An E-Learning Strategy in Academic Physics Education[1]

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Abstract: The e-learning strategy of the Faculty of Physics at the University of Vienna – developed and implemented since 2005 – is described, and experiences are reported. The strategy relies on a combination of concepts and approaches, due to the diversity of course types and learning needs. Its primary goals are the homogenisation of beginners' competencies and the enhancement of students' success, the guiding principles being free accessibility to electronic learning material, collaborative students work and the use of state of the art computer techniques.

1. The project *eLearnPhysik* and its goals: Overview

Physics education at universities usually is confronted with number of problems. The most severe challenge is provided by the diversity of students regarding their pre-knowledge and pre-competencies. In this respect, the Faculty of Physics at the University of Vienna is no exception:

- There is a considerable variation in the knowledge brought along by the students from their previous education in secondary school.
- A significant portion of students have problems comprehending physical (and mathematical) concepts and notions, structures and interrelations, and operating with them.
- The possibilities provided by scientific software (like computer algebra, visualisation tools and electronic measurement data acquisition) played a minor role in physics education for a long time, even after these techniques became part of the scientific state of the art.
- A further challenge is provided by the simple fact that most students heading to become teachers will be confronted with e-learning activities in their professional future.

Since 2005, the Faculty of Physics is developing and implementing an e-learning strategy whose primary goal is to improve on these issues and to support the students' learning process in a number of respects:

- The main focus of the project lies on the support of students during their first one or two years.
- Electronic learning material of various types is developed and provided (content strategy).
- The responsibility of the students for their learning process is strengthened by enhancing the level of their personal activities and their collaboration.
- Learning scenarios are optimised, and methods of blended learning are integrated stepwise into the courses.

These activities run under the name *eLearnPhysik*. Formally, *eLearnPhysik* is a three-year strategic project of the Faculty of Physics, supported by the rectorate of the University of Vienna. It was applied and accepted in 2005 and will run until January 2009. Thereafter, e-learning shall become part of the "regular" lecturing activities at the Faculty of Physics.

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During the first phase of the project, in spring 2006, some basic concepts were designed by a relatively small project team of three (meanwhile six) persons, including the "e-learning co-ordinator" of the Faculty (a position installed at most of the Faculties at the University of Vienna). In order to incorporate a variety of courses which are all characterised by different conditions and constraints, goals and traditions, appropriate methods were adapted in individual co-operation with the respective lecturers. The main focus was on the "big" introductory courses the students have to attend during their first year, in which they learn the basic concepts of physics, mathematical methods and experimental techniques necessary for the more specialised courses that will follow in the subsequent years. A number of lecturers were convinced to introduce elements of e-learning into their courses as supplementary activities, mainly on a voluntary basis for the students. This approach may seem limited in scope, but it had the advantage of covering a substantial part of the learning activities of the beginners. Furthermore, a team of advanced students assigned to act as "e-tutors" was incorporated in the process and trained to work with the electronic tools chosen to be used. Finally, a "student e-learning representative" was assigned in order to bring in the undergraduate students' point of view.

In winter term 2006/7, the first implementation of e-learning started. The methods and scenarios are described in the next section. Since then (including the summer term 2008), a total number of 69 courses was incorporated into the project in one or the other way, giving approximately 400 students the possibility to participate in electronically supported forms of learning.

In the course of an internal re-organisation of the Faculty of Physics, the e-learning project team was assigned to be part of the research group *Physics Education and eLearning*, which illustrates that e-learning is seen as an educational rather than a technical issue.

Co-operations took place with the university's central service units (the *Center for Teaching and Learning*, the *Vienna University Computer Service* – ZID, and the project *Permanent Hosting, Archiving and Indexing of Digital Resources and Assets* – PHAIDRA) as well as with the Faculty of Mathematics, the Faculty of Computer Science, the Institute of Astronomy and the University of Düsseldorf.

