Development and Evaluation of an Activity- and Tutorial-Based Learning System for Students in Modern Physics at the University of Munich

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Abstract

Most of the time university lectures do not show success and effectiveness given the time that students spend learning. Therefore to remedy these and other defects at the Ludwig-Maximilians-University of Munich an activity-based learning-system for the introduction of Modern Physics has been designed. During the development cycles it has been tested and improved continually.
During the lessons the students work alone or with a partner on a multimedia enriched text, on problem solving and on interactive experiments. So the lecturer's primary responsibility is to organize the lecture and to act as an advising tutor. Most of the participating students will become teachers for secondary school (grades 5-10). The learning-system is used in a lecture called "Physics of Matter" which spans two semesters each with 6 hours per week. The learning-system has been evaluated using a comparative design.
The empirical research regarding knowledge gain, concept development and attitudes show the following results: The students achieve a definitely higher learning success than in traditional lectures. The learning time during the lesson is sufficient – additional homework is not necessary. The students enjoy the climate in the class.

Reasons for the Learning System

The development of the Learning System at the University of Munich started with the following question:
How could students' work during a typical lecture be characterized?
An interview study, showed the following results:

- During a traditional lecture students are occupied by transferring information on the chalkboard
- Gaining knowledge takes place after the end of lectures, i. e. at home.
- Students invest in no regular out-of-class studying but start intense learning shortly before the exams.

To increase the lessons' effectiveness the Learning-System has been developed. The priority of that system is to support the endeavor of students as well as self-controlled learning behavior. A supporting climate of maintaining higher skills of learning should be generated as well.

Particular Characteristics

During the lesson the participating students work within the Learning-System in an individual way or in peer groups on a multimedia enriched text, on problem solving and on interactive experiments. So, the lecturer's primary responsibility is to organize the lecture and to act as an advising tutor.

That course is addressed to students of physics as a subsidiary subject and to students who will become teachers for secondary school (grades 5-10). The Learning-System is used in a lecture called "Physics of Matter" which spans two semesters each with 6 hours per week (in a traditional way four lessons per week as a lecture, and the residual two lessons as practice). The lecture introduces Modern Physics including quantum physics and particle physics with the theory of relativity in the first semester. The second semester includes nuclear physics and solid-state physics.

Particular characteristics of the Learning-System are:

- Active learning supported by the tutor
- Learning with multimedia
- Cooperative learning

The students achieve knowledge during the lessons by reading, discussing and working on problem solving. The tutor gives support to the students. With interactive multimedia elements the student's activity will be increased.

Cooperative behavior will be supported to maximize the success of learning. By cooperative learning the students will be motivated by belonging to a cooperative group [Burge, Rogerts 1993] as well as by processing of content of teaching [Dansereau 1988].

Elements

The elements, which are included into the Learning-System, are:

- short lectures
- basic texts
- controlling questions
- exercises
- a web-based course with multimedia elements

The short lectures include tutorial briefings, summing-ups and introduction of discussions. The students read the basic texts during their lessons in an adequate time frame. After that they try to solve the key questions, which are questions taken from the text. This happens in groups. The exercises are worked on and discussed at present, contrary to a traditional lecture, in which the exercises must be worked on as homework.

The web-based course follows the chapters of the basic texts. It contains integrated multimedia-elements like java-applet-experiments and

animations. The experiments are performed in group work and the results are discussed together with all members of the class.
The materials have been developed during the past three years, especially for participants of the course “Physics of Matter”, tested in the class, evaluated by the participants and also improved continually in every cycle of evaluation.
You will be able to find the whole original course at the webpage:
http://www.cip.physik.uni-muenchen.de/~traupel

Design of Evaluation

Two criteria of the evaluation needed to verify the learning-efficiency [Issing, Klimsa 2002] are:

- the acquired knowledge
- the students’ acceptance.

The data had been recorded by
- learning tests
- interviews
- questionnaires.

