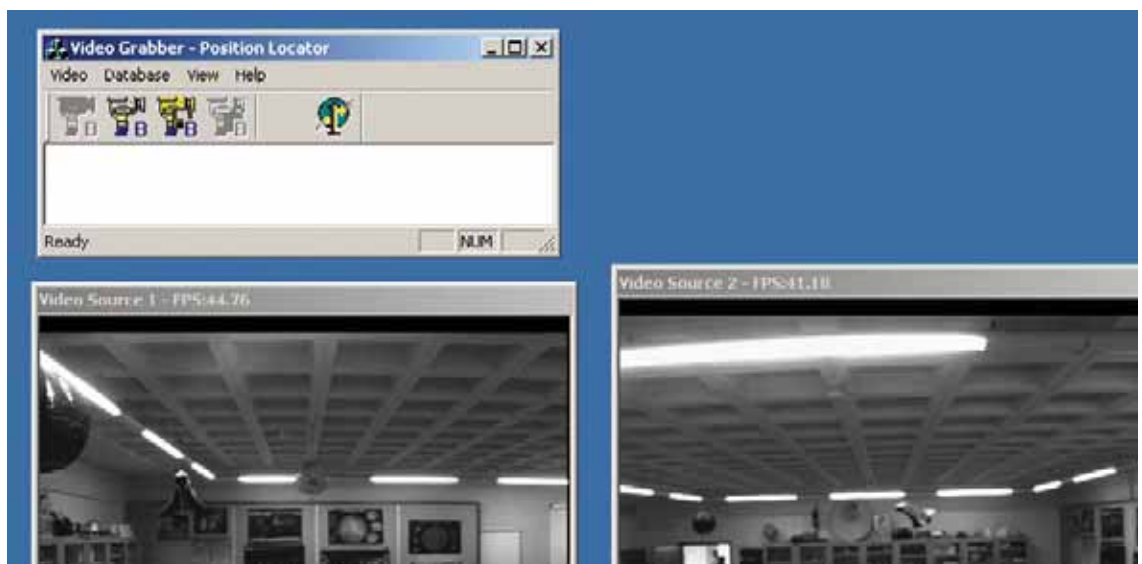
4.1. Button overview



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.



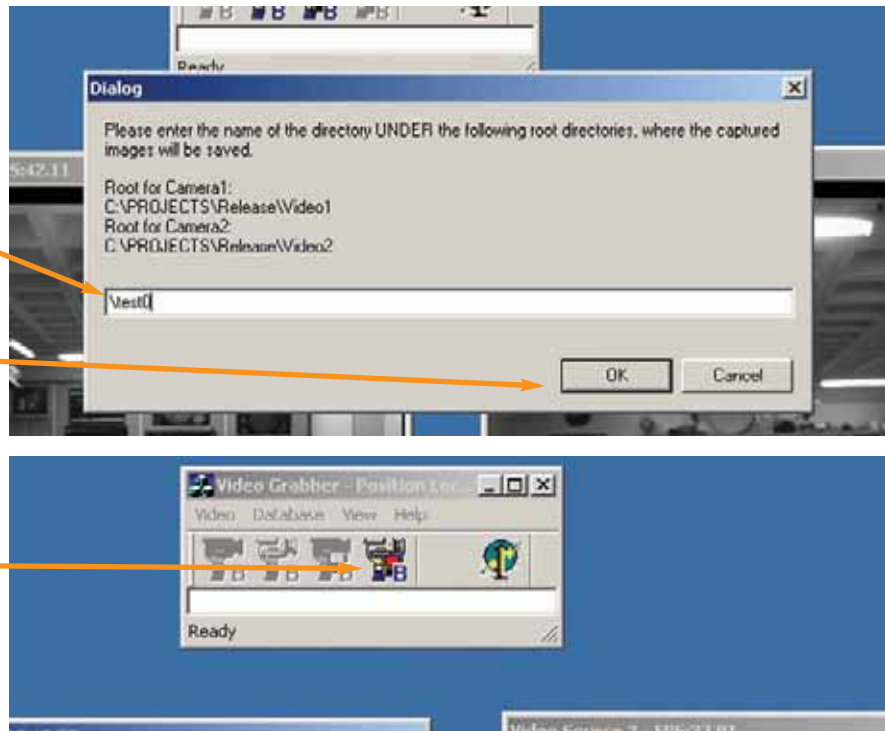
- 4.3. "Close Camera"
The two video windows disappear