The complete and detailed documentation (Embacher e*t al* 2007, Embacher *et al* 2008, Embacher *et al* 2007b) of the project as well as all material produced is available online (in German language), the relevant addresses are:

- http://physics.univie.ac.at/eLearning/eLearnPhysik/ (documentation)
- http://physics.univie.ac.at/studium/ (students' entry)
- http://www.univie.ac.at/physikwiki/ (Wiki of the Faculty of Physics).

Last but not least, the project *eLearnPhysik* received the *Bank Austria* award for innovative academic education in 2007.

2. Implementation

Due to the variety of involved course types and learning needs, e-learning at the Faculty of Physics is a combination of different methods and scenarios. Here we give a brief description of the most important issues. The results of the preliminary evaluation and experiences are summarised in the subsequent section.

a.) The Content Strategy and its Implementation

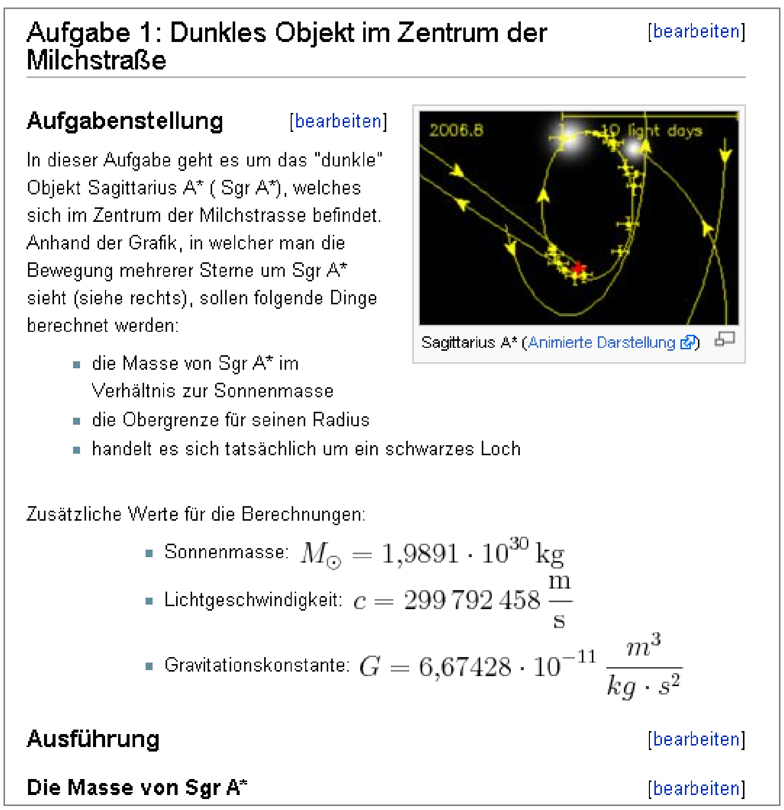
A particular challenge the project has to face is how to design and organise digital learning material and how to give students access to it. Beside the "official" learning material provided by the academic staff there is a lot of material written by students. In addition, in the framework of the project, a variety of new electronic content was generated by lecturers as well as students, ranging from supplementary visualisations (videos of demonstration experiments), a complete e-learning environment for the physics lab, further supplementary learning material like texts and visualisations of physical issues (mostly written by e-tutors), computer algebra notebooks as well as the documentation of students' work.

Due to the principal decision that all material should be freely accessible at the web, most of the content was stored and provided (much of it also written) on the platform *Wiki of the Faculty of Physics*. This platform is based on the software *MediaWiki*. By adapting and extending its base with regard to didactical and organisational needs (central login for lecturers and students, access management, support for *LaTeX* – a tool enabling the *Wiki* to display mathematical symbols and formulae – and the computer algebra system *Axiom*), the *Wiki of the Faculty* has been established as a major e-learning tool. Most of the material contained therein is published under the Creative Commons License.

