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Experimental Learning in Mechatronics: The Lab in your pocket

Abstract

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Mechatronics is a thematic and a cross-disciplinary academic subject where the education typically focuses on a hands-on approach; experiments, project-organized and problem-based student activities. Examples of themes are robotics, smart products and embedded systems.

The project 'The Lab in you pocket' aims at investigating the possibilities of students to have constant access to adequate equipment, portable hardware, web-based communication, necessary other material as well as interesting projects that stimulates active problem-solving activities.

The basic idea of the project is that this access in combination with exercises and projects that stimulates problem-solving activities will gain a greater activity and interest for the students, and further to gain a greater understanding for the subject of Mechatronics. The assessment of the activities will be based on a comparative study that involves students taking the same course but with traditional laboratory-based exercises. These assessments will be based on the students own descriptions of their situation, gathered primarily in interviews, as well as on independent analysis's of the actual results of the course in terms of test results and the outcome of the experimental projects.

The project started in July 2001 with the development of the hardware modules and the projects as well as with a study of the necessary changes to existing courses in Electrical Engineering, Microcontrollers and Mechatronics to prepare these courses to the changing teaching strategy.

During the first semester of 2002 the concept will be introduced in four courses in Electrical Engineering and Basic Microcontroller Theory, courses with from four to eight credits followed by the total of approximately 400 students. In each course two teams of students will use the concept; one team with 20

randomly chosen students (20 students from two similar courses) and one team with 20 volunteers. The team with the volunteers will act as a reference group where discussions regarding the administration of the projects will be held, which projects to use, as well as more general issues regarding the entire course. These discussions will be used as reference material when the final implementation is due. The team with the randomly chosen students will work with their projects without interfering discussions regarding the project, and the results will be evaluated after the end of the course. All other students will not be part of the project, and therefore do their projects and experiment in a traditional laboratory setting. These students, however, will act as a reference group.

During the last phase of the project, the second semester of 2002, the results from the experiments with the four courses will be analysed and necessary changes will be made in the material, projects, experiments and exercises. The aim of this last phase is to present a concept that can be used in full scale in all courses from the beginning of the second semester of 2002.

Link to the project-web:
http://www.md.kth.se/research/projects/mda/p2.shtml?eng

KTH Machine Design

Experimental Learning in Mechatronics – The Lab in Your Pocket

The "Lab in Your Pocket" project started in July 2001 and ended in June 2003. This report describes the various activities of the project. The question we wanted to answer was: "*Can individualized, mobile access to advanced experimental laboratory equipment increase knowledge, skill, and understanding in a particular subject?"* The subject of Mechatronics was the preferred test bed. The project was financed by the Council for the Renewal of Higher Education and the Department of Machine Design, KTH.

Introduction

The "Lab in Your Pocket" project ran as part of a larger research and development project called the Mechatronics Learning Concept (or MLC). The focus of this report will be on activities within the MLC project that were directly related to the "Lab in Your Pocket" project.

The Department of Machine Design, Royal Institute of Technology gives courses related to Machine Design, Electrical Engineering, and Computer and Control Engineering, gathered under the name of Mechatronics. In November 1998, the department began a project involving development of a partially new concept for creating modularised courses in Electrical Engineering and Mechatronics. This was the MLC.

The MLC project involves the development of small, handheld, portable and user-friendly "kits" of laboratory equipment for use either at home or in a laboratory, together with essential material including literature and channels for communication.

Why this project?

When the project was initiated, the situation in the first two courses in Electrical Engineering and Mechatronics was as follows: The first course, *Basic Electrical Engineering*, contained only one laboratory experiment (in the "Lab in Your Pocket" area), although there had previously been more experimental exercises earlier in the course's history before downsizing became necessary for economic reasons. The (second) *Introduction to Microcomputer Systems* course contained two smaller and two more extensive exercises (2hrs and 4hrs respectively); they required extensive and precise planning and organisation to enable all students to participate, do the exercises in the right order, and in synchrony with the rest of the lecture and parallel course schedules. With more difficult financial constraints, the student groups tended to grow larger and larger, with fewer exercises in the course.

In September 2000, the "Lab in Your Pocket" was introduced into *Digital and Microcontroller Fundamentals*, a 10-credit course that runs twice a year with about 20 students each session. This course is given in distance education form, primarily for students already graduated from KTH or elsewhere. The results were positive.

Project start

The "Lab in Your Pocket" concept was gradually introduced. During the Fall 2001 session, the project team and 10 students in the *Basic Electrical Engineering* course formed a group to discuss the project, how to implement it in the course, etc. When the equipment was handed out, in February all members of the student project team chose to use the "Lab in Your Pocket" as their experimental platform during the course.