- 4.4. "Start recording"
press the button

enter a name for
the experiment

then start
recording by
pressing "OK"

only the
"stop recording"
button is enabled
now

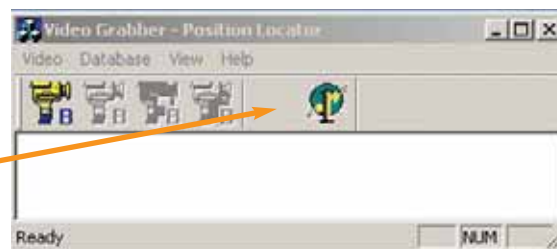


- 4.5. "Stop recording"
Press the button, when the movement you want to record has finished

5. Analysing the videos

- 5.1. Press the button
"open database"

open database

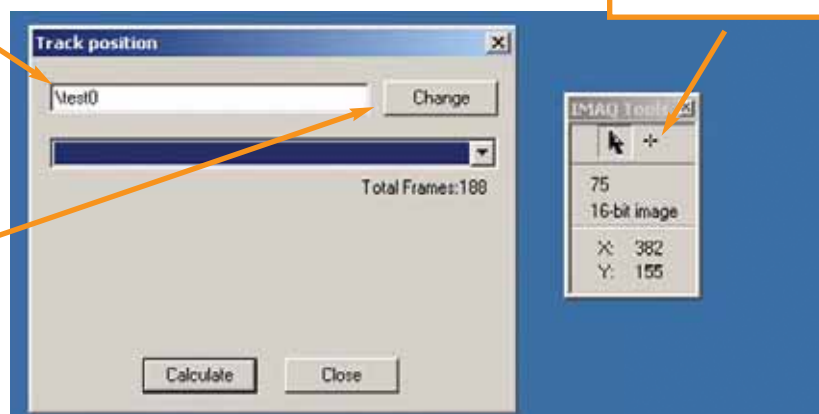


- 5.2. Choose the experiment and the tool

enter the name of
the experiment

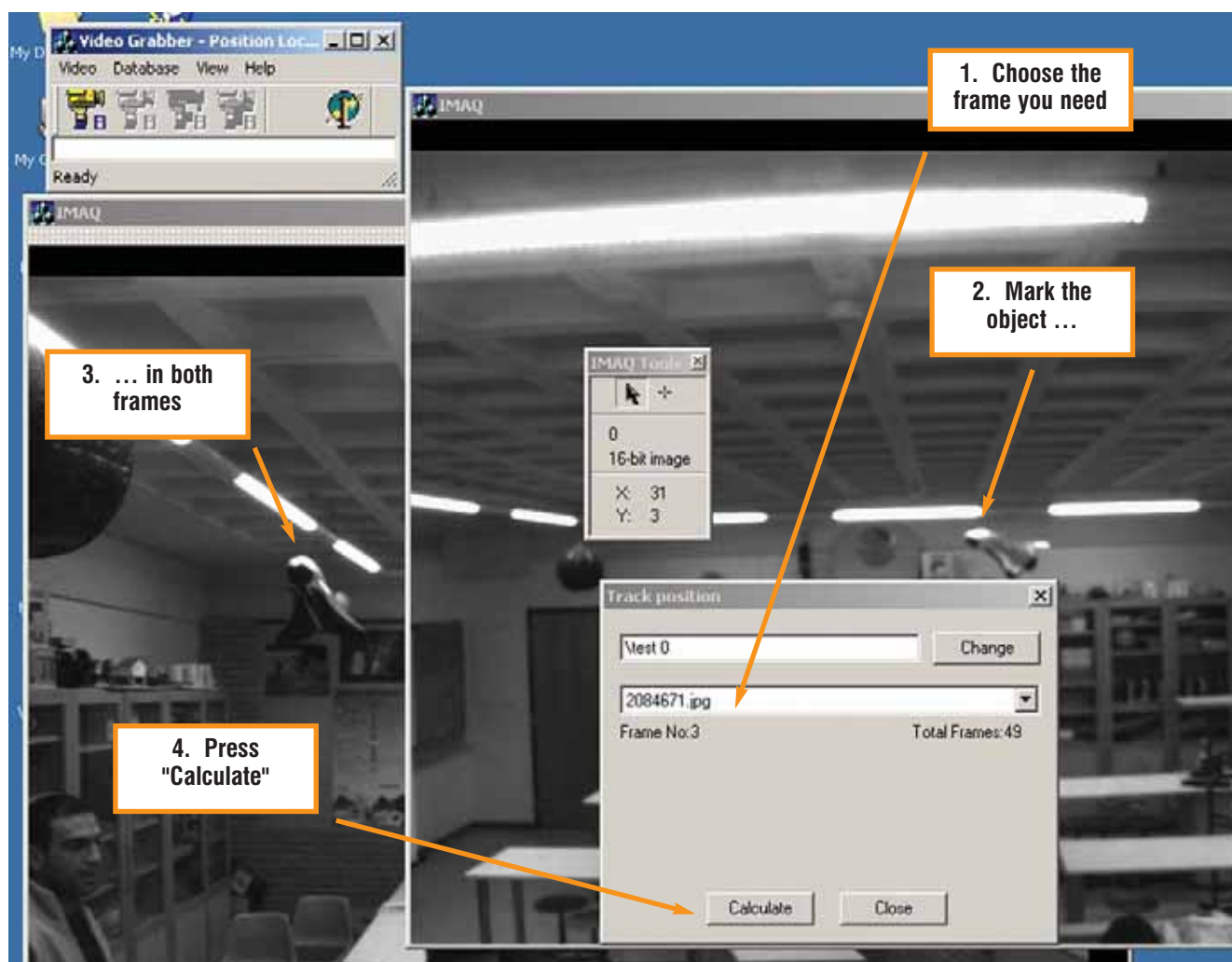
press the button
"Change"

