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Distance Education in Physics *via* Internet

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We report here about three connected projects in physics: a very successful physics course at university level; a collection of several thousands multimedia materials worldwide, its status and evaluation and its dissemination; and about web experiments, i.e. experiments at location A which can be controlled by a user at location B *via* Internet.

1. Introduction

During the last decades modern information and communication technologies (ICT) as well as the Internet have evolved to such an extent that a variety of opportunities in distance education allow to go beyond traditional forms. In particular, distance education in science disciplines like physics is confronted with the challenge to support student learners with experiments as it is the usual case in on-campus teaching. Real experiments, either demonstrations in lectures or hands-on activities in lab practices, play an essential role in introductory science courses at university (Kirschner et al. 1993), (Forinash, and Wisman 2001), (Kennepohl et al. 2005), (Lambourne 2008).

Here we report on our efforts to realize a distance education course for physics majors at university. In order to make real experiments available to the students we produced a couple of remote labs controllable *via* the Internet. In addition, multimedia applications like simulations or interactive video can serve as educational aids or can replace static figures in textbooks or even real experiments. Since there exists are huge amount of multimedia materials available for physics teaching it has to be discussed if that can be used for teaching and learning purposes, i. e. the quality of the material has to be considered. Thus, we report here also on evaluation of multimedia material for physics education.

2. Distance lecturing in physics (FiPS)

Because of the declining number of students in physics all over Germany, our department started a project in 1997 called FiPS (Früheinstieg ins Physik-Studium – early entrance in physics study), which was a university study at a distance for physics majors of the first and second semester, granted by federal funds. Figure 1 shows the distribution of first-year on- and off-campus students being enrolled at our physics department. For several years we have about 80-100 students in the distance courses without intense advertising.

Fig. 1

The target group is mainly the students finishing secondary school (age 18-19 years), who have to fulfill their military or community services within about one year.[1] During the last ten years an increasing number of these off-campus students are gifted students at secondary school (from 1%

in winter term 1999/2000 up to around 20% now) selected by their physics teachers (Fig. 2). All these students are excellent in many respects: knowledge in physics and mathematics, in computing or use of computers, eager to work hard, high intrinsic motivation, and excellent grades.

Fig. 2

The lectures in physics (and mathematics through the department of mathematics) we offer here are first-year university, the so-called introductory physics (Fig. 3).

Fig. 3

Our aim is to offer serious, highly accepted courses. Therefore, both the off- and on-campus students have to pass the same exam at our department at the end of the winter/summer term. The modules are accepted for transfer by all physics departments in Germany as well as in Austria and Switzerland, each weighing 12 credits (ECTS).

Before starting our project in 1997, we made a worldwide inventory and found about 450 distance education courses dealing with physics more or less comparable with the courses at our university. The major fraction of these courses were located in large area countries, in particular in USA and Australia (21% and 19%, respectively), as well as in Canada and India (11% each). Common to all was the use of mostly ‘traditional’ methods (delivering printed manuscripts, written exams, sometimes video-lecturing or broadcasting, and/or telephone tutoring) according to the state-of-the-art technology (Bates 1995). Furthermore, these courses did not have the appropriate level or content for our purposes (Schweickert 2002) and did not fit into the German situation, see for example (Grimm, and Riquarts 1992), (Kappel et al. 2002). Almost all of these physics courses did not make extensive use of modern ICT or Internet for communication or some kind of computer based multimedia in supporting the learners. Even the Open Universities, though experts in developing and implementing communication technologies, were faced with challenges due to the diverse educational background, poor technical equipment, and rural constraints, for example, of their target groups as well as providing lab practices in science courses, e. g. (Shott 1985), (Meester, and Kirschner 1995), (Ross, and Scanlon 1995), (Cilliers et al. 1997), (Garg et al. 1998), (Holmberg et al. 1998), (Kennepohl, and Last 1998). Our target group, on the contrary, is almost homogeneous in age and educational background. Furthermore, we did not plan to provide practicals in the framework of the distance courses, since the courses should serve as an early entrance in physics study, and the lab work is offered when students enter the on-campus stage (Fig. 3). However, at that time there were a few reports in literature on physics education at a distance which gave us the opportunity to learn the lessons and to try to avoid the pitfalls experienced by the authors (Ross, and Scanlon 1994), (Smith, and Taylor 1995), (Christian et al. 1997), (Frye 1997), (Safko, and Edge 1997), (Wilson 1997), (Venables 1998), (Wallin 1998), (Novak et al. 1999), (Suson et al. 1999). Again, these reports did not fit into our specific purposes. However, one of the most important impacts on our project was the decision to consequently use the Internet as preferred medium for distribution of course material and communication, although the connection bandwidth at that time was much lower as to date (56k modem against DSL). We had to cope with at least three major problems: First, due to the target group (off-campus, working all day long somewhere), we had to choose a traditional text book covering the first year of introductory physics (Demtröder 1994, 1995). The delivery of additional material like study guides, assignments etc. was realized *via* Internet. The major reason was to enable the students some kind of flexibility in working on the content with respect to their individual needs and duties. In addition, as reviews in literature pointed out, learning with hypermedia has only limited value (Dillon, and Gabbard 1998). Hence, a learning scenario completely organized as virtual environment seems not to be recommended weighed against the amount of load on the staff to create an environment of eventually doubtful success. Second, the physics lectures are based essentially on demonstration experiments. This shortage we overcame by integrating all kinds of multimedia such as videos, e. g. (The Education Group), see also section 3, animations and simulations, e.g. Physlets® (Christian, and Belloni 2004), interactive screen experiments (Kirstein, and Nordmeier 2007), and web experiments (see section 4). They were fully integrated in our teaching environment (i.e. in the reading/studying process of students, hyperlinked in the study guides and associated with the weekly assignments). For this purpose a media server has been developed and set-up which contains about 270 useful media of different kind covering the topics of the two courses (Roth 2001), (FiPS). Third, the learners need to communicate about physics and to discuss their problems in comprehension after studying the text book or during problem solving. It was well recognized in literature that the learning process must be supported by interactions amongst the learners as well as by interactions with tutors, e. g. (Laurillard 1993). Therefore, we implemented various possibilities for discussion and tutoring: threaded e-mail newsgroup as discussion board, sorted by different topics like problem number or book chapter, for example. We adapted a web interface of this discussion board to allow students more flexible access on it. Our evaluation showed that the newsgroup discussion was highly accepted by the students (Schweickert 2001).[2] Even if not every student participated to the discussion it was reasonably to assume that those individuals were able to benefit from as well (Sutton 2001). Although each student was individually assessed we fostered cooperation in problem solving by tutoring. Since social interaction was recognized as an important ingredient in distance education, e. g. (Sonnenwald et al. 1999), one thematic topic of the discussion forum was devoted to personal issues and exchange of thoughts and experience of general character, called ‘Café’. Moreover, besides the asynchronous forum we encouraged the students to make use of tools like ICQ, and phone or to organize meetings by private appointment[3] or to meet during our offer of on-campus weekends. Another set of problems, apart from isolation of students, frustration about technical demands (Hara 2000) have been recognized too and was solved by pre-course assignments on technical issues (FiPS).[4] However, as (Schweickert 2001) stated, most problems were caused by the limitations of the techniques and less by the students’ competence to use them.