During the past years, the Faculty of Physics acted as a pilot partner in the development process of a university-wide content strategy matching the Faculty's needs. In April 2008 the digital library system PHAIDRA (the acronym for *Permanent Hosting, Archiving and Indexing of Digital Resources and Assets*) became available. Since then, part of the *eLearnPhysik* content was transferred to this system.

b.) Collaborative Student Work

In order to enhance the learning process in terms of modern pedagogical methods, collaboration between students is encouraged in a number of courses and implemented in a systematic way in some of them. The background of this action is the growing importance of learning groups. Thus, students are encouraged to form learning groups from the very beginning of their study.


Aufgabe 1: Dunkles Objekt im Zentrum der Milchstraße [bearbeiten]

Aufgabenstellung [bearbeiten]

In dieser Aufgabe geht es um das "dunkle" Objekt Sagittarius A* (Sgr A*), welches sich im Zentrum der Milchstrasse befindet. Anhand der Grafik, in welcher man die Bewegung mehrerer Sterne um Sgr A* sieht (siehe rechts), sollen folgende Dinge berechnet werden:

- die Masse von Sgr A* im Verhältnis zur Sonnenmasse
- die Obergrenze für seinen Radius
- handelt es sich tatsächlich um ein schwarzes Loch

Zusätzliche Werte für die Berechnungen:

- Sonnenmasse: $M_\odot = 1{,}9891 \cdot 10^{30}\,\mathrm{kg}$
- Lichtgeschwindigkeit: $c = 299\,792\,458\,\frac{\mathrm{m}}{\mathrm{s}}$
- Gravitationskonstante: $G = 6{,}67428 \cdot 10^{-11}\,\frac{m^3}{kg \cdot s^2}$

Ausführung [bearbeiten]

Die Masse von Sgr A* [bearbeiten]

Figure 1: Best practice example for collaborative student work.

The most advanced scenario is a combination of collaborative work in small groups (with 3 or 4 members) with a presentation of the results in the *Wiki of the Faculty of Physics*. Three impressive best practice examples are https://elearning.mat.univie.ac.at/physikwiki/index.php/LV014:LV-Uebersicht/WS07_08/Arbeitsbereiche/Keplerproblem, https://elearning.mat.univie.ac.at/physikwiki/images/b/b8/Phasenport.pdf and https://elearning.mat.univie.ac.at/physikwiki/index.php/LV017:LV-Uebersicht/SS08/Arbeitsbereiche/Galaxien/Gruppe2 (see Figure 1).

Although a voluntary offer in some courses, most of the students in these courses participate in this sort of activities and are ready to spend some extra time on them.

c.) E-learning in the Physics Lab

The introductory physics lab courses – mandatory for physics students as well as for nutrition scientists – were largely reconstructed. Under the address http://www.univie.ac.at/anfpra/, a new learning environment including content based e-learning sequences was developed and systematically implemented into 4 lab courses for more than 40 course-days (90 experiments). This provides a major chance for students to improve their understanding of technical terms and physical contexts even if they are lacking previous knowledge. The learner centered environment also provides a constructivist way to homogenise students' different pre-concepts arising from different educational backgrounds. The evaluation of this part of the project was accomplished in terms of a case study using qualitative social research methods. The methods and results of the reconstruction of the physics lab were communicated in a number of events (Gorgas & Nagel 2006, Gorgas & Nagel 2006b, Nagel 2008).

Furthermore, in the framework of a co-operation with the University of Düsseldorf, the "physics lab for nutrition scientists" is about to be newly designed, with special emphasis to the nutritionists' specific educational needs.

In addition, the physics lab has been modernised with respect to computed aided acquisition and procession of data gained in physical experiments, which is a key technique in research, and becomes increasingly important for physics teaching in school.

d.) Integration of Computer Algebra

The use of computer algebra (which helps solving all sorts of mathematical problems and draws graphs of all kinds) has become state of the art in physics research within the last two decades (see Figure 2). In order to integrate techniques based on this powerful class of software into the students' learning process, a comparably low priced campus licence of *Wolfram's Mathematica* (see http://www.wolfram.com/) is offered to all students by the University Vienna Computer Service (ZID) since 2006.