During the next course (Spring 2002), we invited more students to participate in the project. The *Introduction to Microcomputer Systems* normally attracted 100 students, and the student project team now consisted of 35 members, leaving the remaining 65 students as reference group. The 35 students in the project group used the personal lab equipment, while the other 65 did their laboratory work in the traditional way. Both groups attended the same lectures, theoretical exercises, and wrote the same examination.

To enable an evaluation of the project, several variables such as time spent by each student, level of the finished project, communication between students and between students and teachers were constantly monitored.

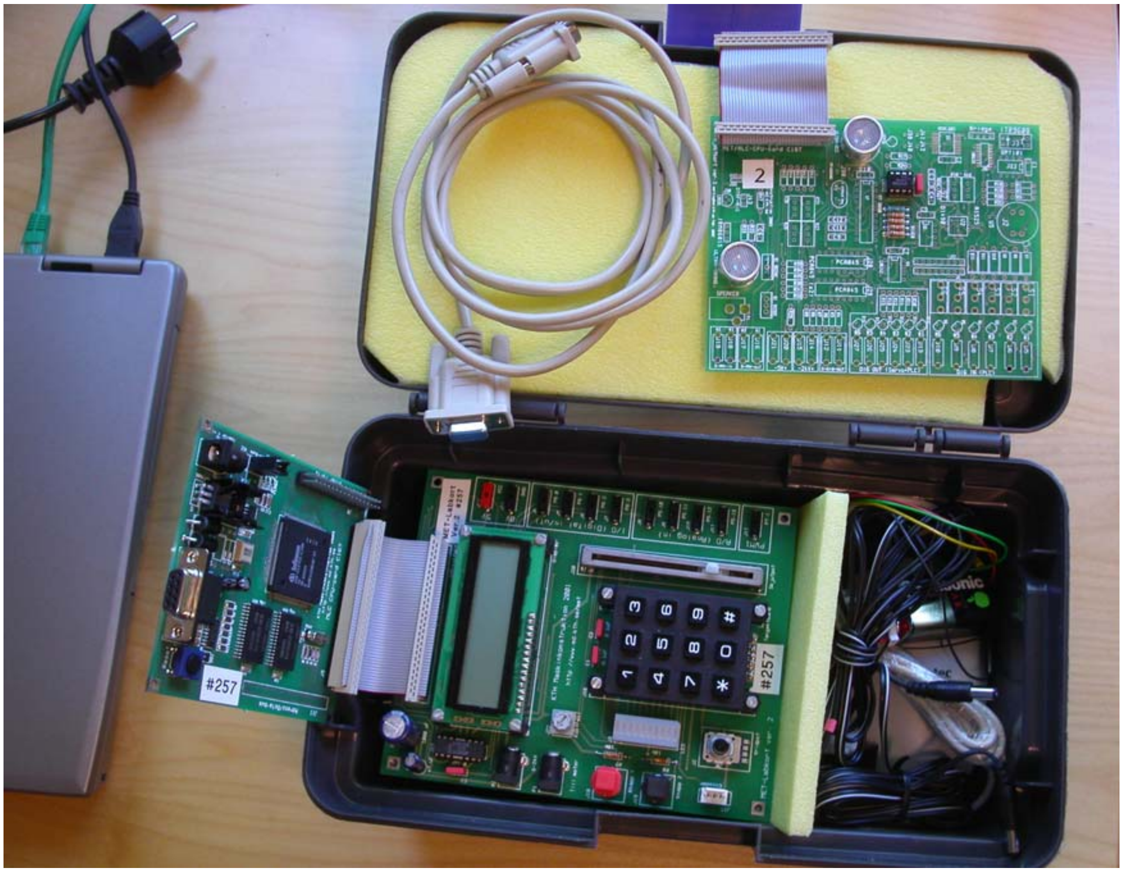
Comparing the two courses, this second course was more advantageous for the "Lab in Your Pocket" as more than half of the course was related to project work and laboratory exercises, all of which had been modified to be able to be completed with the lab kit. All students chose an individual project, which constituted approximately 40% of the work in the course, and a total of 10 new projects were developed, each with an average of 3 variations—thus, 30 projects in all.

The "Lab in Your Pocket" equipment

The "Lab in Your Pocket" equipment kit consisted of a CPU module with an Infineon C167CS microcontroller, an I/O interface module, a sensor or actuator module (individual choice), a C compiler module, and necessary cables and adapters. All modules were designed by faculty; the production cost of each set of laboratory equipment is approximately 100 €. The lab kit was small and light enough (weighs less than 1 kg) to be easily carried in a suitcase or sent by mail.