As a consequence, we built up this distance course in the following way: every week we provided a reading guide online, whose content concerns typically one chapter of the text book, that is the equivalent of a lecture for one week. The off-campus students were assigned to read one chapter in the book while they were taking hold in the hands of the study guide. This guide contains comments, questions, amount of time we recommend to invest, the weight of a specific topic (e.g. importance of certain content or concept), and links to media as an illustration (Fig. 4).[5] Each week of the semester the off-campus as well the on-campus students have to solve about 4-6 problems, available online for download. After one week they have to send in their solutions by any means (paper, fax, e-mail; whatever is available at their present situation).[6] These solutions are printed and passed to the tutors, who correct them and send them back to the students with detailed comments. In due time the students are provided with exemplary solutions of all problems for further studies and to allow them to classify their own solutions. In addition, the heading tutors provide each week a summary of performance of the solutions, e. g. when typical problems in comprehension appeared, when misinterpretation was multiply observed, highlighting conceptual aspects of a problem, discussion of problem solving strategies, giving positive feedback, and so on.

Fig. 4

An evaluation of the success of this distance lecturing is made internally every semester. After all tutors have corrected the solutions of their students (ca. 20 students per group, off- and on-campus) the success, i.e. the points achieved by the students in problem solving, is processed by a grading tool (Roth 2001), (FiPS). A typical result of performance in problem solving is shown in Figure 5. The bars in that figure indicate the percentage of students who solved or tried to solve a given problem. The diamond shaped symbols, on the other hand, indicate the success in problem solving, i. e. the average score for each particular problem (in percent). The students have to attain in total about 50% of the maximum points achievable to take part in the final exam at the end of the term; this is the reason why the evolution of bars is decreasing towards the end of the respective term.

Fig. 5

This huge amount of data (ca. 100 students times ca. 12 weeks times ca. 5 problems) can be accessed *via* Internet and is supported by a the grading tool in different ways: (1) an individual student interested in his or her own success in comparison with the sum over all other students can follow his or her achievement points; (2) a tutor is able to take count of all students of his or her group individually; (3) whereas the lecturers and heading tutors can have a look at all the data. During weekly meetings of the teaching staff involved, the data are examined and discussed, like performance and drop-out rate; or if one particular problem was not solved at all then we are forced to reconsider the problem assigned; if a problem needed the use of multimedia and was not solved we had to look for the instructional design or feasibility of the material; etc.

Since this distance lecturing is now working for more than 10 years for more than 1000 students we can state that it is highly accepted; without any additional publicity we have a more or less constant enrollment every term.

3. Multimedia in physics teaching and learning (MPTL)

As the computer became widely available in educational institutions it was well recognized as a teaching/learning tool. In particular, the application in physics education was straightforward since physical phenomena can nicely be modeled by means of mathematics. Therefore, many simulations have been developed and one important issue, on the quality of the material as an educational aid, was getting more and more obvious. In the past, there have been many efforts to judge simulation software, though, in general, as largely disconnected activities locally at a national level, as an example for the USA (Donnelly 1999).

During the last 30 years we have been collecting information about multimedia used in physics teaching and learning from around the world, e. g. (Jodl 1985), (Depireux, Jodl, and Wilson 1989), (Jodl 1997), (Eckert, and Ronen 2004); when we produced multimedia by ourselves, e. g. (Korsch, Jodl, and Hartmann 2007); when we installed our media server in the framework of FiPS (FiPS); and when we started an annual European workshop for interested colleagues in 1996 (MPTL). As a result, we know of several thousand multimedia materials worldwide at all kinds of students' level (age 10-25 years) for teaching and learning physics. However, the major fraction is of poor quality. Mostly, standard topics are modeled always again by another author. In addition, an interested person, like a teacher at school, a lecturer at university, or a committed learner, cannot readily find these materials, in particular the valued ones. Furthermore, what he or she may find does not always fit exactly in what he or she is looking for. That's why a group of educators and researchers in the field of computer based learning in physics decided to solve this problem in general and to offer a service for their colleagues. This group collected multimedia products, evaluated them, and made recommendations for those people involved in the teaching/learning process who do not have the time to search by themselves, whenever they need a multimedia item.[7]

The group consists currently of about 20 experienced professors/teachers in physics as peer reviewers - about ten from the USA (MERLOT-Physics) and about ten from Europe (EPS-PED).

Each year another topic from introductory physics is chosen and updated again after four or five years. Both groups used their own (but slightly different) catalogue of criteria for evaluation (Table 1).

Table 1

To collect the materials we used about ten different web servers and digital libraries in different countries. We are confident in finding about 80 to 90% of all material available through the Internet due to repetition and saturation effects. Then, in the first evaluation cycle, we look at these multimedia products (several hundred each year and topic) relative quickly applying KO criteria; for example, is this product working, is it physically correct, is it of relevance etc. In general, about 30% of the material is kicked out in this round. In the second cycle, the remaining material is divided among the reviewers such that each item is judged by at least two reviewers from the US members and the European members of the board. In the third cycle, we select only excellent material for recommendation in order to define a standard of what is ‘good’. The yield is below a few percent of total amount of material. The agreement between the two groups judging independently is, in general, more than 60 to 70% (Mason 2006).

The result of this procedure is briefly presented in Table 2. The interested reader may have a detailed look at the annual reports, which contain all hyperlinks of the materials found. The reports are presented during international workshops (MPTL) every year to an audience of physics teachers/professors (ca. 100 participants) highlighting the best practice examples, as well as discussing ‘bad’ examples with respect to the applied criteria. Of course, the educational potential and benefit of multimedia can only be exploited if it is integrated in a meaningful learning environment, e. g. (Kozma 1991), (Laurillard 1993), (Muller et al. 2006). However, the focus of evaluation of multimedia is primarily on the particular material itself as a first step in judging its suitability.

Table 2

Next, we present an example (on the Coriolis force) where physics students at school and at university commonly have problems in understanding and where multimedia material may help to bridge. Since the Coriolis force is a real phenomenon, we selected from the various kinds of multimedia the video type. In general, videos are passively watched and a proper video analysis of the motion of an object is too time consuming. We, therefore, developed our own style of what we call a measuring video. That is, when looking at the video to solve a problem given in a lecture for homework, students have to perform quantitative readings (Wagner et al. 2006).

Fig. 6

In the video, a ball rolls down an inclined rail mounted on a rotating disc. At the centre of the disc the ball leaves the rail and rolls further with constant speed (Fig. 6, set-up). A motor drives the disc with constant angular velocity. Now, this experiment is viewed by means of two separated cameras: one is mounted in the system at rest (the so called laboratory system), and one is mounted in the rotating system (the so called accelerated system; the rotating disc is an accelerated system even if the disc rotates with constant speed).

Fig. 7

Figure 7 shows the results of one and the same motion after marking the trajectory at equidistant time intervals (left: view in the laboratory system at rest; right: view in the rotating system). We recognize in the left part of figure 7 an almost straight line as trajectory, because the ball after leaving the inclined rail is moving free of forces except that of gravity (and a negligible amount of friction). In the right part of figure 7 the trajectory is bent, because only in this frame of reference (the rotating disc) an additional force appears to be acting, this is the so called Coriolis force.

The added value of this medium is that the learner can have a look at this experiment repeatedly; he or she may have a look qualitatively or quantitatively (e. g. if a problem is assigned); the student can recognize details which he or she can never achieve by demonstration experiments in a lecture hall, only.

As prototype examples, we realized several measuring videos of well-selected topics where students typically have comprehension problems: Coriolis and centrifugal force (Wagner et al. 2006), Navier-Stokes equation in fluid dynamics (Wagner et al. 2007), absorption and emission spectrum of sodium (Wagner et al. 2006), determination of Reynolds number (Wagner et al. 2003), Rayleigh criterion of optical resolution, entropy and melting line, Bernoulli equation (fluid dynamics), and determination of small length changes by means of a Michelson interferometer.