This opened the possibility for lecturers to use *Mathematica* in their presentations, and for students to resort on it when solving problems in courses (in general on a voluntary basis, with a few exceptions) and at home, whenever reasonable. In a number of courses, the use of *Mathematica* is combined with collaborative students work and presentation of the results on the *Wiki of the Faculty of Physics*.

e.) E-Learning in Student Teacher Education

In addition to the general motivations for integrating elements of e-learning into the course system at the Faculty of Physics, student teacher education has some specific goals. In the second half of their study, students are prepared for their future profession as physics teachers. In this respect, the work with e-learning platforms and related systems and the ability to organise learning processes using electronic tools play an important role. The main focus is on the methodical work with a number of systems, combining the use of "new media" with the "new culture of learning". In this sense, e-learning as a new way of teaching requires new methodical approaches in experimental work, conceptual understanding and soft skills like communication or management of knowledge.

In the respective courses, students learn the handling, advantages and disadvantages of systems like *MediaWiki*, the *BSCW* Shared Workspace System and the *Moodle* platform. While *MediaWiki* is used since the beginning of the study (see above), some emphasis is laid on *BSCW* (used for big data transfer and evaluation by online-questionnaires) and *Moodle* (which runs in many schools and is used as information, communication and organisation platform).

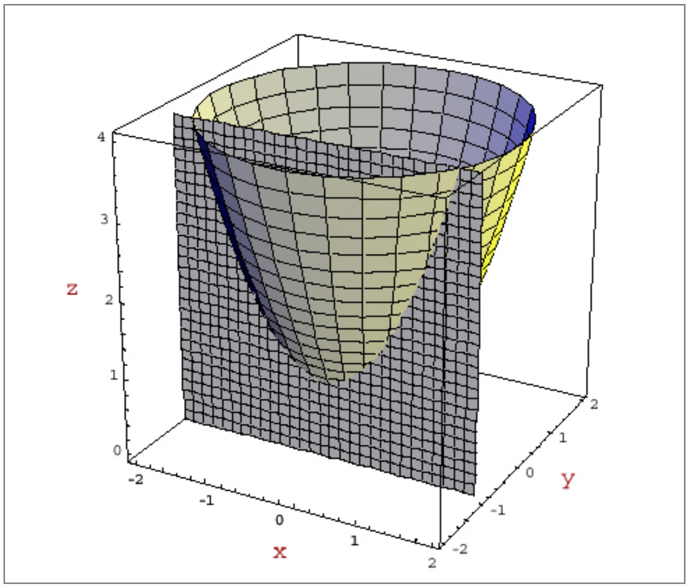


Figure 2: Computer algebra is an invaluable tool in modern physics.

f.) University-wide E-learning Platform

Since 2004, the University of Vienna provides the e-learning platform (learning management system) *WebCT Vista* (now *Blackboard Vista*) to all its lecturers and students. Although considerable effort has been made to integrate it into the course system, a number of shortcomings limit its use, some of them particularly for applications in the fields of the natural sciences:

- The closedness of the system (access to content is restricted to students attending a course) stands contrary to the principle decision to give *all* students access to *all* learning material.
- Mathematical symbols and formulae (as used in physics) are supported only rudimentarily, and work-arounds are complicated.
- Students frequently report technical problems when uploading documents.

For these reasons, the *Wiki of the Faculty of Physics* has become the major e-learning tool, while the "official" platform is used only occasionally for organisational needs. Difficulties of this type (which are experienced also by other Faculties) will be taken into account by the University when implementing a follow-up system in 2009.

g.) Supplementary actions

In addition to the main project activities, some supplementary actions were taken:

- Important parts of the project's infrastructure are regular meetings of the project team and the e-tutors in order to exchange information and experiences. The e-tutors and the student members of the project team showed considerable efficiency in self-organisation.
- The academic staff was offered some qualification actions. For several reasons, the acceptance was behind the expectations. As a consequence, the system of e-tutors supporting the staff with their knowledge has become crucial for the project (and will continue to be crucial for the post project phase).

