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Integrating Labs into Learning Environment

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Introduction

Importance of practical work in engineering education is growing significantly. Labs are most effective and important part of nowadays engineering education [1]. That's why the amount of lab assignments should be increased [2]. Another reason is fresh students: in modern virtual world they have less and less capabilities to make practical experiments and therefore they have less experience. Also lack of experience makes theoretical considerations too abstract and is considered by students as something that has to be learned but has no evident practical value.

Traditional labs have some disadvantages. The labs are often performed by groups of students, may be 2-4 students and often they prepare common report. They must handle a large amount of information at same time and effectiveness is weak [3]. Even if they make personal reports, it appears frequently that the amount of work done by different students is very different. Second, the labs usually can't be repeated – student simply passes it, probably accompanied by some 'defense' procedure. It is also difficult to know student's knowledge after lab, especially if the work has been done in group. The third disadvantage is that lab places and free time for labs are limited (that's why student groups are formed). The most serious deficiency of traditional lab assignments   is that it is very difficult to analyze results of the work. However, the student's wrong answers and mistakes are a great source of information. On this basis, it is possible to make statistics on the outcome of the student, and also to provide necessary teaching materials. In addition, recent lab activities should be accompanied by analysis of results and the comparison between expected and actual results [4].
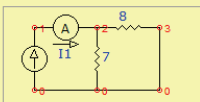
Single lab experiments

To increase student's learning effectiveness the amount of learning material should be minimized. Simple material is easy to remember. This comes from the fact that its simplicity makes is easy for the brain to process it always in the same way [3]. In 2007 we introduced "single lab experiment" system. The traditional labs were split into simple experiments. In traditional lab student makes a large lab report (even if the report is in electronic form) that contains a lot of data. In a single experiment, student has to consider only one simple assignment (Fig. 1). The advantage of this method is that performing a simple assignment needs a quite little time and therefore it is possible to integrate it into interactive learning process and also class tests.

The second usage of the HomeLabKit [5] is possibility to create large amount of different assignments. In addition it makes easy to repeat unsuccessful lab attempts. Labs are integrated to E-learning environment along with other assignments.
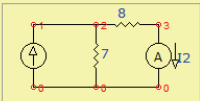

Fig. 1. An example of lab assignment (current divider)

Learning Environment

Learning environment has been developed during last 8 years as a fully web-based one. That means absence of any paper documents and keeping logs of all activities performed by students. All assignments that had to be performed in fixed places (computer class or lab room) need pre-registration. From fall semester 2005 the courses we teach were transferred to hierarchical assignment

structure where a student has to start from lower level assignments and moving up after successful completing at predecessor levels (Fig. 2). The structure represents either logical order or replaces time schedule. All time deadlines were abolished and contrary to common assumption that students do nothing without strict deadlines, appeared to be not valid. Every assignment is accompanied by some amount of credit units (0.1 … 0.4) which appeared to be very motivating environment. However, it became clear even before that feedback system targeting to success in specified assignments creates temporary knowledge and skills.
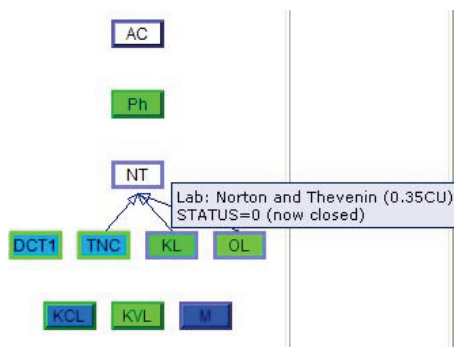
Fig. 2. Assignments diagram

That's why the student forgetting model was applied [6]. All assignments include tasks of 128 levels of difficulty; transitions between them are controlled by a state machine. For any level achieved by a student in one session, exponential forgetting function was applied. Time constants are used for theoretical tests and lab experiments. Recalculation of level, time constant, and floor was applied after any successive session.

HomeLabKit

The first HomeLabKit was introduced and designed to support the same works that existed before [5]. Because of success and popularity of the first HomeLabKit, the second and more functional version of HomeLabKit was designed in 2007 (Fig. 3). Also the number of kits was increased from 25 to approx 75.

The HomeLabKit contains all necessary equipment needed to do lab assignments both in lab and at home. The list of set includes AC and DC sources, multimeters, some electronic components (resistors, capacitors, and inductors) and specific course based test devices. All components are packed into case 23×12×38 cm (Fig. 3). To learn essential electronics there is no need of expensive equipment [7].

Statistics

Initially, it was assumed that kits will be used mainly as true home labs and not by all students. But in reality three usage modes are used:

1. True home lab: a student takes the kit and performs his/her labs fully at home. The time needed depends on all activities as assignments are logically dependent. More 30 kits are used for home labs and the kits are reused by other students. From 60 students, who had passed course 6 students made his lab activities fully at home (Fig. 4.)