To summarize our experience about multimedia in physics teaching and learning: First, there exists a huge collection of several 10^3 items; so there is no need to 'reinvent the wheel', unless a new software/technique appears on the market provoking new developments. Second, a group of peer-reviewers claim to know what a 'good' material is based on their experience and on evaluation criteria, therefore, 'standards' are known to future developers. Third, all kinds of multimedia materials are available from videos, animations, simulations, and remote experiments. Fourth, multimedia materials are used in many kinds of teaching/learning environments: e. g. traditional lecturing, blended learning, e-learning, self-paced learning. Fifth, multimedia items come along with textbooks, as a tutorial, as a stand-alone solution, or as a solution for a specific teaching situation. Finally, according to us there is an increasingly acceptance rate of multimedia materials among the younger generation even if, up to now, forces are at work which make implementation worse (Åkerlind, and Trevitt 1995).

4. Remotely controlled labs (RCL)

Real experiments are central and essential in the teaching of physics at school and at university. There is still an ongoing debate on how far can real experiments be substituted or complemented by multimedia, in particular, in distance education. Remotely controlled laboratories are viewed as one important component in delivering real physics experiments and in teaching a variety of skills related to practical work.

Figure 8 shows the principle of a remotely controlled lab. For example, a real experiment is set up at our department and the off-campus student at home can control this experiment *via* Internet. Of course, the principle of remote operation has been known for years in research and technology. The merit here is that we exploited this technique in the field of physics education. During the last decade we have set-up about 20 remotely controlled labs. We have solved technical problems, such as the video transfer of data by means of web cameras, and didactical requirements, i.e. how an RCL should come along in comparison with the real on-campus lab. Details on this and a brief review on similar efforts worldwide have already been published (Gröber et al. 2007), (Gröber et al. 2008).

Fig. 8

Why do we need RCLs as a solution in physics education? What is a 'good' RCL? Running real experiments has some disadvantages. For example, some teachers at their schools/universities do not have the proper equipment; the real experiment costs too much to perform it only once per year; to conduct the experiment quantitatively consumes too much time in class; to evaluate data of one specific experiment one would need to collect too many data; the performance of the experiment is somehow dangerous; and, last but not least, the off-campus students need more than a static figure of experimental setup and a table with measured values in a text book to gain insight in the real experiment.

Before we started our project on larger scale we made a worldwide inventory; but we could not find a proper solution for our purposes of distance education in FiPS, cf. table 3 (Gröber et al. 2007).

Table 3

Since we now have experience with RCLs for several years and since we have a critical knowledge about what is available (including solutions based on commercial software like LabVIEW©), we are able to specify essential requirements for remote labs which agree pretty well with efforts of other groups, e. g. (Forinash, and Wisman 2005), (Kennepohl et al. 2005), (Schauer et al. 2009). First of all, one must choose/select the proper topic. We recommend not to choose an item which can be executed without any problems as a real experiment in class.

Second, when changing technical parameters, the user must have the possibility to watch what he or she is doing in the remote experiment *via* web cameras (authenticity). Third, the use of an RCL *via* Internet must be intuitively clear and the user should not be forced to read a detailed manual. Fourth, the user must get back (*via* Internet) his or her own measured data for further analysis or for being processed by additional tools. Fifth, the experiment must be robust enough to be used 24 hours a day over extended periods of time. Sixth, the presentation of one specific experiment must be autonomous, i.e. without reading further texts. Didactical material presented in the accompanying website will help the implementation in a teaching environment. Seventh, the RCL should be more interesting and more flexible the more actions are available in the lab user interface, i.e. variation and control of technical parameters. Finally, the use of RCLs must be free of charge, public in a common language, and independent of a specific operating system at the client side.

Now, one example from our RCLs (table 4) will be briefly introduced: the wind tunnel. The aim is, on one hand, to teach physics students the main topics (like air friction, laminar and turbulent flow) and, on the other hand, to motivate non majors in physics or laymen to perform this experiment qualitatively (like the dependence of air drag on wind speed, on the cross section, and on the shape of a vehicle). The experimental set-up of this experiment is presented in figure 9.

Table 4

Fig. 9

A homogenous flow of air is produced by a vacuum cleaner and is streaming from left to right. A real toy car on top of a thin steel wire is positioned into that flow such that the air friction on the car will bend the wire. The higher the wind speed the more the wire will be bent. This force on the car (i.e. the degree of bending) is measured by means of a strain gauge mounted on a steel blade below the wire. The modifications of this experiment for remote operation are as follows: (1) the user can choose between three different vehicles (sports car, off-road vehicle, and fire engine), different in their drag coefficient (C_W value); (2) the user can vary the speed of wind, i.e. the relative velocity of air with respect to the vehicle; (3) the user can read the wind speed on a standard speedometer; (4) the user can read the voltage of the strain gauge giving him or her the amount of force acting on the vehicle. Besides systematic measurements the user can have a look of what is going on: how much the wire is bent; when it is bent differently due to the shape of the given vehicle at constant speed. Systematic measurements then deliver results for the different drag coefficients of the three vehicles, and the dependence of air drag F on wind speed v (i.e. car velocity), according to $F \sim v^2$.

The structure of the website is presented in Figure 10, left part. In the middle the user can view the status of the experiment by means of streaming video. On the right side, the laboratory page can be viewed where the user can vary all technical parameters (e.g. choose a vehicle, start airflow, vary amount of flow). The user can take the measurements (read the wind speed, observe bending of wire with selected car, read voltage of strain gauge), and calculate the frictional force.

Fig. 10

The value of this experiment as an RCL is multifold. First, it is a relevant experiment with respect to everyday life (e.g. design of vehicles, fuel consumption) which is difficult to perform (e. g. expensive setup). Second, the experiment can be performed qualitatively as well as quantitatively. Third, the experiment is best suited as a project work; the user must inform oneself (e.g. Wikipedia, automobile industry), set up his or her own research program and evaluate his or her data. In the end, the user should realize the impact of air friction on car driving and on the waste of energy due to overcome this friction at high car speeds.

An important issue with all RCLs is the interactivity (i.e. number of actions, their quality and complexity) which can be recognized at the laboratory page of each RCL. However, these actions do not consist only in pushing buttons, cf. (Oliver 1996). Behind this are the following activities which the user of an RCL or the experimenter of a real experiment has to perform in a meaningful way:

- select and position sources (e.g. of light, of radioactivity),
- select and position samples from a pool under investigation,
- vary technical parameters like angle, distance, number of scans,

- measure and read values,
- choose proper time intervals for accurate measurements,
- re-align experimental set up, etc.

All these capabilities and skills are typical for tasks given to students in a beginner on-campus laboratory course in physics, e. g. (Jodl 1997).

The popularity and quality of our remote experiments is best reflected by the number of users per time. We have been collecting data since 2003 and in 2007 we registered about 15,000 visitors of our web portal (http://rcl.physik.uni-kl.de), which means an average of about 3-4 visitors per RCL per day worldwide (cf. table 5).

Table 5

Most of our RCLs were built up by students in the course of their master's thesis (4-6 months duration) in physics teacher education. The regular maintenance of each experiment is like that of a real experiment: replacing a light bulb, repairing electronics etc. On the other hand, we had chosen all components of the RCL experiment for a robust usage 24 hours a day over weeks. Currently, most RCLs are delivered to foreign institutions (schools, companies) where local technicians take care of the set up.

In conclusion, these web experiments can trigger new ways of teaching and learning in comparison with traditional forms. For example, after the teacher has briefly introduced an experiment in reality in the class, maybe by running it qualitatively, then the students are assigned to conduct their own experiment remotely as homework. Some of the RCLs are very complex and powerful (e.g. radioactivity, or computed tomography) so students have to schedule their own measuring program depending on their research aims. Furthermore, some of the RCLs are best suited for self-studying with a tutorial aside (e.g. Fourier optics).