- In 2007, the architecture of physics studies at the University of Vienna has changed from *diploma* to *bachelor* and *master*. E-learning methods and competencies have been integrated into the new curricula to some extent.

Let us finally mention that the technical infrastructure of the Faculty (IT equipment in lecture halls, PC labs for students and WLAN) has been steadily improved during the project period.

3. Result of Preliminary Evaluations and Experiences

The general IT boundary conditions provided absolutely no problem for the project *eLearnPhysik*:

- The problems with IT and IT related skills reported by students are significantly decreasing in importance. The current generations of beginners is either well-experienced in computer handling or ready to acquire the necessary competencies quite quickly.
- Thanks to the technical infrastructure of the University and the Faculty, access to computer and the web were no issues of importance.
- Antiquated software (web browsers and Java versions) on the students' private PCs – mainly in connection with the University's e-learning platform – sometimes caused frustration.

Concerning the preliminary evaluation of the project's actions, the evaluation was based on quantitative access statistics (log file analysis), feedback of the students by quantitative questionnaires, qualitative interviews and qualitative questionnaires, and personal communication of the project team with the teaching staff.

The most important results were found to be:

- Both student collaboration and online-publishing of results in the *Wiki* is found helpful by the students. According to their feedback, these activities enhance the learning motivation and strengthen the feeling of responsibility for their work.
- Although the participation in the collaborative work activities was voluntarily and afforded some extra time, nearly all of the students took part.
- A critical factor enhancing the disposition of the students to participate in extra activities was the inclusion of corresponding topics and techniques in regular courses. In particular, when computer algebra was integrated into the face-to-face presentation just a few minutes every lecture, the students were far more ready to use this software for problem solving by their own as compared to traditional lectures. Participation in collaborative work activities seemed to be stimulated when the formation of the learning groups was performed *within* the regular lecture and organised by the lecturer.
- Concerning the optimal size of the working groups, the students found that small groups (of about three persons) were preferable over larger groups.
- Collaborative work activities took place in some courses. However, students not involved in these, did *not* spontaneously develop learning groups. In other words, the building of learning groups was tied to initiative and stimulation by lecturers in particular situations. In total, after the first year of their study, two thirds of the students still learned alone (see Figure 3).

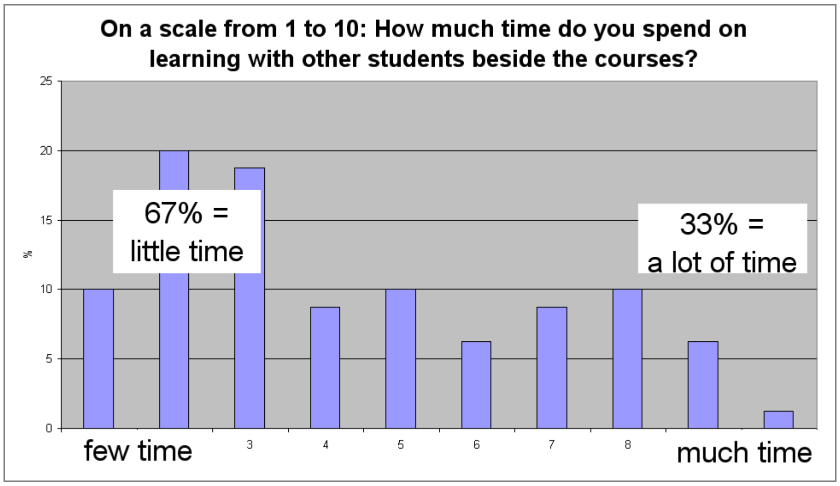


Figure 3: Still, two thirds of the students learn on their own.