Fig. 3. Home LabKit

2. Using kits in lab room. Most of students were not confident enough to start with home labs from the beginning and they started visiting lab room. The reason was their need to get help in assembling circuits, getting familiar with meters etc. Also students are using kits in lab rooms when they do class tests.
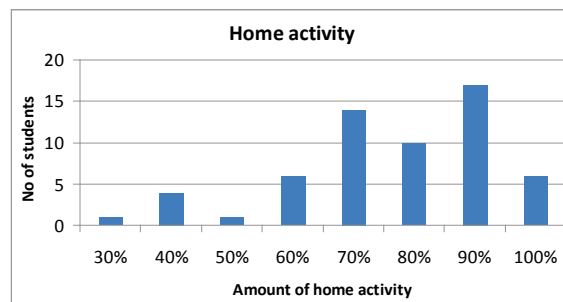
Fig. 4. Amount of home activities

3. The most popular mode for home lending is short-time lending. Students take kits for a night or few days, preferably for weekend (Fig. 5). Since the number of kits was small in 2007, "overnight lending" appeared to be the most popular. In Fig. 5 it is shown as 0 days. Some long lending times (larger than month) are omitted because they are special cases (distant learners).
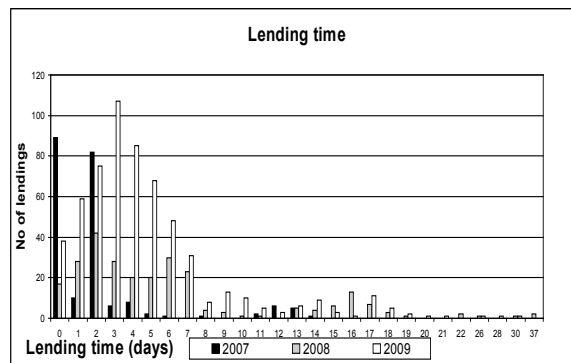
Fig. 5. Lending time.

Finally, the statistics shows that HomeLabKit became very popular (Fig. 6). Also, in 2007 when single lab assignments were started the amount of lab attempts grew

significantly. Until 2007 each student passed exactly 7 labs. After splitting, it increased approx 115 attempts per student.
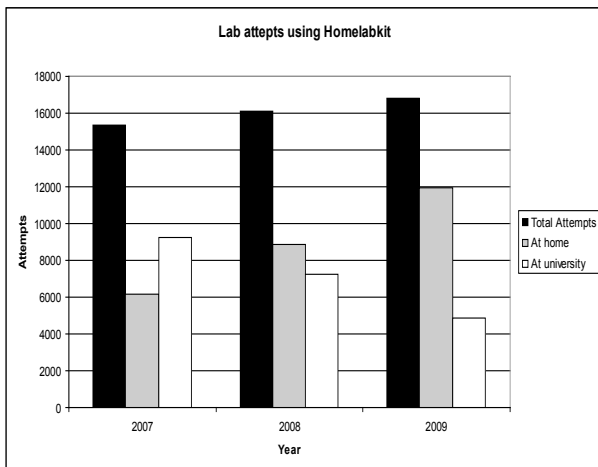

Fig. 6. Lab attempts using HomeLabKit

Fig. 4 shows that learning activities are moving to home: in fall semester 2009 the number of students who performed 90% of all online time at home is the largest group. Those who use mostly university rooms (at home less than 50%) form a minority (about 10% of students). This trend is supported by having very few lectures which is nowadays the most inefficient form of learning.

We have to emphasize that diversity in students' preparation and may be ability, are remarkable. As we have now rather correct measurements, we can confirm that the time (and number of attempts to reach acceptable level) differs at least 4-5 times. That also shows that using credit units bound to 'average time of learning' is at least questionable.

It is even somewhat surprising how attractive is interactive learning environment that proposes solving problems that are not too complicated and react instantly. Our experience shows that in the mixed assignment set, non-interactive student postpones home works as far as possible. At the same time, they start exercise on truly interactive environment from the first day.

Handling lab results

As noted above it is quite easy to collect and analyze data of lab assignments. However, difficult problem when evaluating experiments is processing results provided by students. As there is no simple correct-wrong scale, real values of correctness were calculated using theoretical behavior of measured circuit. By comparing expected and theoretical values some types of student's errors are determined.