5. Conclusion

The examples described above (FiPS, MPTL, RCL) demonstrate the feasibility to implement modern ICT in distance education of physics. According to us, these powerful communication techniques are essential to trigger new ways of teaching/learning such as distance education, e-learning, blended learning, and student centered teaching as well as innovative learning environments. However, as the developments of the past decades have shown us educators didactical considerations often lag behind the rapid technological improvements. For example, many traditional methods of course delivery are easily be replaced by modern ICT, at least in well developed countries.

Our initiatives reported here may be understood as a positive contribution to globalization in the sense that we are able to communicate worldwide, for example. We can be all at the same level and we can learn positively from each other, in principle.

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Notes

[1] Germany has conscription for male citizens, where men are obliged to serve in military service. However, they can refuse and, instead, have to serve in alternative civilian or community service in the field of health or social works, for example.

[2] For example, on average we counted ca. 100 messages (questions, comments, replies etc.) per day which compares to ca. 80 students active in their study (during winter term 2000/01). We also found that the difficulty of writing formulas or drawing graphics due to the text based newsgroup was no restriction to the ongoing discussion. Where it was necessary students contributed to the discussion with attached images of graphs or formula.

[3] For that purpose the students were initially grouped together by their regional proximity of home or place of work, as far as it was possible.

[4] For example, we made questionnaires on the technical equipment of our off-campus students as well as on their familiarity with communication tools. In winter term 2000/01 (1999/2000) the result was: computer 100% (90%), modem or otherwise Internet access 91% or 93%, respectively (77%). Tools were rated as follows: e-mail 95%, FTP 39%, ICQ38 %. In the first beginning, some individuals had no access to computer; therefore, those students were supplied by laptop computers with built-in modems on loan. In the meanwhile, about ten years after beginning of the project, the demands resulting from technical problems as observed earlier (hardware, software, Internet connection and bandwidth) do no longer play any role. This confirmed our decision to consequently use the Internet. Since then, it is exciting to observe how students manage these modern technologies with a kind of naturalness, being it application of LaTeX for formulas in the homework assignments and many more. This continuing change in everyday use of ICT arises interesting questions like that on possible integration of features of the so called Web 2.0 for educational purposes.

[5] The media are organized by and stored in a media server which has specifically been developed for that purpose (Roth 2001), (FiPS).

[6] The submissions are typically in electronic format ranging from scanned handwritten solutions to word processed by means of LaTeX and pdf format, for example.

[7] Only such material which is easy to access *via* Internet and, in general, free of charge has been collected. Since the beginning of the evaluation process an increasingly number of commercial products appeared on the market (stand-alone, or CD-ROM attached to a physics text book). This evolution has to be considered in the near future.

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EPS-PED

The Physics Education Division (PED) of the European Physical Society (EPS) hosts several working groups on educational issues. The website is at http://education.epsdivisions.org/

FiPS

Unfortunately, this distant course is offered only in German language. The interested reader may have a look at the website, http://www.fernstudium-physik.de. Additional information, for example about course syllabus including media, discussion forum, grading tool, technical pre-course (partly in English) is available at http://pen.physik.uni-kl.de/fips/

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MERLOT-Physics

The Multimedia Educational Resource for Learning and Online Teaching hosts a huge archive of links to multimedia material in a variety of disciplines. Each discipline is managed by an editorial board. The material is peer reviewed and described in detail. The website is at http://www.merlot.org

MPTL

Multimedia in Physics Teaching and Learning is part of the Physics Education Division of the European Physical Society. This working group organizes annual meetings where multimedia material is presented and discussed. In particular, a core team of the members collects and evaluates multimedia material on a specific topic of physics curriculum. Since 2004 there is a joint evaluation of material with the MERLOT-Physics editorial board. The website is at http://www.mptl.eu

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(Web sites accessed as of March, 17 2009)

Tables

Table 1: Review criteria of the two groups of referees (MPTL; Mason 2006).

EPS – PED		**MERLOT – Physics**
Motivation ▪ User friendly: easy to start, understand, control, and is documented ▪ Attractive: appealing, interactive, and interesting ▪ Clear Description and Context		**Quality of Content** ▪ Correct Models: numerical, textual, notation ▪ Important Topics: standard or unique ▪ Conceptual: understand parameters ▪ Effective Graphics ▪ Flexible: multiple uses
Content ▪ Relevant: Important topic and media use ▪ Scope: broad and profound topic ▪ Correct: content accurate and models indicated		**Effectiveness as a Learning Tool** ▪ Learner: level, challenge, control ▪ Relevant Knowledge: learning goals, application ▪ Experience: dynamic, flexible, interactive, progress ▪ Feedback: clear, immediate, positive
Method ▪ Flexible: broad audience and topic ▪ Matching Target: correct level, background, objectives ▪ Realization: media is well used ▪ Documentation: operation, references, teaching process		**Usability** ▪ Understandable: runs easily ▪ Intuitive: attractive, controlled, input/output ▪ Feedback: clear communication ▪ Documented

Table 2: Evaluation and recommendation of multimedia materials, see (MPTL); joint activities of the EPS-PED group together with the MERLOT-Physics group are marked by an asterisk.

Year	**MPTL meeting**	**Field of physics**	**Number of items**
2008*	XIII Cyprus	Quantum Mechanics	~ 200; report in progress
2007*	XII Wroclaw (Poland)	Condensed Matter Physics, and Particle Physics	~ 100; ~ 10 excellent
2006*	XI Szeged (Hungary)	Electromagnetism	~ 700; 26 excellent
2005*	X Berlin (Germany)	Thermodynamics and Statistical Physics	~ 110; 11 excellent
2004*	IX Graz (Austria)	Mechanics	~ 250; 11 excellent
2003	VIII Prague (Czech Republic)	Optics	~ 200; 5 excellent
2002	VII Parma (Italy)	Quantum Mechanics	~ 30; 4 excellent

Table 3: Summary of the worldwide inventory on remote labs (Gröber et al. 2007).

Year	Total number of remote labs	Free to access *	Worked without problems *	Subjects *
2004	~ 70	~ 70 %	~ 15 %	~ 90 % engineering
2006	~ 120 (~ 60 projects)	~ 20 %	~ 20 %	~ 60-70 % engineering ~ 30 % physics ** < 10 % other disciplines

* In percent of total number.

** Including such remote labs dealing with electronics.

Table 4: List of remote labs which have so far been set-up in the framework of our approach.

Topics of physics curriculum	
▪ Electron Diffraction (wave nature of electrons, example for structure determination by diffraction) ▪ Photoelectric Effect (model of light as particle, determination of Planck's constant and work function) ▪ Millikan's Oil-Drop Experiment (proving and determining elementary charge) ▪ Rutherford's Scattering Experiment (exploring structure of atoms) ▪ Speed of Light (determination by a time-of-flight method) ▪ Fourier Transformation (based on diffraction of light)	▪ Radioactivity (exploring different kinds of radioactive radiation, absorption of radiation, statistical nature of nuclear decay) ▪ Diffraction and Interference of Light (various diffraction objects can be studied systematically), two variants ▪ Voltage-Current Characteristics of Semiconductor Devices (introductory electronics); two variants ▪ Oscilloscope (how does it work, preparation for lab work) ▪ Order-/Disorder (modeling, based on diffraction objects reflecting crystal structure)
Examples for students' project, motivational and lay-people oriented	
▪ Toll System (model with toy train, how does it work, identifying moving vehicles) ▪ Robot in a Maze (playful approach to remote operation) ▪ Wind Tunnel (air friction of different vehicles, impact on gasoline consumption); see Figs. 9-10 ▪ Computed Tomography (how does it work, how to gain 'hidden' information)	▪ 'Hot Wire' Game (hoe to build and to control a robot based on toy construction kit) ▪ 'World Pendulum' (determining the Earth's surface gravitational field strength depending on geographical latitude by means of distributed high-precision pendulums) ▪ Optical Tweezers (moving tiny particles with laser light, introduction to front-edge research)

Table 5: Access rates and usage of some selected RCL experiments. We differentiate visitors and users: number of visits reflects how often the RCL lab was called up; users, on the other hand, are visitors who changed at least one parameter of the experiment.