The efficiency of the new method of teaching was tested by a comparative design between the traditional education and the Learning-System. The comparative design includes the comparison within
- a group of students (various subjects)
- a subject (different groups).

The results are shown in Table 1.
The participants of 2004th summer semester had been taught by a lecture at first and after that by the Learning-System. This structure gets along with contents, because two subjects are taught during the summer semester: quantum physics at first and particle physics after it. A learning test after every stage assesses the gain of knowledge.

This kind of comparison within a group having different subjects is not adequate. Maybe particle physics had been easier to the students than quantum mechanics. On that score a comparison within the subject must be made. That implies, that particle physics is taught in summer term 2005 to a new group of students once again using the method of traditional lecture. That gives us the possibility to compare both methods of teaching in relation to the subject of particle physics and to compare the criteria of evaluation.
Also, quantum physics was taught in the summer semester 2005 once again with the Learning-System. So it is possible to draw comparisons within the subject quantum physics and once more within the group of students in the summer semester 2005.

The configuration of lectures was modified in one way. The required exercises, which had been made to complement lectures, were completed by the students during the class (like the Learning-System). It had to be done in such a way in order to guarantee that the participants of lectures had the same workload as the participants using the Learning-System while working through the same subject. This modification has probably an effect on

- the learning success
- the climate in the class.

Results - Learning Tests

Assessments have been made in terms of written learning tests with usual length of 45 minutes. The learning tests within the same subject were identical for both tested groups of students.
The average percentages of all points that could be achieved by students on each learning test are presented below:

Table 1: Results of the learning tests

Semester	**Subject**	**Method of education**	**Result**
SS04	quantum physics	lecture	26%
SS04	particle physics	Learning-System	63%
SS05	particle physics	lecture	35%
SS05	quantum physics	Learning-System	61%

Within a group the comparisons show significant learning success for both groups of students in the summer semester 2004 and the summer semester 2005. Making comparisons within a subject like quantum mechanics shows greater learning success using the Learning-System. Likewise a similar comparison is seen in the subject particle physics. The comparative design shows the dominance of the Learning-System over the method of a traditional lecture.

Results - Acceptance

The results regarding the second criterion of evaluation -- the acceptance by students – are also important. The interview study shows how students estimated their perceived learning success plus climate during lectures and while working on the Learning-System.
Students estimated their learning success during the lectures of “Physics of Matter” at high level, higher than in any other lecture they know from

their studies. Also the climate during the lectures of "Physics of Matter" evaluated very well: Students said that it differs substantially from any other lecture they knew. The general climate during typical traditional lectures is characterized as a passive one. The relation between lecturer and students is aloof.
Students are inhibited to ask questions. And there are no realistic possibilities of interaction between students and lecturer.
On the other hand students rank the ambiance during lectures of "Physics of Matter" as very pleasant and so it reinforces for learning.
Students name the following reasons for their attitudes:
- Communication and cooperation during the exercises
- Openness for questions
- Small distance to lecturer

The self-assessment of students during the Learning-System about the perceived learning success is very high (that agrees with the results of the learning tests). The ambiance was rated at a higher level, too. The following reasons are mentioned:
- More communication between students
- Higher motivation, because students notice the gain of knowledge

The main differences between the Learning-System and a traditional lecture are as follows
- Active learning
- Notice of individual learning success
- Communication with lecturer

Summary

The aims of the Learning-System have been achieved. The effectiveness of the lecture could be maximized. Working time of most participants is limited to the time frame of the lesson. The acceptance of the Learning-System by the students is high. The students enjoy the learning climate in the class.
The scale of acquired knowledge is much higher for students in the Learning System than for those in traditional lectures as the comparative design shows. Therefore the Learning-System shows a higher efficiency of learning. For a complete description of the development and evaluation of the Learning System see [Traupel, 2006].
The use of this conception for teachings at universities should be integrated into all course. The German Physical Society (Deutsche Physikalische Gesellschaft) postulates a new conception of education of teacher's next generation in physics [DPG, 2006]. The Learning-System seems to be predestined for it.

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