The most frequent common errors are wrong measurement unit and sign error. Other errors are lab specific but usually they can be detected. The result of the lab or test is evaluated by a numerical value in range [0.0, 3.0] as 3.0 mean absolutely correct and 0.0 - absolutely incorrect answer (Fig. 7). All other cases are placed between them. Including some measurement errors, we consider answer as correct if the result is larger than 2.8.
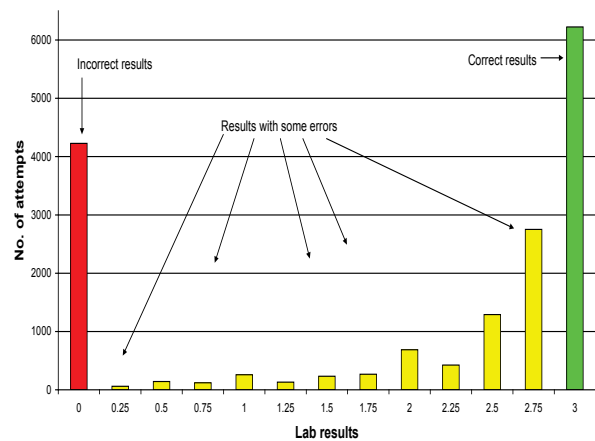

Fig. 7. Lab answers

However, even in such simple cases the evaluation is summative as we have to compromise several aspects of solution. This implies for example, wrong reflection if a student has measured two values (e.g. voltage and current) and has made an error when calculating resistance (it happens frequently). We may evaluate it by 0.0 which is wrong as 2 of 3 is correct, or 0.67 as two of three are correct etc but none of those conclusions is correct just because of summative character.

Correct solution of such situation is extracting specific evaluations from the results. For example, we recognize correctness of measuring voltage and current; but at the same time misunderstanding concept of resistance, or misunderstanding units, or detect occasional error, etc. So, even from a simple experiment it is possible to extract a lot of information concerning student's knowledge. To support learning in most effective way we have to do such deep analysis and use it to learning process.

We have started systematic analysis of data collected over years to specify elements of knowledge that can be extracted from results obtained. This activity is under way but it is clear that there are a lot of elements that are not included even in a large collection of tasks (thousands of theoretical tasks and hundreds of experiments)

Conclusions

Main conclusions from the done so far are the following.
- Decreasing simultaneously acquirable information (in our case using single lab experiments) noticeably increases effectiveness of learning process.
- Collecting and analyzing lab data helps us to give immediate feedback to students. Data can be collected and used in the future to make learning process easier and more comfortable. It also shows where are students' weaknesses and helping them to guide to appropriate learning materials.
- The importance of labs is increasing. To gain more time and space, part of labs was moved to homes. Lab experiments are integrated into learning environment along with other components that means more and smaller experiments embedded into logical structure of assignments.

- Learners have changed dramatically during last decade. Now we have freshmen who started using computer before they recognized that words can be formed from signs on keyboard called letters. Never before so many useful (and also dangerous) information has been available. The young people behave is totally different from previous times. It follows that learning environment must be as fast and reactive as everything else around us. As an example we notice here a critical experience that has become more and more common. When solving a problem a student does not read manuals or even direct instructions on the same page where the problem is presented. The only acceptable way is to detect possible misunderstanding and reacting to this just during problem solving.

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M. Jaanus,V. Kukk, K. Umbleja. Integrating Labs into Learning Environment // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 6(102). – P. 27–30.

In this paper, we present analysis of 2.5 year experience of integrating lab experiments into web-based learning environment. Previously, labs were provided in the classical format – experimental work with prescribed content that had to be replicated by a student (7 labs). From fall semester 2007, a new format was introduced where all practical work is based on the same model as theoretical tests: large number of simple experiments and a student has to obtain certain level of confidence. To reach that level minimum number of attempts is less than 10 but usually much more is needed. It was somewhat surprise how much this made passing the course more complicated for students. We present along with description of environment a detailed and critical analysis of learning process. Ill. 7, bibl. 7 (in English; abstracts in English, Russian and Lithuanian).

М. Юанус, В. Кук, К. Умблея. Анализ влияния лабораторного помещения на успех освоения дисциплин // Электроника и электротехника. – Каунас: Технология, 2010. – № 6(102). – С. 27–30.

Дано сравнение старого классического метода проведения лабораторных работ с методами на основе экспериментов в виртуальном пространстве. Указано, что данный метод осложняет процесс изучения, но углубляет познания студентов по полученными экспериментальными результатами. Ил. 7, библ. 7 (на английском языке; рефераты на английском, русском и литовском яз.).

M. Jaanus, V. Kukk, K. Umbleja. Laboratorinės aplinkos įtakos mokymuisi analizė // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 6(102). – P. 27–30.

Pristatoma 2,5 metų trukmės tyrimų laboratorinėje aplinkoje, integruotoje integruotos virtualioje internetinėje erdvėje, analizė. Anksčiau laboratoriniai darbai būdavo atliekami klasikiniu metodu – studentas turėjo pakartoti nurodyto turinio eksperimentinį darbą. 2007-aisiais metais buvo pristatytas naujas laboratorinių darbų atlikimo metodas. Tai leido atlikti daug paprastų eksperimentų virtualioje erdvėje, kas padėjo studentui įgyti tam tikrą pasitikėjimo lygį. Nustatyta, kad minimalus bandymų skaičius yra mažesnis nei 10. Pastebėta, kad tokio metodo taikymas apsunkino studijas. Il. 7, bibl. 7 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).