	Period of tracking	**Visitors per day**	**Fraction of users**	**Averaged time of usage**
Topics of physics curriculum				
Electron Diffraction	Aug – Nov 2006	2.2	-	[1]
	Dec – May 2007	2.6	62 %	[2]
Millikan’s Oil Drop Experiment	Nov 2006	3.2	-	-
	Feb – Apr 2007	3.2	68 % (51%)*	3’ (3’40”)*
	May 2007 [$]	6.3		
Radioactivity	Aug – Nov 2006	1.2	-	-
		2.3	69 %	7’
Diffraction and Interference of Light	Nov 2006	1.8	-	-
	Dec – May 2007	1.3	79 %	[3]
Examples for students’ project, motivational and lay-people oriented				
Wind Tunnel	Aug – Nov 2006	2.5	-	-
	Dec – May 2007	2.4	73 %	[4]
‘Hot Wire’ Game	Aug – Nov 2006	1.1	-	-
	Dec – May 2007	1.5	73 %	3’11”
Resume		1 – 3 visitors per day	60 – 80 % or 1 - 2 users per day	Several minutes working in the lab

[1] About 45 % of the visitors changed the acceleration voltage at least 3 times per visit.

[2] On average the users changed the acceleration voltage 6.1 per visit.

[3] Averaged number of diffraction objects chosen by users was 4.0 per visit.

[4] On average each user has chosen 1.6 vehicles different from the one which is pre-set when entering the laboratory site.

* In parenthesis are given the values which indicate an, in principle, meaningful experimentation.

[$] Due to public announcement (hyperlink at Wikipedia) we could observe a strong increase in visiting this RCL.

Figure Captions

Fig. 1 Evolution of enrollment at the Physics Department of University of Technology Kaiserslautern (Germany), numbers of on-campus students (black bars), off-campus students (white bars). The duration of the FiPS project was from winter term 1998 till summer term 2002; after that this distance course is offered as a matter of routine by the department. Due to federal constraints the numbers of the summer term enrollments are slightly lower than that of the winter term: on average, on-campus students ~35 against ~55, off-campus ~49 against ~90. In consequence, we have more off-campus enrollments than on-campus and at almost constant level per semester.

Fig. 2 Distribution of employment/activity of off-campus students in winter term 2000/01, as an example. The main group are students staying in community (civilian) and military service (~81%), however, the fraction of students in military service (~39% in winter term 1997/98) decreased in favor of students in civilian service and school. Currently, about 27% of the first-semester off-campus students (winter term) are at school (~17%, summer term). A growing fraction of off-campus students has an occupation, is enrolled at another university (study), or is abroad from Germany (now constantly at 10-15%).

Fig. 3 Time line of the distance courses offered by the department of physics and by the department of mathematics at University of Technology Kaiserslautern.

Fig. 4 Part of a typical study guide given once a week to the off-campus students, here as an example on the topic ‘frames of reference’ in mechanics. The whole study guide contains an introductory text about the book chapter, the reading guide organized as a table, and some additional remarks. The first column of the reading guide relates to the chapter of the text book. The second column (‘Hinw.’) contains numbers how deep a topic has to be treated and informs the students about the weight, for example, ranging from 1 (low) to 5 (high). The third column is devoted to the particular physics topic, additional questions and links to multimedia (arrows in 2nd column) are integrated. The last column (‘Zeit’) quotes an averaged time for studying a subchapter in order to facilitate students’ time planning.

Fig. 5 Representative example of problem solving activity (bars) and success (diamond shaped symbols) during one semester off-campus exercises. The grey scale of the bars have the following meaning: a problem with multimedia application (white), standard calculus based physics problem (grey), and problem from the mathematical addition (black). Since there are 4-6 six problems assigned to the students each week and a semester has ca. 13 weeks, in total there are ca. 60 problems per semester.

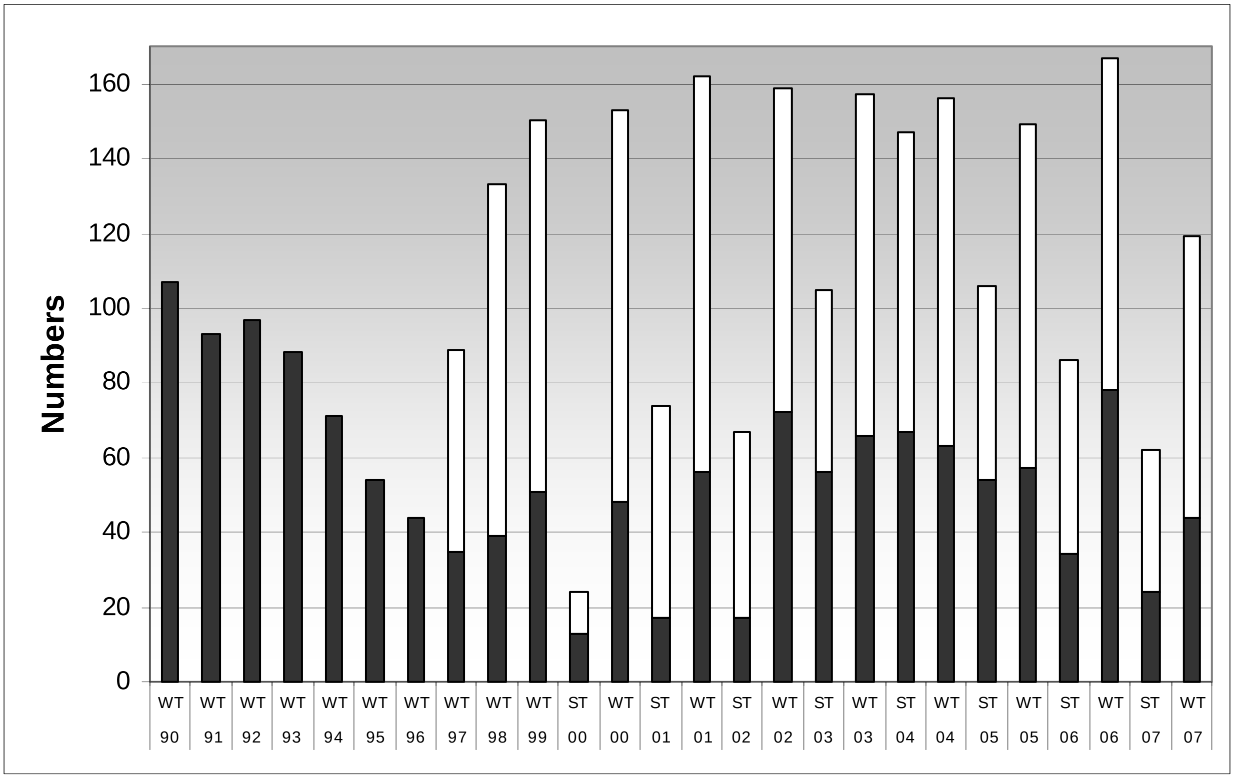
Fig. 6 Setup of the experiment on Coriolis and centrifugal force appearing in a rotating frame of reference. Left: scheme, right: still photo of the real setup (screenshot from the video).