There was also a commercial Web-based educational platform for the course. From this platform the students could download all necessary material, including the C compiler module with debugger, sample programs, and manuals. The platform was also used for the assessment; each laboratory exercise was assessed using a web form where the results were evaluated by the faculty. Perhaps most important, the educational platform provided a communication facility where the students could post questions, to be commented on and answered by either a peer student or the faculty, and where important facts could easily be posted on a notice board.

In the individual project, the student could choose which grade she/he wanted to work for.



First-year evaluation

All 35 students in the student project teamanswered a questionnaire, and 10 of these students were selected for interviews. In the questionnaires and interviews the students were asked to describe their approaches towards the experimental work: when, where and how the exercises and projects where done, their overall attitude towards the concept, how much time was spent experimenting, etc. The reference group (who had done their laboratory exercises in the traditional way) were also asked to answer the same questionnaire. The results can be summarized as follows:

1. The project group appreciated the exercises, the project, and the teachers considerably more than the reference group (grade 4.4 compared to grade 3.8).
2. The project team group attended fewer lectures than the reference group (53% compared to 68%) but did more exercises (87% compared to 80%).

3. The project team group chose to work for considerably higher grades on the projects than the reference group (grade 4.7 compared to 3.9). Both groups also received the grades they targeted.
4. The project team group used the educational Web-based platform to collaboratively support each other, and consequently the faculty spent less time supervising this group than the reference group.
5. The project team group appreciated the freedom to choose when and where to work with their laboratory and project work. They also finished their practical work before the time limit.
6. The faculty spent less time supervising the project team group than the reference group.

Second year of the project

As a result of the first-year evaluation it was decided to go ahead with full implementation, and 40 new sets of MLC kits were produced. All 100 students in the second course, *Introduction to Microcomputer Systems*, could use their own sets (on loan) during the courses. The number of projects in the course were increased from 30 to 45 (5 new, with 3 variations each). One new laboratory exercise was produced. Some new course material was produced to better support the students in their experimental work at home.

In the first course, *Basic Electrical Engineering*, where only a small part of the course was supported by the existing MLC equipment, only 20 students chose to use the MLC lab kit.

The students were free to work at home or at the KTH laboratory. The educational web was put up, and the students were asked to start at once to work with the lab kit. All students were asked to take a questionnaire at the end of the course to report on time use and attitudes. In the conferencing system, special groups were set up, one for each type of individual project.

Second-year evaluation

The results of the second-year evaluation can be summarized as follows:

1. The students attended more theoretical exercises than lectures.
2. Only 30% of the students started directly with their experimentation; the rest waited to be more sure of how and what to do.
3. At least 40% of the students used their equipment mostly at home; the others responded that they used it more at KTH than at home. At special hours teaching support was provided in the laboratory.
4. Time consumption for the two laboratory exercises was reasonable. For the first, well-guided exercise, the average time spent was 6 hours. This exercise normally took 4 hours in a traditional laboratory format with a teacher present. Some

students spent reasonably more time, and the responses to the questionnaire showed that these students had done no experiments with the equipment before the exercise. The second (new) laboratory exercise was far more advanced; it could be seen that there were two groups—one group who spent an average of 15 hours and a smaller group who spent an average of 35 hours.

5. To finish the individual project, students only used an average of 20 hours (ranging from 4 to 60 hours). Their time consumption should be related to the chosen target grade for the project, but this was not measured. Student comments included "This was too easy" and "We can learn more skills here."

Conclusions

The aim of the "Lab in Your Pocket" project was to investigate the question, "*Can individualized, mobile access to advanced experimental laboratory equipment increase knowledge, skill, and understanding in a particular subject?"* with the subject of Mechatronics as the preferred test bed.

The full-scale (second-year) experiment in 2003 showed that this aim was achievable. The grades in the course were higher during this semester than in the first year (2001).
As a bonus, the students felt very satisfied with the opportunity to work at their own choice of time and place, while the faculty spent less time supervising the students and students showed a lot of collaboration.

	Grade 3	Grade 4	Grade 5
2001	47%	32%	20%
2003	33%	44%	23%

However, the project showed the necessity of encouraging students to start work early with their equipment as there were always parallel courses with time limits. From the economic point of view, the "Lab in Your Pocket" equipment kits were more cost efficient than the traditional use of laboratories and assistants at KTH.

Although this project was only conducted in the Mechatronics area, it appears to be a potentially good choice for other areas.

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