- Due to their close and daily contact to each other and to their lecturers, the students hardly used web based discussion forums. They prefer posing questions and discussing scientific problems in face-to-face situations. On the one hand, students prefer to receive answers immediately, without the delay characteristic for asynchronous communication. On the other hand, a crucial factor responsible for this preference seems to be a lacking ability to express themselves sufficiently concise in written form.
- Concerning the use of computer algebra in problem solving, approximately one third of the students is enthusiastic, a third uses computer algebra when they feel it helps doing some work, and a third uses it only when compulsory.

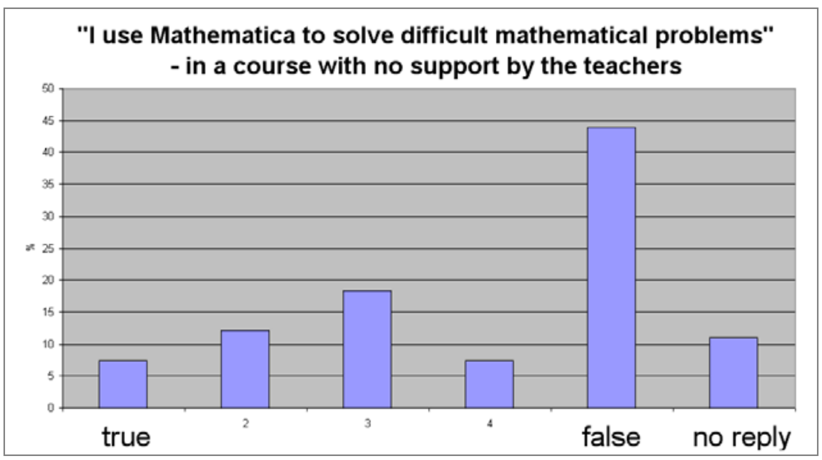


Figure 4: Usage of *Mathematica* in courses with no support by the staff.

Implementing computer algebra as accompanying tool from the very beginning of their study seemed to be essential for the dynamics of this process: It allowed students to become familiar with a major state of the art technique, and guaranteed some space for repetition and deepening of its use and application to simple physical problems. Furthermore, it was useful for enhancing the students' understanding of the role of mathematical techniques in physics. (In particular, the version *Mathematica 6* contains features allowing to implement novel types of visualisation and interactivity in an easy way and is thus well-suited to support understanding of mathematical structures).

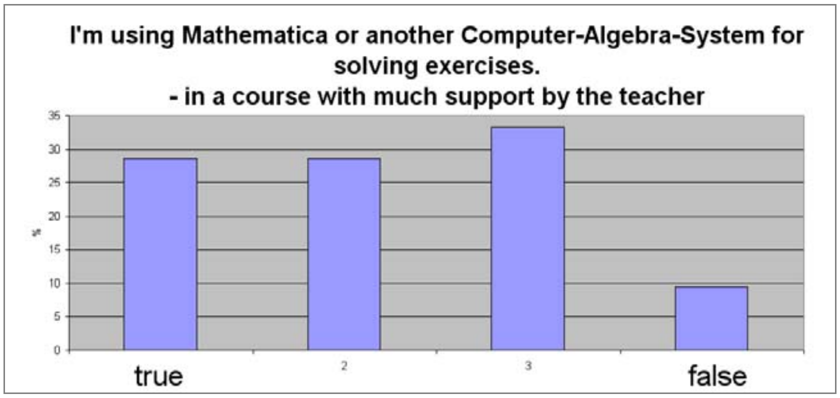


Figure 5: Usage of *Mathematica* in courses with much support by the staff.