Fig. 7 Trajectories of one and the same ball rolling on the surface of a rotating disc. Left: observation of the movement in the system at rest (laboratory system), right: observation in the rotating, accelerated system (see fig. 6). The dots indicate the position after equidistant time intervals. For details see text.

Fig. 8 Simplified scheme of a remotely controlled laboratory.

Fig. 9 Sketch of the setup of the wind tunnel experiment (left). Three different vehicles can be exerted to an air flow of variable strength. Each vehicle is attached to a strain gauge (only one is shown here for simplicity). The real setup is shown for one toy vehicle in the photograph (right).

Fig. 10 Screenshot of the laboratory website of the remote wind tunnel experiment. On the left the navigation menu can be seen which is organized like typical lab course exercises. On the right there are the control buttons of the experiment. In between the streaming video shows which of the three vehicles is currently placed in the wind tunnel as well as the relevant values of the wind speed and the voltage of the of the strain gauge.



Numbers
0
20
40
60
80
100
120
140
160
WT 90
WT 91
WT 92
WT 93
WT 94
WT 95
WT 96
WT 97
WT 98
WT 99
ST 00
WT 00
ST 01
WT 01
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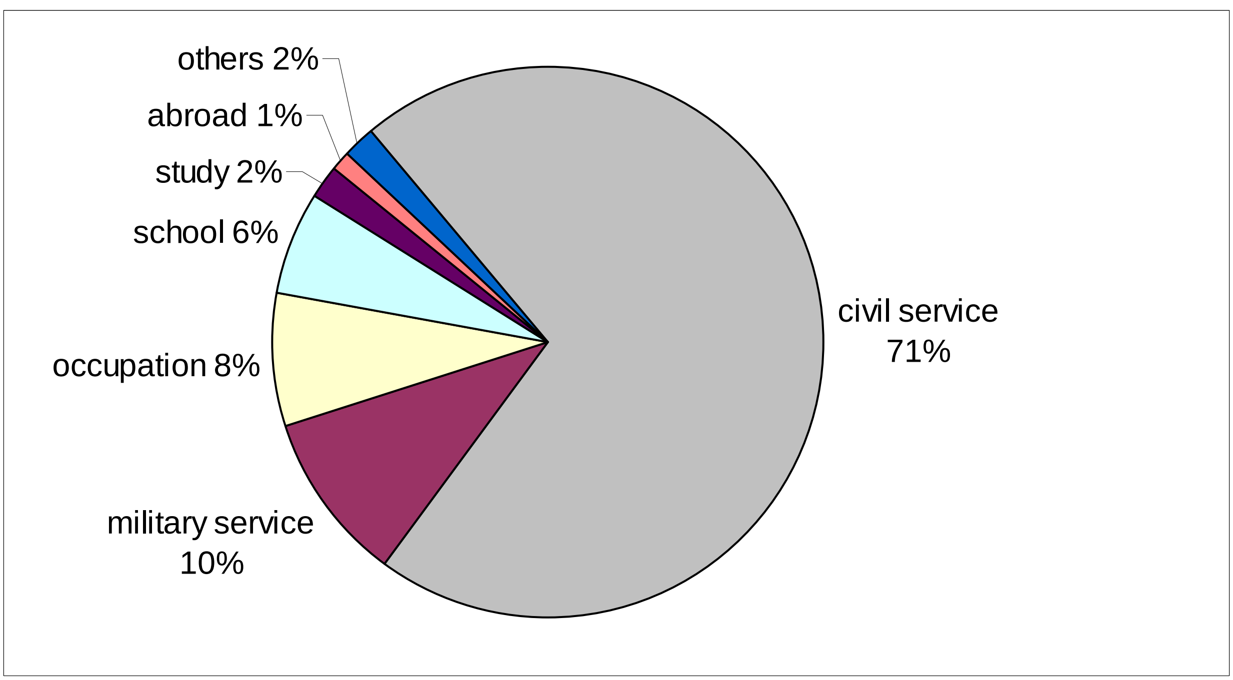
WT 02
ST 03
WT 03
ST 04
WT 04
ST 05
WT 05
ST 06
WT 06
ST 07
WT 07

Fig. 1



others 2%
abroad 1%
study 2%
school 6%
occupation 8%
military service 10%
civil service 71%

Fig. 2

First semester	**Second semester**	**Third semester**	**higher**
▪ Experimental Physics I (Mechanics, Thermodynamics) ▪ Mathematical additions I	▪ Experimental Physics II (Electrodynamics, Optics) ▪ Mathematical additions II	▪ Experimental Physics III (Introductory Quantum Physics) ▪ Theoretical Physics (Classical Mechanics)	
▪ Mathematics for physics students I	▪ Mathematics for physics students II	▪ Analysis	
Off-campus (FiPS)		**On-campus**	

Fig. 3

Kap.	Hinw.	Physik	Seite	Zeit
3		**Bewegte Bezugssysteme**	83	**2h45'**
	➔	**Video:** Galaktische Bezugssysteme		□
3.1	❹	**Relativbewegung**	83	**5'**
		Im Hinblick auf Kap. 3.5: *Wo wird hier "naiv" vorausgesetzt, dass die Zeit in A genauso vergeht wie in 0 und dass B, vom bewegten A aus gesehen, genauso weit weg ist, wie man es von 0 aus misst?*	83	
3.2	❺	**Inertialsysteme und Galilei-Transformation**	83	**10'**
	⇨	**IBE:** Planetenbewegung *Machen Sie im Sonnensystem einen Bezugssystemwechsel und erklären Sie die Bahn des Mars am Firmament.*		
	➔	**Video:** Intertial- und Nichtinertialsysteme		□
		(Abb. 3.2.) *Machen Sie sich die Galilei-Transformation Glg. 3.7. möglichst anschaulich klar und suchen Sie experimentelle Belege auch für ihre scheinbar selbstverständlichen Aussagen. (... schließlich ist sie ja nicht 100% zutreffend! - s. Kap. 3.4...)*	84	□
	➔	**Anmerkung 1:** Inertialsysteme (s.u.)	84	□
		Kann ein rotierendes Bezugssystem ein Inertialsystem sein? (Antwort: "Das kommt darauf an, ob...")	84	□
	➔	**Applet:** Planetenbewegung		□
3.3	❸	**Trägheitskräfte**	85	**50'**
	⌫	(Abb. 3.4.) Im Kasten: t = t' statt 1 = 1'	85	
		(Abb. 3.4.) *Formulieren Sie analoge Gleichungen zu Glg. 3.7.*	85	□
		(Abb. 3.6.) *Aus welchen Kräften ergibt sich die Beschleunigung in a) und b) jeweils für mitbewegte und außenstehende Beobachter?*	86	□
	⇨	**Anmerkung:** In der klassischen Newton'schen Theorie ist ein frei fallender Fahrstuhl kein Inertialsystem, denn Schwerkraft und Scheinkraft gleichen sich nur "zufällig" genau [...]	86	□
		[...]		