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 z-component of the positions and the assigned time ("tick") is stored:

Points : Table					
	X	Y	Z	DateDone	Tick
▶	690,97	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		

Records: 14 of 14

- 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.

Appendix D:

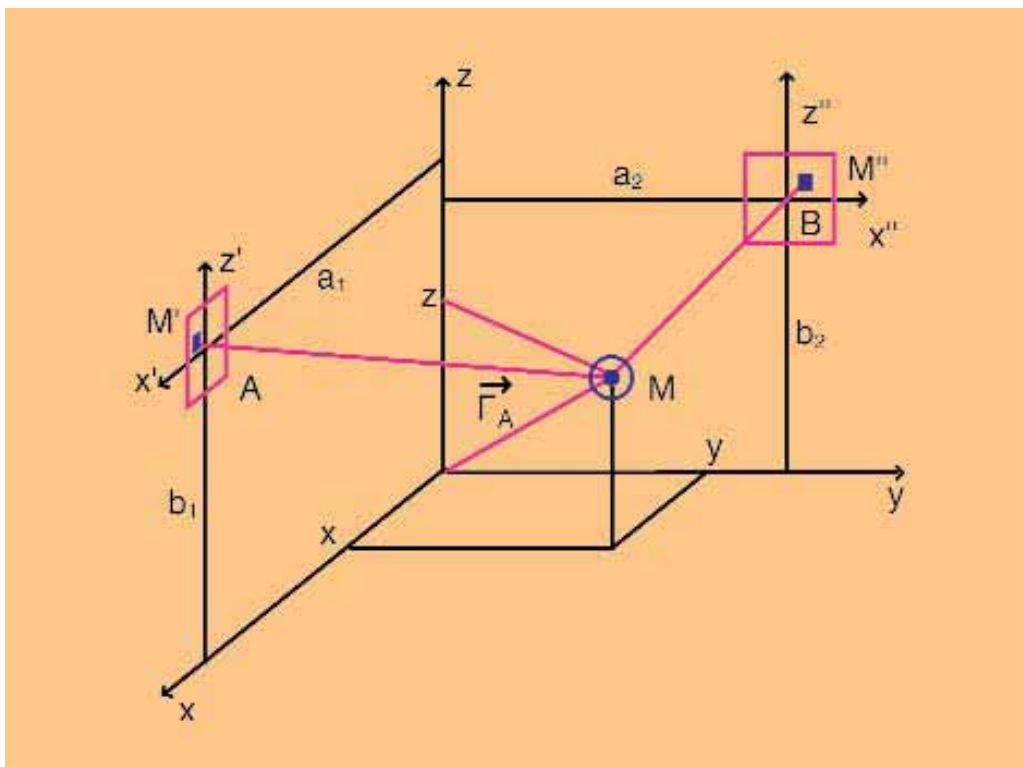
Set-up and calibration of the LPS system

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.



PICTURE 1: 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: a1, b1, a2, b2 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

$$a1a=a1$$

$$b1a=b1$$

$$a2a=a2$$

$$b2b=b2$$

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 physiological and physical parameters during the user's activities.

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, sensvest), 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 streaming from the axions.

Appendix F:

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