- The supplementary content provided in the framework of the project was used by approximately one third of the students. It was no surprise that several weeks ahead of the main examinations the access frequency to the respective web pages increased significantly.
- Students involved in the collaborative work activities used the *Wiki* and the supplementary material more frequently than the others. Since both activities (participation in working groups and the use of supplementary material) were voluntary, and were offered independent of each other, this might indicate some correlation between the readiness of students to join a working group and the readiness of students to use web based content when learning for examinations. On the other hand, students involved in collaboration activities – which in most cases required publishing of the results in the *Wiki* – were familiar with the project web site, navigation issues, web addresses and the like, which certainly reduced pre-existing barriers or occasional lack of skills.
- Furthermore, not surprisingly, the close integration of the material into the courses is one of the most important variables for usage. Digital content produced for the "big" introductory courses was used quite often, due to the fact that these materials *directly* refer to the course activities and learning needs.
- In some courses, the possibility to discuss physical issues in a *Wiki* based forum and to contribute individual solutions to problems posed was offered to the students. The access rates to the according pages were quite high, although only few students actively provided contributions.
- The activities of the e-tutors were essential for the project. Almost all e-learning scenarios have been supported by them. In addition, a big portion of the material production is based on their work. In addition, the benefit of the e-tutors for their own understanding of learning processes was considerable.
- In the physics lab, the supervising tutors reported an improvement of the students' preparation due to the usage of the e-leaning environment provided.
- The implementation of e-learning arrangements in student teacher education was quite exemplary. Parts of the courses took place in the platforms used, and the activities were part of the grading. Students found the acquisition of school-related platforms and different methods of using these platforms as a good preparation for lesson practice.
- The *Wiki of the Faculty of Physics* provided all essential tools for the implementation of e-learning within the project. It turned out that the advantages of using a MediaWiki compared to the university-wide e-learning platform are the following:

    - The Wiki may be in a mode that enables all users (the "world") general reading access. Only users who want to actively contribute (i.e. need a writing access) need to login.
    - The *Wiki* can be adapted to specific needs of the project due to the fact that it is *open source software*. An important adaptation is for example a connection to the central data base of the University of Vienna to enable access of users *independent* of their participation in specific courses.
    - Working with formulas and mathematics is quite easy in *MediaWiki*. *MediaWiki* offers a LaTeX extension for displaying mathematical expressions, a *GNU-Plot* extension for plotting mathematical graphs and a compute algebra-extension for calculations called *axiom*. New extensions are constantly released, without any costs for the project.

- *MediaWiki* as an interactive web based software application is designed for collaborative work. Both the collaborative student work and the creation of supplementary material benefit from this application.
- The syntax is (almost) self explanatory and easy to learn. After their first *Wiki* activities, students generally didn't have problems applying the necessary syntax.

None of these findings, when considered individually, is particularly surprising. However, the project evaluation as worked out so far, provides an overall picture of the *relative* importance of the results. The most important factor critical to the success of e-learning under the conditions described seems to be the *participation of the lecturers* in the process of organising the students' activities. In this respect, the traditional separation of course types into "lectures" (without significant student activity) and "exercises" (in which students present their solutions to problems posed) is not very helpful. A second point of major importance seems to be the active involvement of e-tutors firmly rooted in the subject of profession (physics).

A final evaluation of the project will be performed and worked during its last months. The results will be available in winter 2008 at the project documentation web page.

4. Outlook

The project *eLearnPhysik* officially ends in January 2009. Thereafter, the e-learning activities and methods developed shall become part of the regular course system.

The project evaluation as worked out so far basically relies on feedback by the students and personal experience made by lecturers and e-tutors. Subjects for a long-term evaluation will be the effects of using computer algebra for beginners and the impact of e-learning activities on the students' learning culture. In particular, still too many students are learning and studying on their own (see Figure 3)! Maybe new methods stimulating group building processes must be invented.

Finally, a study of the impact of e-learning (or rather: of various e-learning scenarios) on the *actual* learning success of students, e.g. their understanding of physical concepts, is much more difficult to accomplish. However, in the long range, evaluations of this more sophisticated type will be a crucial factor in the further development of e-learning.

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Figure 6: The *eLearnPhysik* web page.