Fig. 4

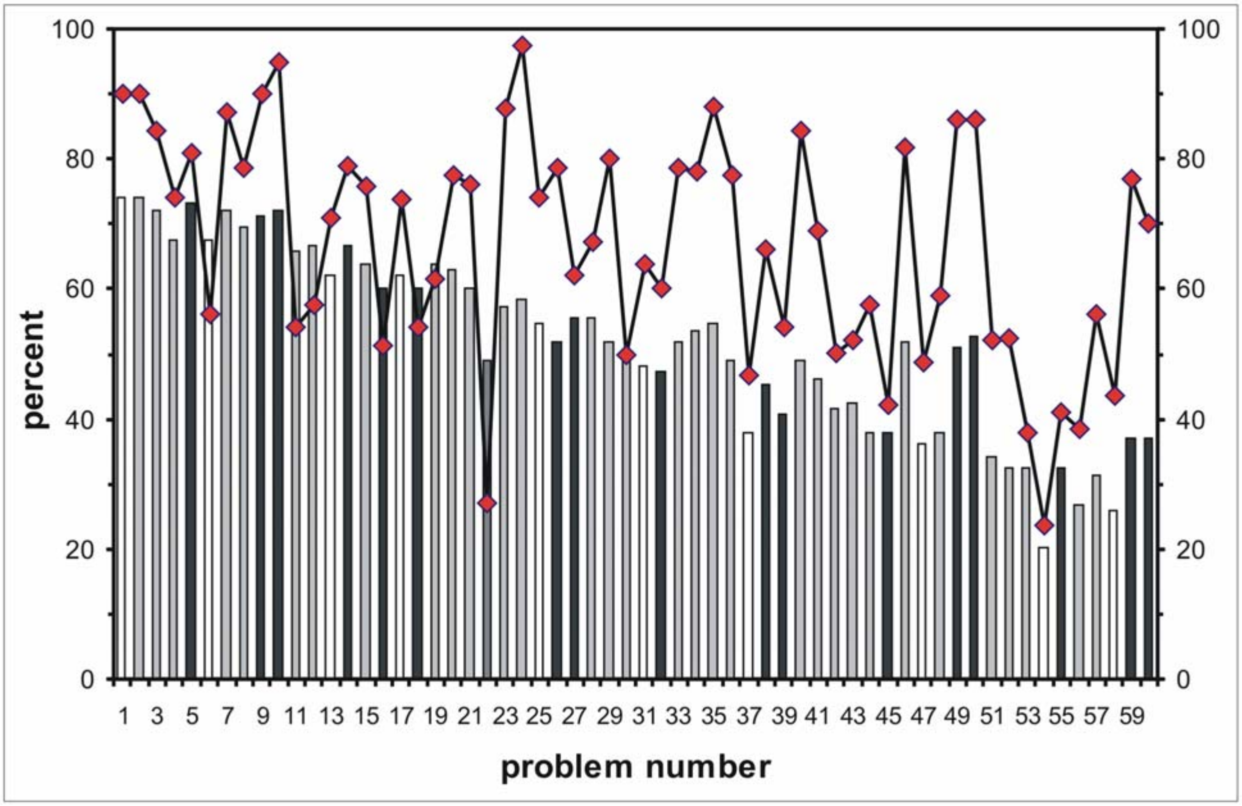

100
80
60
40
20
0
percent
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
problem number

Fig. 5

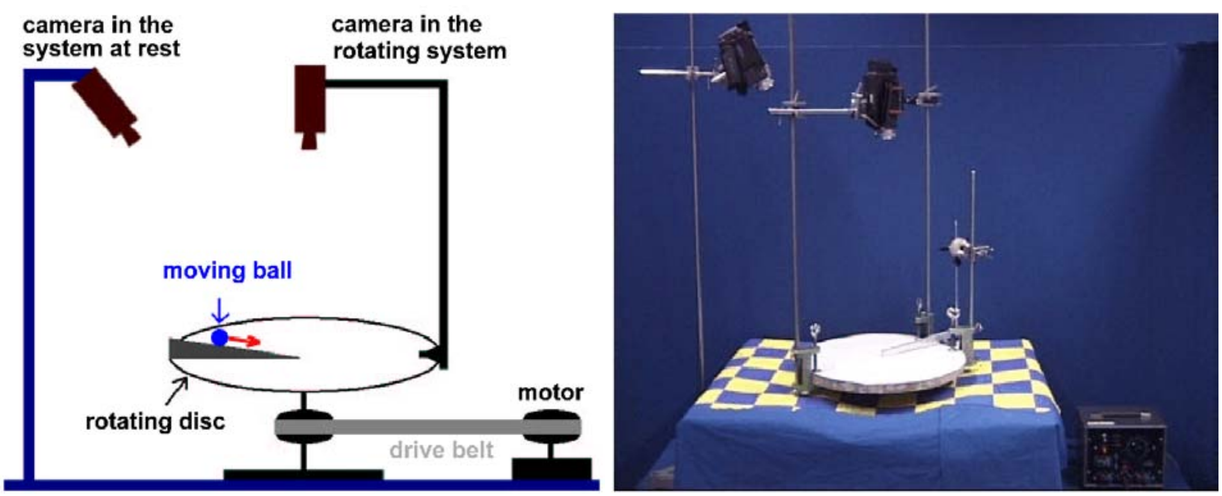

camera in the system at rest
camera in the rotating system
moving ball
rotating disc
motor
drive belt

Fig. 6

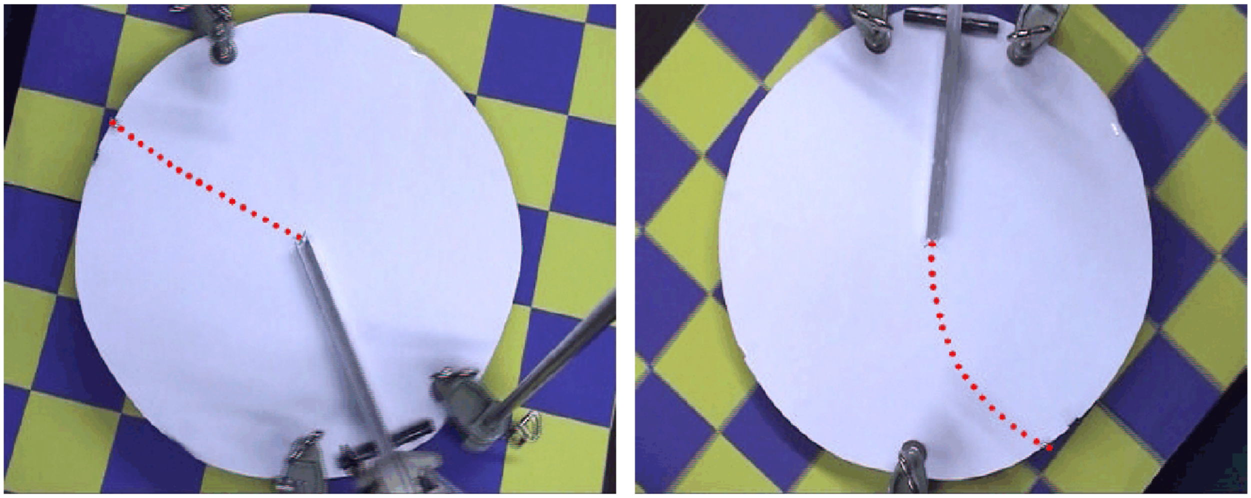


Fig. 7

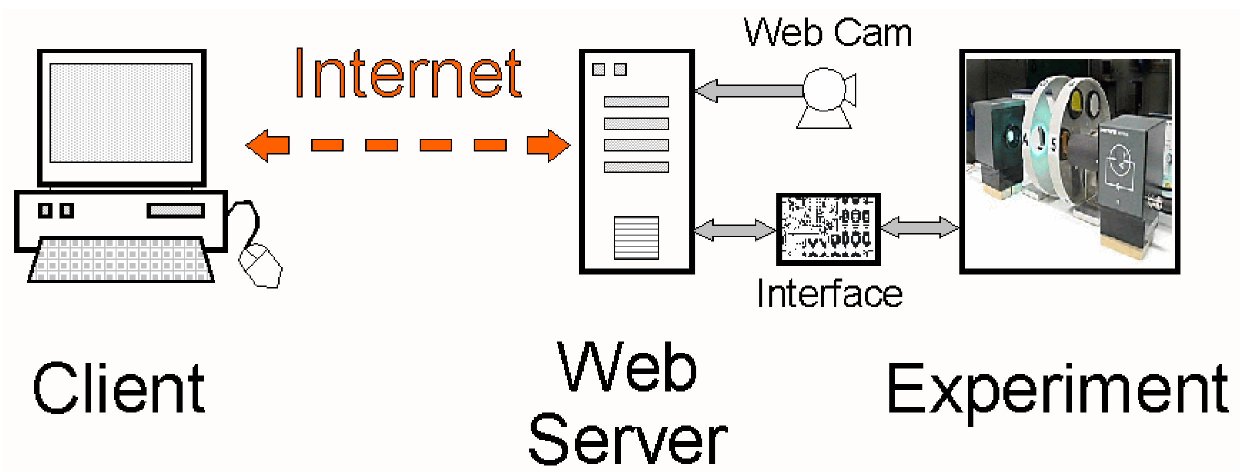


Fig. 8

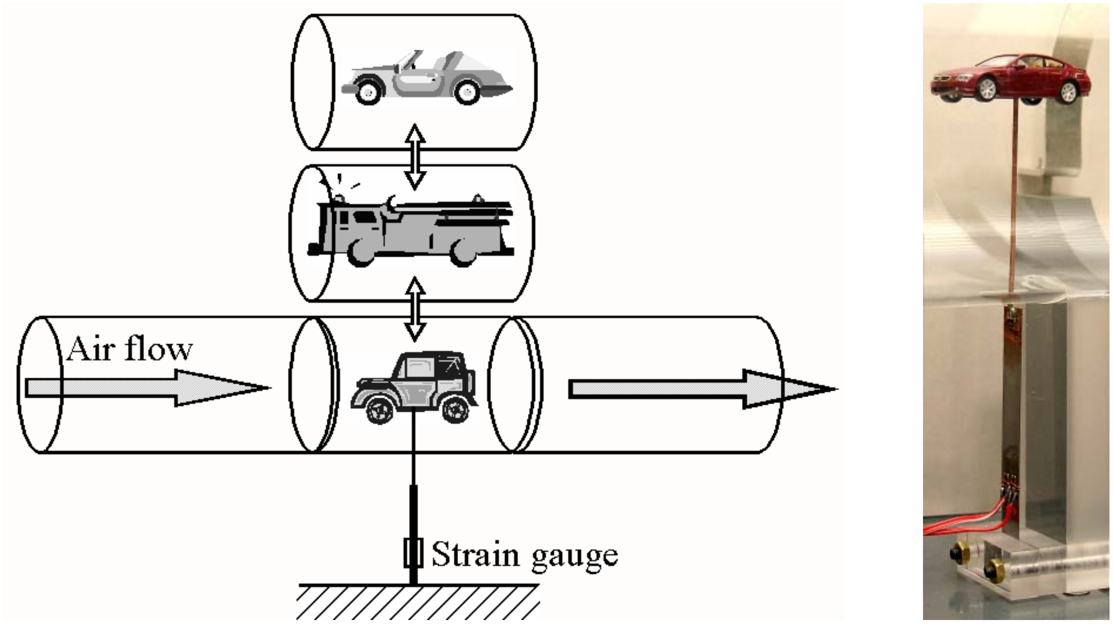

Air flow
Strain gauge

Fig. 9

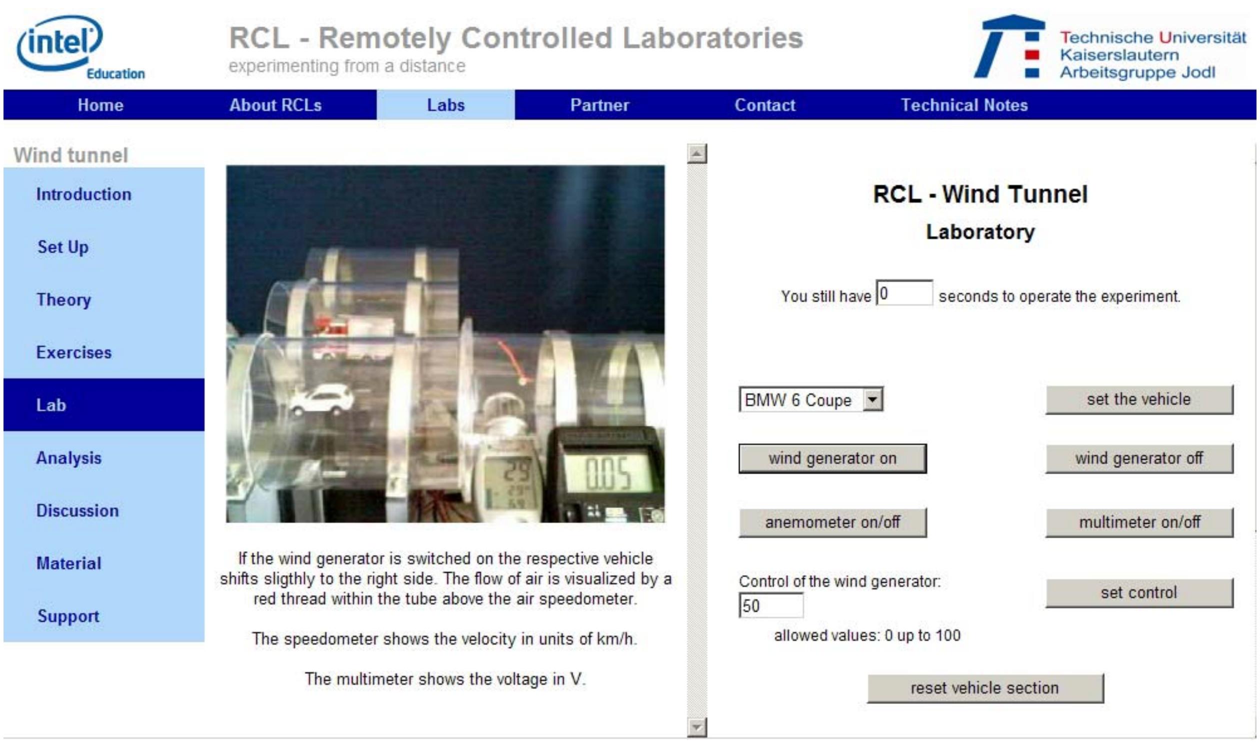

intel
Education
RCL - Remotely Controlled Laboratories
experimenting from a distance
Technische Universität
Kaiserslautern
Arbeitsgruppe Jodl
Home
About RCLs
Labs
Partner
Contact
Technical Notes
Wind tunnel
Introduction
Set Up
Theory
Exercises
Lab
Analysis
Discussion
Material
Support
If the wind generator is switched on the respective vehicle shifts sligthly to the right side. The flow of air is visualized by a red thread within the tube above the air speedometer.
The speedometer shows the velocity in units of km/h.
The multimeter shows the voltage in V.
RCL - Wind Tunnel
Laboratory
You still have 0 seconds to operate the experiment.
BMW 6 Coupe
set the vehicle
wind generator on
wind generator off
anemometer on/off
multimeter on/off
Control of the wind generator:
50
set control
allowed values: 0 up to 100
reset vehicle section

Fig. 10